FERTILIZER RECOMMENDATIONS FOR SEASON FOLLOWING DROUGHTS

PAE McGEE, Sasol Fertilizers and G C H VENTER, Fertilizer Society of South Africa

Introduction

The current devasting drought had of course has an equally devastating effect on the financial well-being of our farmers. For this reason all of us are frequently faced with the situation of making a fertilizer recommendation to a farmer who cannot afford to apply the optimum amounts of fertilizer. The question now arises as to what or how we should advise the farmer in this situation. Many and varied "solutions" to this problem are on offer. Some of the main arguments advanced to overcome this problem include the following:

1) Cut back arbitrarily on P & K whilst keeping N fertilization normal in terms of the soil potential. This sort of argument is currently much in favour on the Highveld.

2) The farmer should cut back on his hectarage (especially marginal lands) and fertilize the remaining hectarage optimally. This solution is not very much liked by the farmer who knows that he will only get himself out of debt by obtaining a bumper harvest. As a born optimist he will (in the absence of quotas or really good economic evidence concerning his marginal soils) tend to go for broke.

3) The farmer should merely lower his normal yield target and fertilize accordingly.

All of the above do of course have at least some merit. The first argument assumes that P & K are less critical than N for yield and also includes an allowance for carryover of P & K from the previous season. However the likelihood of obtaining optimal yield with suboptimal P & K is small and the odds are that one will waste N.

The second argument is basically sound. However in most cases we do not have the data to be able to make such radical recommendations. This argument also fails to answer the question as to what would happen if the farmer merely cut his N, P or K fertilization by ay 20% on his whole farm.

The third argument on the other hand ignores the fact that fertilizer responses are most often logarithmic and that one gets more for a rand at certain levels of application than at others. Cutting back on yield target merely boxes the farmer in at a lower level without giving him the flexibility to play around with his inputs on a logarithmic curve.

All of the above arguments tend to ignore the fact that the N, P & K may have different response curves and also cost different amounts/unit. The problem can be illustrated by recourse to Figure 1 where N, P & K parameters are plotted against yield.

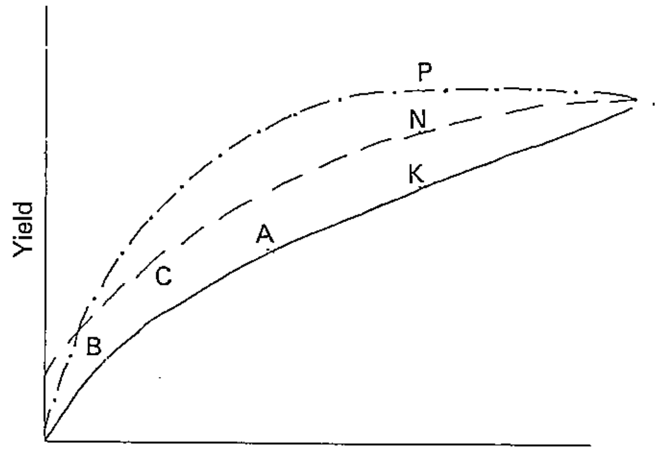

FIG 1: Generalized maize yield response curves for selected N, P & K parameters.

A farmer may find himself at point A on the K response curve, point B on the P response curve and point C on the N response curve. It is obvious that any arbitrary cut in one or other of the elements without recourse to these response curves could be incorrect.

Furthermore the individual costs of N, P & K would play an important part in determining the optimal balance he could obtain with limited finance. In this regard it should be noted that the price/kg of nutrient is the following N — R0,7717 (Urea) P — R1,4762 (Supers 10,5) and K — R0,444 (KCℓ). Potassium is thus by far the cheapest nutrient element at present. It is thus obvious that one can only really advise the farmer properly under these circumstances by returning a s it were to basics. Thus the nutrient response curve on which the fertilizer recommendations are based, together with nutrient costs need to be analysed and integrated into any fertilizer recommendation.

