Interim Report:

CORRELATIONS BETWEEN BRAY 1, BRAY 2 AND ISFEI (Volume) SOIL–P EXTRACTANTS

A J BUYS & G C H VENTER, FSSA

Introduction

Since 1964 the soil analysis laboratories of the fertilizer companies in South Africa have been using the Bray No 2 (1:7,5 extraction ratio) extractant (Bray & Kurtz, 1945) in a standardised soil analysis programme (FSSA, 1974). Only the extraction ratio was modified. At present altogether 15 laboratories — 10 from outside the fertilizer industry — are using the standard methods of the FSSA.

The usefulness of the Bray No 2 extractant for alkaline soils — defined here as soils with pH(KCl) > 6,0 — and for soils that had received applications of sedimentary rock phosphate, have for a number of years been questioned.

The Bray 2, citric acid, Truog and double acid North Carolina methods have been done unsuitable for P determination in calcareous soils and soils that had been treated with calcium rock phosphates (van der Merwe 1980). The Olsen bicarbonate method (Olsen, 1954), or Hunter's ISFEI modification hereto (Hunter, 1974), or the Bray No 1 (Bray & Kurtz, 1945) weak acid extractant had been suggested as alternatives for Bray 2. Van der Merwe (1980) maintained, on the evidence of correlation experiments, that the ISFEI, Bray 1 and water extraction methods should be considered in the choice of a method for soil–P extraction with a view to reference and communication purposes. He suggested that the ISFEI method had to be preferred for a standard reference method for the RSA.

An investigation has been done to compare Bray 2 with Bray 1 and with ISFEI (volume) with a view to possible change-over. To be acceptable, for purposes of crop yield prediction and fertilization recommendations, a new method must be at least as reliable as Bray No 2 for acid soils where no sedimentary phosphate had been applied.

All P calibration work by the FSSA has been done with respect to Bray 2 on acid soils that had not received sedimentary rock phosphate. As the Olsen type of method is accepted as sufficiently reliable for alkaline soils, and because ISFEI (volume) has been accepted as a reference method in the RSA (not necessarily a standard method) the new method should be well correlated with the ISFEI (volume) method. All P values are given in mg/kg soil ('ppm') or mg/litre soil ('ppm'), the latter applying to ISFEI (volume).

Results : Early work reviewed

Van der Merwe (1978) reported very good correlation between Bray 2 (1:7,5) and ISFEI (volume) and between Bray 2 (1:7,5) and Bray 1 for a mixed batch of soils. (See Table 1). Möhr (1975) also found very good correlations between Bray 2 (1:7,5) and Bray 1 for acid soils (soils of field trials), alkaline soils (soil analyses submitted by Fedmis' soil analysis laboratory, Sasolburg) and soils to which sedimentary rock phosphate had been applied (soil analyses submitted by Chemfos' soil analysis laboratory, Meyerton). The regression equations for alkaline soils and rock phosphate — treated soils are, however, quite different from that for acid soils (See Table 2).

TABLE 1 Correlation between soil P extractants on different soils (Van der Merwe, 1978) (See Figures 1, 2 and 3)

n	Methods	Regression equation	Correlation coefficient, r
36	ISFEI (vol)(Z) vs Bray 2 (1:7,5) (X)	Z = 1,08 + 0,63 X	0,86 **
36	ISFEI (vol(Z) vs Bray 1(Y)	Z = 1,07 + 1,49 Y	0,95 **
36	Bray 1 (Y) vs Bray 2 (1:7,5) (X)	Y = 1,44 + 0,42 X	

(Y vs X was calculated from the other regressions. See Figures 1, 2 and 3)

TABLE 2 Correlation between soil P extractants Bray 1 (Y) vs Bray 2 (X) (Möhr, 1975)

n	Soils	Regression equation	Correlation co-efficient, r
many	Acid soils, FSSA maize trials	Y = –2,03 + 0,930X	0,98
27	Soils treated with sedimentary rock phosphate – ex Chemfos (See Figure 3)	Y =–12,48 + 0,526X	0,80 **
280	'Alkaline' soils: pH(KC1) > 6,0 – ex Fedmis (See Figure 2)	Y = –19,07 + 0,799	0,84 **

