GUIDELINES FOR FERTILIZATION OF MAIZE ON SOIL SERIES OF THE AVALON AND HUTTON FORMS : 1 PHOSPHORUS*

(Met opsomming in Afrikaans)

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Abstract

From an investigation of the results of 143 NPK field experiments on maize, soil series was found to be an important factor regarding phosphorus reaction patterns. Significant correlations between P-analysis of the soil and P-reaction were found only when the experimental data were grouped on the basis of soil form. With further subgrouping of the data, it was found that production class and the S/100g clay ratio of the soil are also related to P-requirements. Regarding pH and soil texture, a clear relationship could, however, not be established. Using the various regression curves for soil form, production class and S/100g clay ratio as a basis, guidelines for P-requirements at varying soil-P levels have been compiled.

Introduction

At the Fourth National Congress of the Society of Soil Science, preliminary NPK-fertilization patterns, based on an investigation of results of 66 NPK experiments, were presented (Möhr, 1971). The motivation, objectives and experimental methods of the investigation have been fully described (Möhr, 1970; 1971). Following on this investigation, the results of an additional 77 NPK experiments on maize, conducted during the 1970/71 and 1971/72 seasons, were added. From this, NPK fertilization guidelines were compiled (Möhr, 1972a). The present paper, however, reports only on the patterns and guidelines for phosphorus on soil series of the red ferralitic Hutton and yellow ferralitic Avalon forms. Furthermore, these guidelines were evaluated using the experimental results of the 1971/72 season (Möhr, 1972b). Soil forms and series as used in this context, refers to the nomenclature and classification system of Van der Eyk, MacVicar & De Villiers (1969), as modified and extended by Loxton, Hunting and Associates (1970, 1971).

Material and Methods

As previously mentioned, results of 143 NPK experiments on maize served as material for this investigation. Most of the experiments had been conducted on a co-operative basis since 1960/61 in the most important maize growing areas of the country. Distribution of the experiments are shown on the map in Figure 1.

The experimental procedure, design, and the forms of NPK used have been fully described (Möhr, 1970).

Soil analyses for pH, P, K, Ca, Mg, Na, S-value and CEC were carried out for all experimental sites. The methods used have been described (Möhr, 1970). The pH (KCl) was determined in a 1:2,5, suspension (soil:1N KCl). Phosphorus was extracted with Bray No 2, and the cations with ammonium acetate at pH 7. Apart from the normal soil analysis, profile descriptions and physical and chemical analyses for the various profiles were carried out. From these data, soil series were classified according to Loxton et al (1970). A summary of the analysis data for the particular series and full particulars on the various trials have been reported by Möhr (1970; 1972a and b).

Simple and multiple correlation studies on grouped data formed the basis of the investigation. According to various researchers such as Hanway (1967), prior grouping of data is usually a prerequisite for studies of this nature. In fact, correlations on ungrouped data did not attain significance in the majority of cases. The problem normally, however, is to decide on a basis of data grouping.

Although the type of grouping will be determined by various factors, many researchers are in agreement that it should be done on a soil type or series basis (Loxton & MacVicar, 1965; Dahl, 1968; Scaife, 1968; Van der Eyk, MacVicar & De Villiers, 1969; Van Wyk, 1970 and Orchard, 1970).

The method of simple and multiple correlation calculations grouping indices and discussion of and motivation for using particular factors (eg S/100g clay ratio) have been presented (Möhr, 1970; 1972).

Results and Discussion

From the preliminary investigation (Möhr 1970), using stepwise multiple regression analysis, it was shown that soil series, optimum yield, soil-P content and to a lesser degree, soil pH and soil Ca content, were in some way or other related to expected P reactions. Apart from a significant correlation between applied P and P analysis, provided the experimental data was grouped on a soil form basis, no further clear differentiation regarding the other mentioned factors could be established. The reason for this is possibly the fact that the data used per group was too limited and variable. The same applied to factors which were not shown up in the multiple regression analysis such as S/100g clay ratio (Skeen, 1971) and clay content (Sperling, Olsen & Watanabe, 1971), but which may be important in establishing P-fertilization guidelines.