Having said this it is fairly obvious that an advisor out in the field could hardly do this for each individual case. Even if he had a computer at hand he would find even the data input for each land somewhat of an onerous task. In this paper a method is described for producing recommendation tables which will aid the advisor in assisting the farmer along the lines described above.

Recommendation tables for P

In production of the required tables actual response curves from long term FSSA fertilization experiments (Venter, 1982) were used. Thus actual N P response curves and regression equation for FSSA experiment No M1/W were used.

Experiment M1/W which has been running for 5 seasons near Ottosdal, is a factorial with three levels of N and P and two levels of K.

This experiment was used because 5 years of data was available and because responses were considered to be typical of N & P responses found on maize on the Highveld. Long-term yield for this experiment is approximately 5 tons. Soil K analysis on this experiment was relatively high (94 mg kg-1) and no K response was obtained. For this reason, use was made of selected data from FSSA experiment No M5/0. This experiment had a low K analysis (27 mgkg-1) and was also typical of K responses obtained in FSSA experiments. The data selection was carried out on a seasonal basis so that optimal yields obtained approximated 5 tons ie the same as the long-term yield for experiment M1/W.

In Table 1 the currently (FSSA) recommended P application for various soil P analysis are shown for a yield target of 5t/ha. The yield predicted (where no P is applied) by equation 1 is also shown for each soil P level. The data used was the average for the 5 seasons 1978/79 to 1982/83 for which this experiment has been carried out.

Equation 1

$$Y = 802{,}9 - 86{,}96\,P + 1242{,}7\,P^{1/2}$$

Where Y = Yield
P = Soil P level (mg kg-1)

Table 1: Recommended P applications at various soil P levels for 5t yield target and predicted yields for experiment M1/W.

Soil P (Bray 1)	P Recommended kg/ha	Predicted Yield (No P applied) (Equation 1)
5	73	3147
7	58	3482
10	46	3863
15	35	4311
20	26	4621
25	20	4842
30	16	5001
35	15	5111
40	10	5226

The next step was to utilize the same data but this time express it on the basis of yield vs P applied. This relationship is given by the following equation.

Equation 2

$$Y = 3618 - 17{,}0\,P + 323{,}2\,P^{1/2}$$

Where Y = Maize grain yield
P = P applied (kg/ha/yr)

Using equation 2 it is possible to predict the yield that would be obtained by applying various amounts of P. As the yield predicted by equation 2 when no P was applied was closest to the yield predicted by equation 1 at the 7 mgkg-1 soil P level, the latter level was chosen as the base point for further calculations. The actual soil P level in the O P plots was closer to 5 mgkg-1 but a difference of 2 mgkg-1 (7-5) can be explained by experimental error and the consequent inaccuracy of the regression equations.

The amount of P recommended at the 7 mgkg-1 soil P level is 58 kg/ha. Using equation 2 a yield of 5093 kg/ha of grain is predicted when 58 kg/ha of P is applied. Using the same equation we can predict the yield that would be obtained by applying say 10%, 20%, 30% etc. of recommended P. By using a producer price for maize of R0,21405/kg and a price of P of R1,4762/kg it is now also possible to calculate the Marginal Yield/Marginal cost ratio in respectof P applications. Predicted yields and MarginalYield/Marginal cost ratios for various increments the recommended P application level are shown in Table 2 for the 7 mgkg-1 soil P level using Equation 2.

TABLE 2: Predicted yields and Marginal Yield/Marginal Cost $\frac{MY}{MC}$ ratios for various increments of recommended P at the 7 mgkg-1 soil P level.

Percentage of Recommended P	Predicted Yield	$\frac{\text{Marginal Yield}}{\text{Marginal Cost}}$ ratio
0	3482	
10	4297	20,3
20	4521	5,6
30	4670	3,7
40	4780	2,7
50	4865	2,1
60	4933	1,7
70	4987	1,3
80	5030	1,1
90	5065	0,9
100	5093	0,7
Cumulative ratio $\frac{MY}{MC}$		4,0

From the cumulative $\frac{MY}{MC}$ ratio shown in Table 2 it is obvious that addition of P is very profitable although clearly the level of profitability changes dramatically over the increments of P applied.

The next step in the process is to obtain similar data for the other soil P levels. To obtain this data the yields predicted by equation 2 were plotted graphically. The yields predicted by equation 1 (when no P was applied) were used as departure points on the graph and incrementaly ields then calculated using equation 2. In the case of the 5 mgkg-1 level however, where negative values would have been obtained, the intercept 3147 was substituted in equation 2 for 3618 and 373,4 P½ substituted for 323,4 P½. This adapted equation was then used to predict incremental yields for the 5 mgkg-1 soil P level. In this way incremental yields and $\frac{MY}{MC}$ ratios for each increment in P application for each soil P level was obtained. $\frac{MC}{MC}$ ratios are shown in Table 3.

From Table 3 it is clear that P application when soil P is above 30 mgkg-1 are not predicted to be profitable. Reasons for P applications above this level will therefore be based on the philosophy of maintaining soil P ie P applications based on removal. At still higher P levels P applications can only be justified on the basis of the benefits of the pop-up effect. It is also apparent that P applications at soil P levels more than 30 mgkg-1 for this particular trial and at percentages of the recommended level exceeding 90% are not justified on the basis of Marginal return. The FSSA P recommendations do in fact contain an element of soil P build-up which in the light of more stable yields at high soil P level is well as inflationary trends is considered to be a good investment. The great value of Table 3 however lies in the fact that when used with and compared with similar data on N and K, it allows one to make a rational choice (based on yield responses and returns) of where it is most appropriate to cut down on fertilizer inputs.

Recommendation tables for N

Data for N was obtained by using Equation 3. This equation represents the average response to Nitrogen over 5 seasons for the M1/W trial.

Equation 3

$$Y = 3112{,}9 - 5{,}9\,N + 235{,}7\,N^{½}$$

Where Y = Maize grain yield

N = N application (kg/ha)

Data obtained from the use of Equation 3 is shown in Table 4.

TABLE 3: $\frac{MY}{MC}$ ratios for increments of recommended P (5t yield target) at various soil P levels.

Soil P level mgkg-1 (Bray 1)	P Recommended for 5t (kg/ha)	Predicted Yield for 0 P	Percentage of Recommended P										Accumulative $\frac{MY}{MC}$ ratio
			10	20	30	40	50	60	70	80	90	100	
			M Y / M C										
5	73	3147	17,6	5,8	3,9	2,9	2,3	1,8	1,4	1,2	1,0	,8	3,0
7	58	3482	20,3	5,6	3,7	2,7	2,1	1,7	1,3	1,08	,88	,7	3,1
10	46	3863	13,9	5,8	4,1	3,1	2,5	2,0	1,7	1,4	1,2	1,0	2,9
15	35	4311	6,1	4,4	3,6	3,0	2,5	2,1	1,9	1,6	1,4	1,2	2,2
20	26	4621	3,0	2,9	2,6	2,2	2,0	1,9	1,6	1,5	1,3	1,2	1,6
25	20	4842	1,8	1,8	1,6	1,5	1,4	1,3	1,2	1,1	1,0	1,0	1,1
30	16	5001	,4	1,0	1,0	1,0	,9	,8	,7	,7	,6		,63
35	15	5111	0,6	0,4	0,4	0,4	0,4	0,3	0,3	0,3	0,2	0,2	2,6
40	10	5226	–	–	–	–	–	–	–	–	–	–	–

$\frac{MY}{MC}$

TABLE 4: MC ratios for increments of recommended N (5t Yield target)

	N Recommended for 5 t (kg/ha)	Predicted Yield for 0 N	Percentage of Recommended N										Accumulative MY/MC ratio
			10	20	30	40	50	60	70	80	90	100	
			MY/MC										
	95	3113	15,3	5,6	4,0	3,1	2,6	2,2	1,9	1,7	1,6	1,4	3,9

$\frac{MY}{MC}$

TABLE 5: MC ratios for increments of recommended K (5 t yield target) at various soil K levels.