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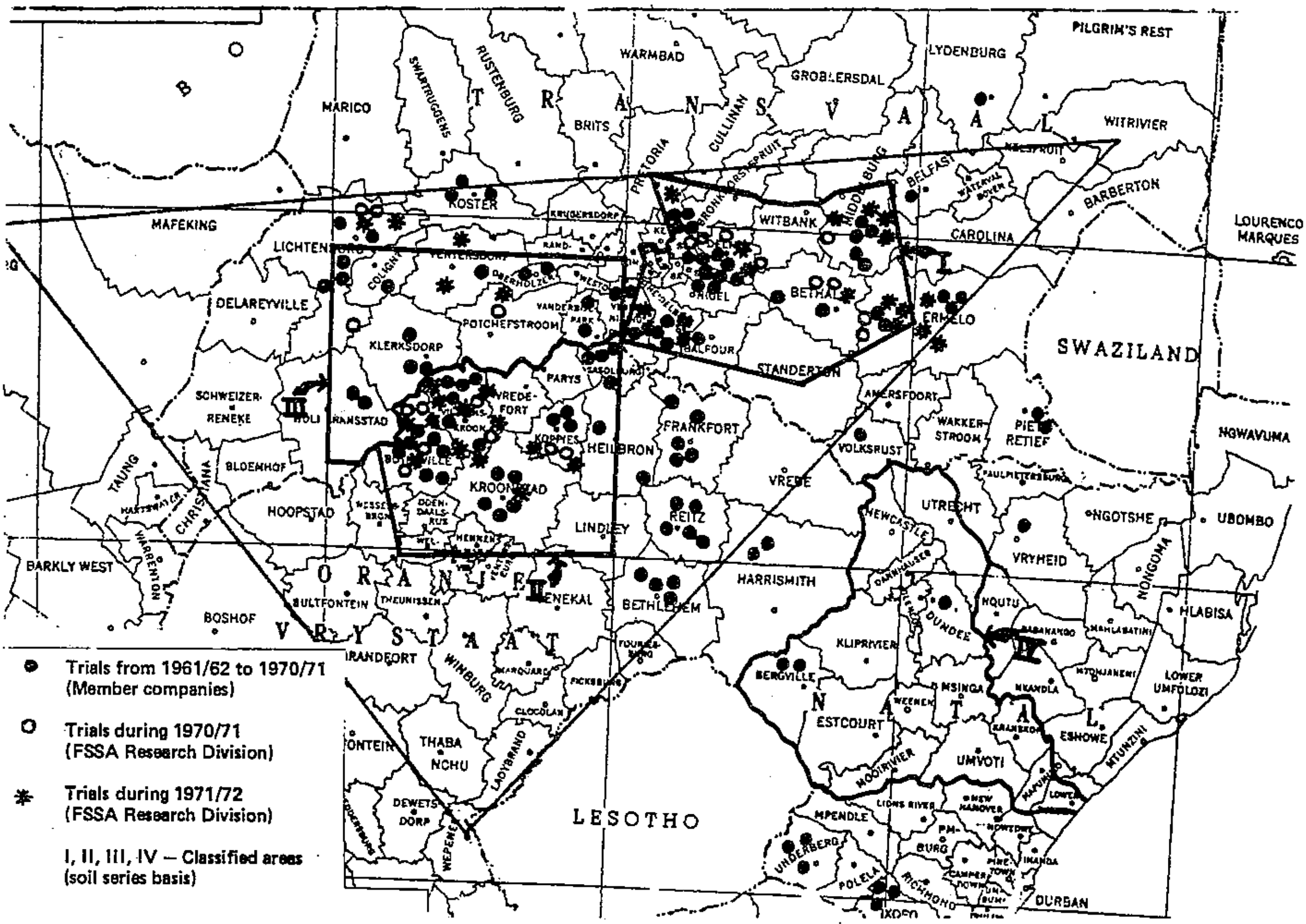

Fig 1 Distribution of maize experiments of the FSSA

With the additional experimental results previously referred to, it was however possible to increase the data per group considerably as well as increase the number of subgroupings. A series of simple correlation and regression analyses, using all the available data, were carried out. Various subgroupings were used. The results are presented in Table 1. Regression curves, based on the equations in Table 1, are presented in Figures 2 to 8. Because the r-value regarding the group: S/100g clay ratio >15 for the Hutton form, is only significant at p=0,10, the particular curve should be interpreted with reservation. All the other r-values are, however, significant at either p=0,05 or p=0,01.

From the curves in Figures 2 to 7, the following conclusions can be drawn:

(i) The marked difference between series of the Avalon and Hutton forms with respect to P reaction and P analysis, is quite clear (Figure 2). From the preliminary investigations, a similar conclusion was drawn (Möhr, 1970) although a bigger difference was shown. The possible value of the curves in Figure 2 is only to show the relative difference between red Hutton and yellow Avalon soils.