Soil K mgkg-1	K Recommended for 5 t (kg/ha)	Predicted Yield for 0 K	Percentage of Recommended K										Accumulative MY/MC ratio
			10	20	30	40	50	60	70	80	90	100	
			MY/MC										
10	63	3122	19,5	7,8	6,0	4,9	4,2	3,8	3,4	3,3	3,0	2,7	5,9
20	52	3770	21,6	8,7	6,5	5,3	4,8	4,2	3,9	3,5	3,3	3,1	6,5
27	46	4068	14,8	9,3	7,0	5,7	5,1	4,5	4,1	3,7	3,5	3,3	6,1
40	35	4448	4,9	4,5	4,1	3,8	3,7	3,4	3,4	3,1	3,0	3,0	3,7
60	23	4779	2,7	2,5	2,5	2,5	2,3	2,3	2,3	2,3	2,3	2,3	2,4
80	16	4932	4,2	2,1	2,1	1,8	2,1	1,8	2,1	1,8	1,8	2,1	2,1
100	14	4970	1,3	1,7	2,0	1,7	2,0	1,7	2,0	1,7	2,0	1,7	1,8

Recommendation tables for K

Data for K were obtained in the same way as that for P and was based on Equations 4 and 5, and Table 5. These two equations represent the average response obtained to K soil level and K applications respectively on FSSA experiment M5/0 for the seasons 1981/82 and 1982/83. The cost of K/kg nutrient was taken as R0,444.

Equation 4

$Y = 987,1 - 40,5\,K + 803,3\,K^{½}$

Where Y = Maize grain yield

K = Soil K level mgkg − 1

Equation 5

$Y = 3990,5 - 0,9635\,K + 104,535\,K^{½}$

Where Y = Maize grain yield

K = K applied kg/ha/yr.

Soil K level in O K plots in this experiment was 27 mgkg-1. (Soil samples taken 5 weeks after planting) This latter figure formed the base point from which the calculations were made.

Comparison

The ratios in Tables 3, 4 and 5 now allow one to compare the marginal returns of N, P & K at various incremental applications and for P and K also at various soil levels. In a situation where a farmer wants to cut back on his fertilizer bill, these tables could be used to ensure that his cut back is balanced (in terms of marginal return). It is also instructive to have available the predicted yields at each increment of nutrient and at each soil level. This will enable the advisor (for the 5 t yield target) to determine the predicted yield and also to enable him to determine the factor (N, P or K) that is most limiting yield at any particular soil nutrient level. For this reason these figures (corresponding to Tables 3, 4 & 5) are given in appendix 1, 11 and 111.

TABLE 6: Norms published for N P & K in 1983 for use on the Eastern Transvaal Highveld for the 5 t Yield Target.

N	P		K	
Recommended N (kg/ha)	Soil P level Bray 1* mgkg-1	Recommended P (kg/ha)	Soil K level mgkg-1	Recommended K (kg/ha) (Soils 25% Clays)
95	5	28	10	36
	10	25	20	29
	15	22	40	21
	20	18	60	15
	25	14	80	11
			100	9

* converted to Bray 1 from Bray 2.

The use of these tables is possibly best illustrated by comparing the recommendations made with those made by one of the current crop of arbitrary norms designed to assist the farmer in these hard times. For the purpose of this comparison we will use a recently published set of norms which are shown in Table 6.

If we assume that a farmer has a normal yield target of 5 t/ha and has soil analysis of 5 mgkg-1 P and 60 mgkg-1 K, the norms in table 6 would represent a saving of R72,88 (40,0%) over the standard norms of the FSSA. The yield in this case would be predicted as 4568 kg of grain since P in this case is the limiting factor. See Appendix II.