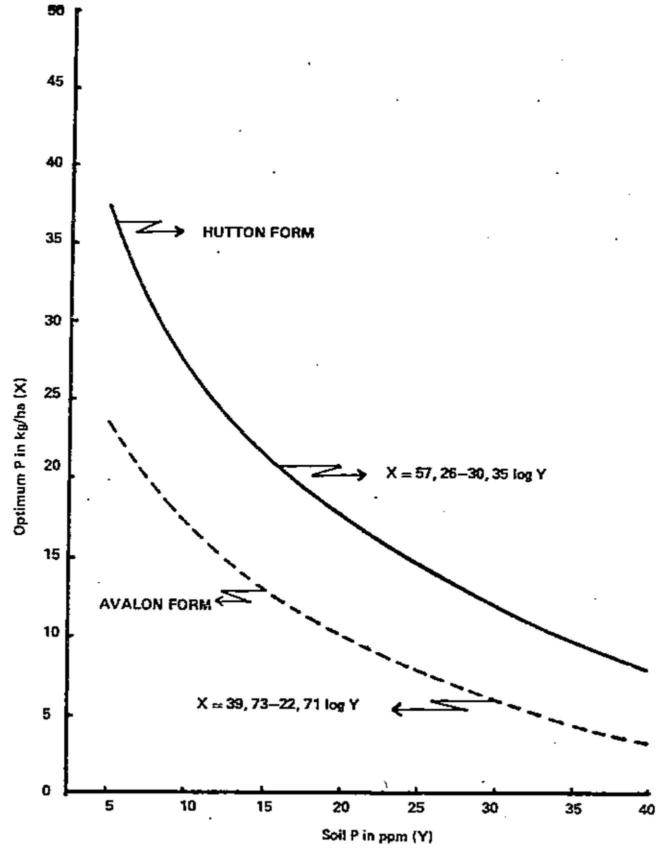

Fig 2 Relationship between the optimum phosphorus application rate and corresponding soil analysis for phosphorus for series of the Avalon and Hutton forms.

TABLE 1 Simple correlation coefficients (r-values) and regression equations regarding the relationship between optimum P (X) and corresponding P analyses (Y) of the experimental soils

Basis of grouping	Data used	Relationship between X and Y	
		r-value	Regression equation
Soil form	Series of the Hutton form	–0,60***	X = 57,26 – 30,35 log Y
	Series of the Avalon form	–0,78***	X = 39,73 – 22,71 log Y
Clay content	Series of the Avalon form with < 15%	–0,76***	X = 36,68 – 20,47 log Y
	Series of the Avalon form with > 15%	–0,77***	X = 42,69 – 24,87 log Y
S/100g clay ratio	Series of the Avalon form with ratio > 15	–0,82***	X = 40,81 – 24,99 log Y
	Series of the Avalon form with ratio 5–15	–0,72***	X = 37,02 – 19,58 log Y
	Series of the Hutton form with ratio > 15	–0,39*	log X = 0,88 – 0,02 Y
	Series of the Hutton form with ratio 5–15	–0,75***	X = 66,89 – 36,92 log Y
	Series of the Hutton form with ratio < 5	–0,77***	X = 80,20 – 45,41 log Y
Production class	Series of the Avalon form with yields < 3000 kg/ha	–0,87***	X = 36,71 – 22,52 log Y
	Series of the Avalon form with yields 3000–5000 kg/ha	–0,77***	X = 42,27 – 25,04 log Y
	Series of the Avalon form with yields > 5000 kg/ha	–0,82***	X = 40,66 – 20,79 log Y
	Series of the Hutton form with yields < 3000 kg/ha	–0,64***	X = 56,58 – 33,15 log Y
	Series of the Hutton form with yields 3000–5000 kg/ha	–0,57**	X = 54,28 – 28,05 log Y
	Series of the Hutton form with yields > 5000 kg/ha	–0,75***	X = 72,79 – 39,20 log Y
pH(KCl)	Series of the Avalon form with pH < 4,2	–0,27 NS	–
	Series of the Avalon form with pH > 4,2	–0,84***	X = 34,31 – 18,87 log Y
	Series of the Hutton form with pH < 4,2	–0,59**	X = 76,80 – 43,24 log Y
	Series of the Hutton form with pH > 4,2	–0,47**	X = 45,38 – 19,36 log Y

NS = Non significant
* = Significant at p = 0,10
** = Significant at p = 0,05
*** = Significant at p = 0,01

(ii) Patterns for the various S/100g clay classes are presented in Figure 3. It is quite clear that the P-requirements increase with a decreasing S/100g clay ratio for both the Avalon and Hutton forms. The fact that the reaction pattern for the 'poorly leached' series of the Hutton form (S/100g clay >15) tends to that of the 'medium leached' series of the Avalon form (S/100g clay 5–15) is interesting. In fact, if results were available on the 'highly leached' series of the Avalon form (S/100g clay< 5), the curves would probably been the same, or the curve for the Hutton form on a slightly higher level.

The statement by Skeen (1971) that S/100g clay ratio is a factor that should be considered, is confirmed by the curves in Figure 3. According to Skeen, the possible explanation for this is that one can expect active aluminium and other possible P-fixing media to decrease with increasing S/100g clay ratio.

(iii) According to Figure 4, grouping on the basis of clay content shows hardly any difference. This is in contrast to the findings of Sperling, Olsen & Watanabe (1971) in Colorado where they have shown that P requirements increase with increasing clay content. They do not, however, subdivide clay on a basis of degree of weathering. From the results presented, the possible importance of clay content cannot be established. On the other hand, it must be kept in mind that grouping for only two clay content classes on one soil form was possible, and generalisation under these circumstances should not be done.

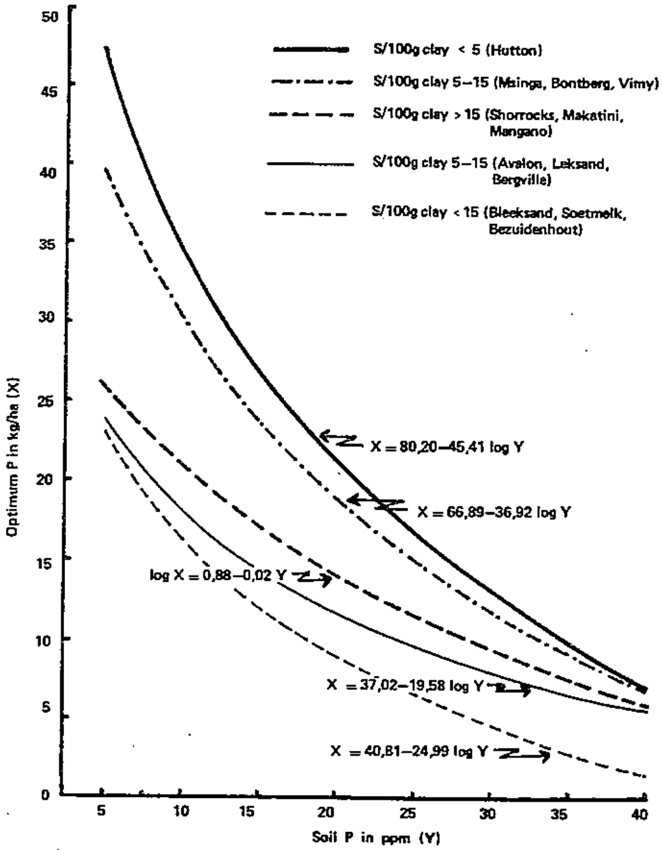

Fig 3 *Relationship between optimum phosphorus application rate and corresponding soil analysis for phosphorus for three S/100g clay ratio classes on series of the Avalon and Hutton forms*

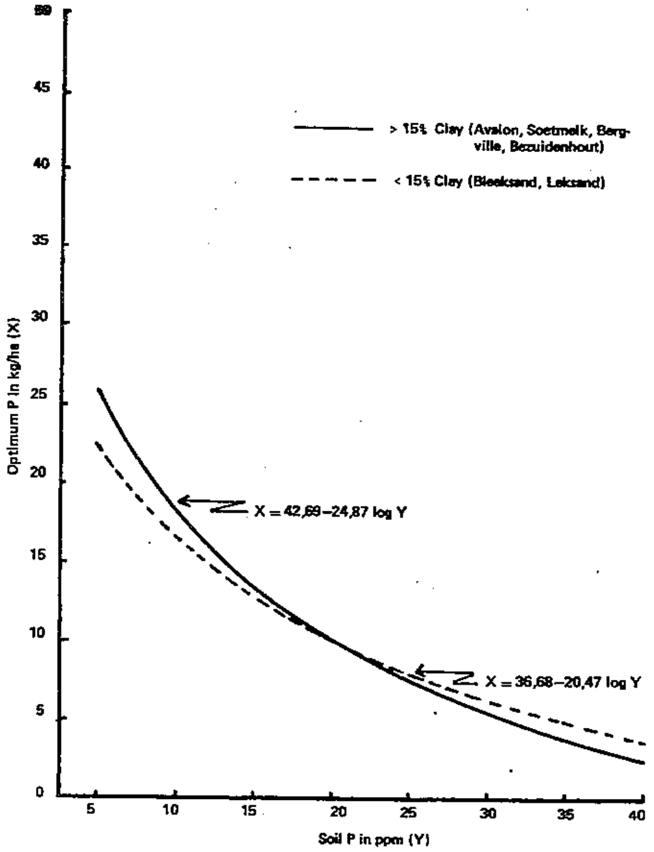

Fig 4 *Relationship between optimum phosphorus application rate and corresponding soil analysis for phosphorus for two clay content classes on series of the Avalon form*