By equating marginal returns from Tables 3, 4 & 5, this farmer could achieve the same (41%) saving shown above on his fertilizer bill by applying 76 kg/ha of N, 36,5 kg/ha of P and o kg/ha of K a saving of 20%, 50% and 100% respectively. However his predicted yield in this case is 4719 kg/ha as N is the most limiting factor (Appendix I). In this case K is not applied even through the $\frac{MY}{MC}$ ratio is relatively high as the limiting factors here are N and P since predicted yield for 60 mgkg-1 soil K level is 4779 kg. This represents a gain of 151 kg of grain or R32,32/ha which whilst not a vast sum is none-the-less significant. In addition it is likely that because the fertilizer has been reduced in a balanced way, the actual yield advantage will be greater than the 151 kg predicted.

For yield targets other than 5 t/ha tables similar to Tables 3, 4 & 5 would have to be developed. It is unlikely however that for yield targets close to 5 t eg 4 & 6 tons the response patterns would be radically different. It is suggested therefore that the $\frac{MY}{MC}$ ratios presented here for a 5 t yield level could be used as a guide for fertilization in the case of field targets from 4 - 6 tons as well.

References

VENTER, G.C.H., 1982. Mielies — Navorsingsverslag 1981/82 FSSA Publication Nr 82.

APPENDIX I: Predicted Yields (kg/ha) for Increments of Recommended N (5t Yield Target)

FSSA Experiment M1/W

N Recommended for 5t (kg/ha)	*Predicted Yield for 0 N*	*Percentage of Recommended N*									
		10	*20*	*30*	*40*	*50*	*60*	*70*	*80*	*90*	*100*
		Predicted Yield									
95	*3113*	*3783*	*4028*	*4203*	*4342*	*4557*	*4556*	*4643*	*4719*	*4787*	*4849*

APPENDIX II: Predicted Yields (kg/ha) for Increments of Recommended P (5 t Yield Target) at various soil P levels.

FSSA Experiment M1/W

Soil P level mgkg-1 (Bray 1)	P Recommended for 5t (kg/ha)	Predicted Yield for 0 P	Percentage of Recommended P									
			10	20	30	40	50	60	70	80	90	100
			Predicted Yield									
5	73	3147	4032	4326	4522	4668	4782	4874	4947	5008	5057	5096
7	58	3482	4297	4521	4670	4780	4865	4933	4987	5030	5065	5093
10	46	3863	4303	4487	4618	4718	4798	4864	4919	4965	5004	5036
15	35	4311	4460	4568	4655	4727	4789	4841	4887	4927	4962	4992
20	26	4621	4675	4727	4774	4815	4852	4886	4916	4943	4968	4990
25	20	4842	4868	4993	4916	4937	4957	4975	4992	5008	5022	5036
30	16	5001	5005	5017	5028	5039	5049	5058	5067	5075	5083	5090
35	15	5111	5117	5121	5125	5129	5133	5136	5139	5142	5144	5146
40	10	5226	5226	5226	5226	5226	5226	5226	5226	5226	5226	5226

APPENDIX III: Predicted Yields (kg/ha) for Increments of Recommended K (5 t Yield Target) at various soil P levels.

FSSA Experiment M1/W

Soil K level mgkg-1	K Recom-mended for 5 t (kg/ha7	Predict-ed Yield for 0 K	10	20	30	40	50	60	70	80	90	100
			Predicted Yield									
10	63	3122	3378	3480	3558	3622	3678	3728	3773	3816	3855	3891
20	52	3770	4003	4097	4168	4226	4278	4324	4366	4404	4440	4474
27	46	4068	4210	4298	4366	4421	4470	4513	4553	4589	4623	4655
40	35	4448	4484	4517	4547	4575	4602	4627	4652	4675	4697	4719
60	23	4779	4792	4804	4816	4828	4839	4850	4861	4872	4883	4894
80	16	4932	4946	4953	4960	4966	4973	4979	4986	4992	4998	5005
100	14	4970	4974	4979	4935	4990	4996	5001	5007	5012	5018	5023