(iv) Curves for three production classes on the Avalon and Hutton forms are presented in Figures 5 and 6. Increasing P requirements with increasing production is clearly shown – but again maintaining the relative difference between the two soil forms. Using these curves as a basis, a so-called 'optimum soil-P' or 'P-saturation' point was indirectly determined. In determining this point, the following was assumed:

- that the various curves in Figures 5 and 6 truly reflect the reaction patterns for the means of the three production classes;

- that 100 kg maize grain removes 0,25 kg P (Orchard, 1971);

- that the intersept between the curves of a particular production and a straight line representing removal or maintenance application for that production, will correspond to the theoretical P-saturation point;

- that the P-saturation points for the means of the three production classes per soil form will not differ significantly.

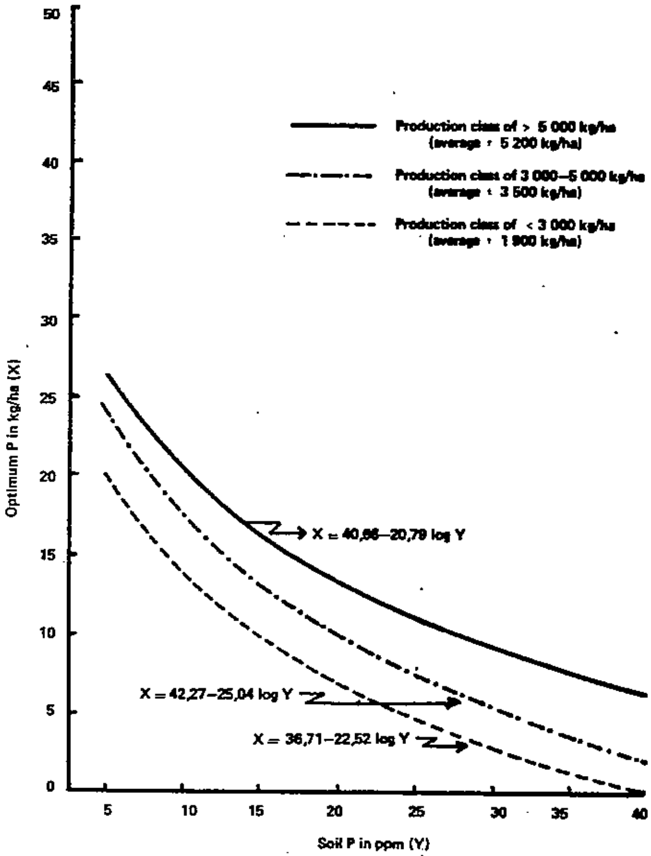

Fig 5 *Relationship between the optimum phosphorus application rate and corresponding soil analysis of phosphorus for three yield classes of the Avalon form*

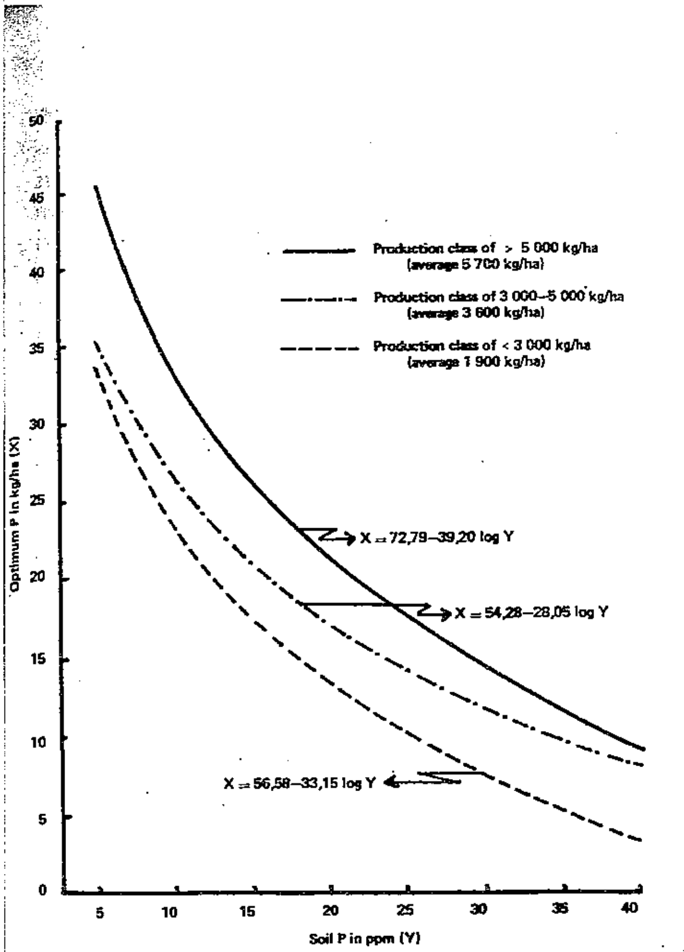

Fig 6 Relationship between the optimum phosphorus application rate and corresponding soil analysis of phosphorus for three yield classes of the Hutton form

The intersepts on the various curves are presented in Table 2.

TABLE 2 Intersepts between production curves and straight lines representing P removal

Soil form	Production class (mean)	Intersepts as presented by soil-P in ppm
Hutton	± 5 700	31,2
	± 3 700	36,9
	± 1 900	36,0
Avalon	± 5 200	20,4
	± 3 500	22,3
	± 1 900	24,7

From these results it would appear that the optimum soil-P for the Hutton form is between 30 and 40 ppm and for the Avalon form between 20 and 25 ppm. The conclusion with regard to the Hutton form is more or less in agreement with the findings of Skeen, Dudding & Clayton (1972), who worked on a Hutton series. For the Avalon form, however, it is approximately 30 per cent lower than the findings of Farina (1971) who worked on a Leksand series.

Although it could not definitely be established, it may be speculated that the optimum soil-P will increase with decreasing S/100g clay ratio within each soil group.

(v) The patterns regarding pH classes are presented in Figure 7. The r-value is not significant in the case of the Avalon form and pH class < 4,2. Therefore, it is only possible to consider the effect of pH for the Hutton form. From the curves, it would appear that less P is required if the pH is >4,2 and the soil-P < 23 ppm. However, with a soil–P > 23 ppm, it is just the other way around which is difficult to explain. Regarding the influence of pH, no clear pattern can therefore be established.

Using the foregoing curves for soil form, production class and S/100g clay ratio as a basis, models were compiled which can serve as guidelines in the planning of a P-fertilization programme. In the compilation of these guidelines, the following assumptions were made:

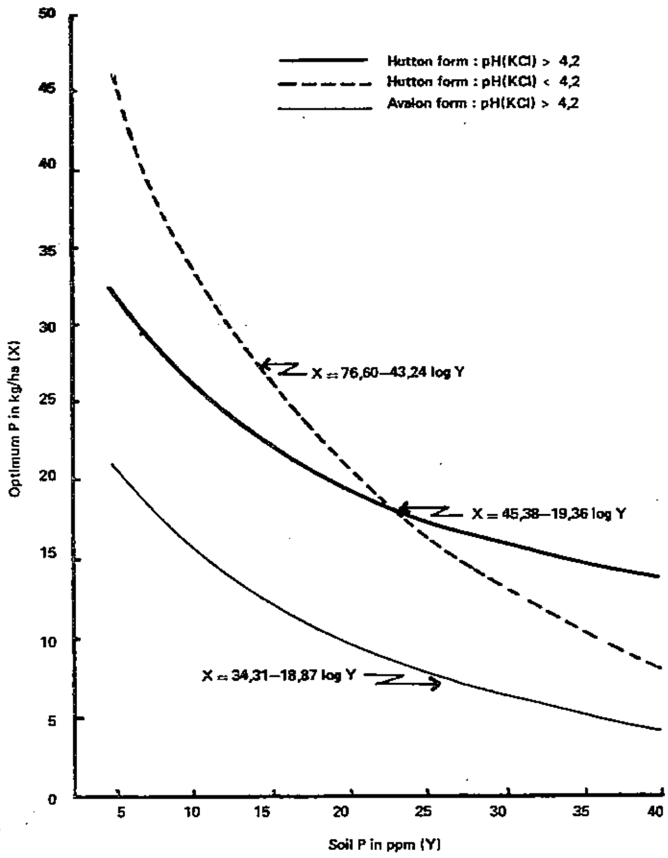

Fig 7 Relationship between optimum phosphorus application rate and corresponding soil analysis for phosphorus for two pH classes for series of the Hutton and one pH class for series of the Avalon form

- that the models are valid only provided factors such as pH do not restrict P reaction to any marked extent;
- that P requirements for the same production class increase with decreasing S/100g clay ratio, and that the order of difference will be the same for all production classes;
- that clay content is not considered at this stage because it could not be concluded that clay content plays any part;
- that the optimum soil-P is approximately 25 ppm for the Avalon and 35 ppm for the Hutton form.

The model for three production classes or yield targets and for 'poorly' and 'highly leached' series for the Hutton form is presented in Figure 8 and for the Avalon form in Figure 9. Values for 'medium leached' series will be more or less the mean of values for 'poorly' and 'highly leached' series.

From these models it is quite clear that soil series or rather forms, and to a lesser degree S/100g clay ratio, are very important factors to consider in the planning of a P-fertilization programme where the soil-P is below the optimum soil-P as has been indirectly determined. Above this point, however, differences in P requirements due to these factors become negligible and maintenance applications based on a realistic removal figure can be considered. Although generalisation at this stage is not desirable, it would seem that a Bray No 2 P-analysis of approximately 40 ppm can be classified as 'high' for the majority of soil series at present planted to maize.

It is quite obvious that the guidelines presented still need considerable refinement and/or confirmation. This is especially true in regard to the P-saturation point as indirectly determined. It may be mentioned that the Research Division of the Fertilizer Society of South Africa has laid down 14 so-called P-depletion experiments on different soil series, with the specific objective of determining optimum soil-P.

As mentioned in the 'Introduction', the accuracy of the P guidelines was evaluated against experimental results from the 1971/72 season. This evaluation is presented in Table 3. From these results it is concluded that the deviations in most cases are of such order as to justify use of the existing guidelines until future research proves otherwise.

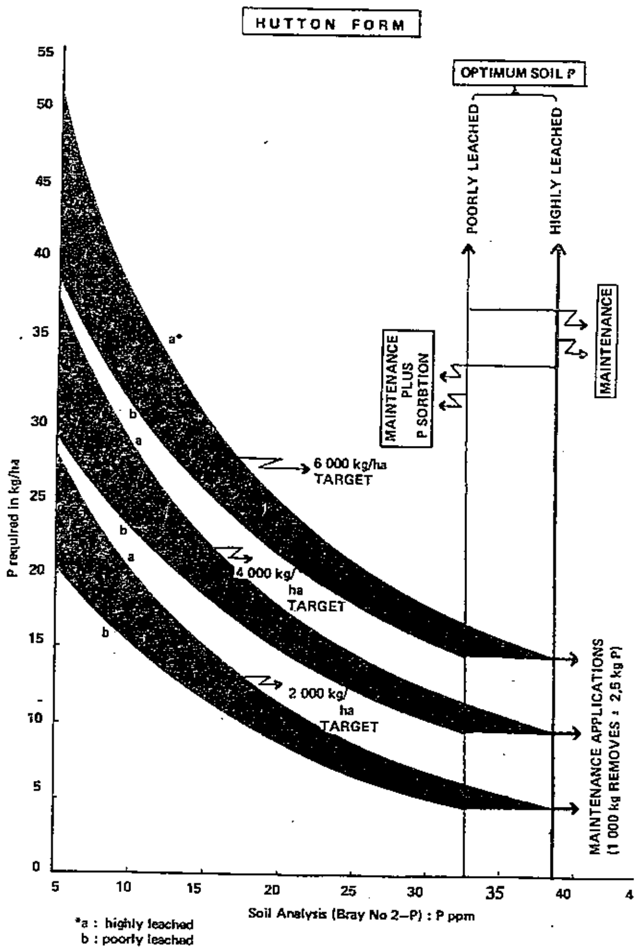

Fig 8 Model for P requirements for three production classes on series of the red soils (Hutton form)

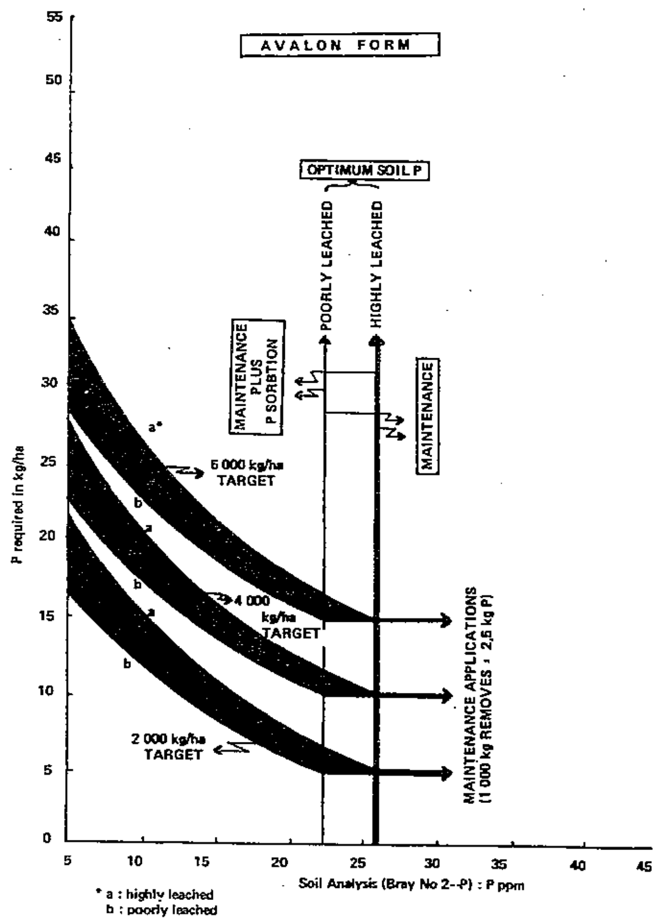

Fig 9 Model for P requirements for three production classes on series of the yellow soils (Avalon form)

TABLE 3 Comparison between actual optimum P-levels and estimated P-values from the models

Code No	Yield kg/ha x 100	Soil series	P-analysis	S/100g clay	P level in kg/ha actual (experiments)	P level in kg/ha estimated (P-model)	Deviation kg P/ha
M38	49	Msinga	25	11	18	17	+ 1
M3	24	"	39	7	00	0	0
M43	45	"	16	8	15	25	−10
M42	52	"	45	14	0	0	0
M40	48	"	13	11	20	26	− 6
M1	50	"	21	9	15	19	− 4
M23	52	Shorrocks	22	19	20	18	+ 2
M33	49	"	33	20	0	0	0
M31	36	"	29	18	0	8	− 8
M21	43	Makatini	17	20	19	19	+ 1
M15	54	Vimy	17	14	30	25	+ 5
M18	55	Hutton	46	2	0	0	0
M29	51	Bleeksand	18	19	15	15	0
M24	46	"	31	48	0	0	0
M28	54	"	20	28	15	14	+ 1
M34 I	51	"	30	28	0	0	0
M34 II	51	"	12	28	25	20	+ 5
M26	47	"	18	28	20	15	+ 5
M25	50	"	18	18	18	16	+ 2
M6	75	"	27	16	0	0	0
M35	43	Mooiveld	29	18	10	0	+10
M10	78	Ruston	6	2	55	43	+12
M11	46	Avalon	50	14	0	0	0

Mean deviation = 3,5 kg/ha

Opsomming

RIGLYNE VIR DIE BEMESTING VAN MIELIES OP GRONDSERIES VAN DIE AVALON- EN HUTTON-VORMS: 1 FOSFOR

Die resultate van 143 NPK-veldproewe met mielies, uitgevoer vanaf 1960/61 tot 1971/72 op series van die Avalon- en Hutton grondvorms is saamgevat en verder ondersoek met die primêre doel om riglyne vir bemestingsaanbevelings daar te stel. Enkelvoudige en meervoudige korrelasie- en regressiestudies op die proefdata wat volgens verskillende grond- en ander faktore groepeer is, het die basis van die ondersoek gevorm. In hierdie gedeelte word slegs die tendense en riglyne ten opsigte van fosfor aangebied.

Volgens die ondersoek het dit geblyk dat grondseries 'n belangrike onderskeidingsfaktor is wat fosforreaksiepatrone betref. 'n Betekenisvolle korrelasie tussen P-ontledings van die proefgronde en P-reaksies is gevind waar proefdata op basis van grondvorm groepeer is. Hiervolgens is getoon dat series van die Huttonvorm 'n hoër P-bemesting as series van die Avalonvorm vereis, maar dat die verskil afneem met verhoogde grond-P. Verdere onderverdeling van die proefdata het getoon dat die opbrengsklas en S/100g kleiverhouding eweneens verband hou met P-vereistes. Betreffende pH en grondtekstuur, kon 'n duidelike verwantskap egter nie vasgestel word nie.

Deur gebruik te maak van 'n indirekte metode, is bepaal dat die P-versadigingspunt van die grond tussen 30 en 40 dpm (Bray Nr 2) vir die Huttonvorm en tussen 20 en 25 dpm vir die Avalonvorm lê. Die lae waardes geld vir laaggeloogde series en die hoë waardes vir hooggeloogde series.

Op basis van die onderskeie regressiekrommes vir grondvorm, produksieklas en S/100g kleiverhouding, is riglyne wat die P-vereistes by variërende grond-P-gehaltes aandui, saamgestel.

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