TABLE 3 Correlation between soil P extractants for P values between 3 and 65 mg/kg soil (Bray 2) (Venter, 1979) (See Figure 1)

n	Methods	Regression equation	Correlation co-efficient, r
475	Bray 1 (Y) vs Bray 2(X)	Y =–0,465 + 0,920X	0,985**
174	ISFEI (vol) (Z) vs Bray 2 (X)	Z = 0,124 + 0,895X	0,963**
174	ISFEI (vol) (Z) vs Bray 1 (Y)	Z = 0,85 + 0,963Y	

(Z vs Y was calculated from the regressions for Z vs X and Y vs X both with n = 174)

The difference between the regression equations in Table 1 and Table 2 may partly be ascribed to the possibility of high pH and sedimentary rock phosphate applications in the case of Table 1, since the soils used were a mixed batch. From Table 2 it is clear that both pH (alkaline range) and type of phosphate applied to the soil have significant influences on the equations, Bray 2 always giving higher (probably too high?) values than Bray 1. Table 1 shows that for a mixed batch of soils Bray 2 gives higher values than both Bray 1 and ISFEI (volume). It also shows that ISFEI (volume) gives slightly higher values than Bray 1.

Results : 1979 soil analyses

FSSA maize trials

Acid soils; no sedimentary rock phosphate applied; several soil forms.

The P analyses of the individual plots of ten FSSA maize trials conducted during the 1978/79 season were used in this correlation study. Bray 2 and Bray 1 soil P were done for all ten trials, but ISFEI (vol) soil for only four of them.

The trials were situated in the Eastern Transvaal Highveld, North-Western OFS and Western Transvaal. The regression equations and correlation co-efficients are given in Table 3. All the correlations are highly significant.

In Table 3 the earlier results are confirmed, viz that Bray 2 gives higher values than both Bray 1 and ISFEI (volume), the latter two giving almost identical results.

Fedmis, Sasolburg – farm samples 1979

The results are given in Table 4.

TABLE 4 Correlation between soil P extractants – Fedmis' routine farm samples (to 50 mg/kg P, Bray 2) : Bray 2 (X) vs Bray 1 (Y)

Soils	Number of sample pairs	Regression equation	Correlation co-efficient, r
Acid soils (See Figure 1)	5 class intervals (10 mg/kg Bray 2) 22 weights (228 individual samples)	Y = 0,73 + 0,681X	(0,996)
'Alkaline' soils: pH(KC1) > 6,0 (See Figure 2)	32 individual samples	Y = 1,02 + 0,233X	0,489**

( ) This r value represents correlation of data pairs within class intervals.

The 228 acid soils of Table 4 represent a great variety and may include some samples from lands reated with sedimentary rock phosphate.

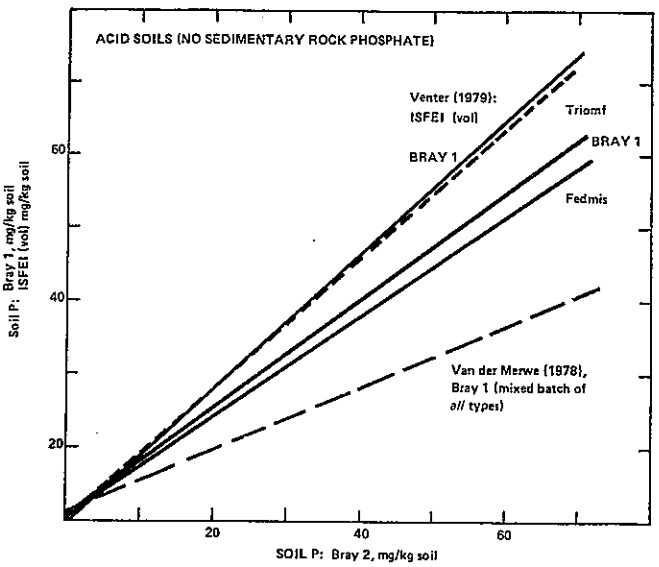

FIG 1 *Regression lines of Bray 1 and ISFEI (vol) soil P vs Bray 2 on acid soils with no sedimentary rock phosphate*

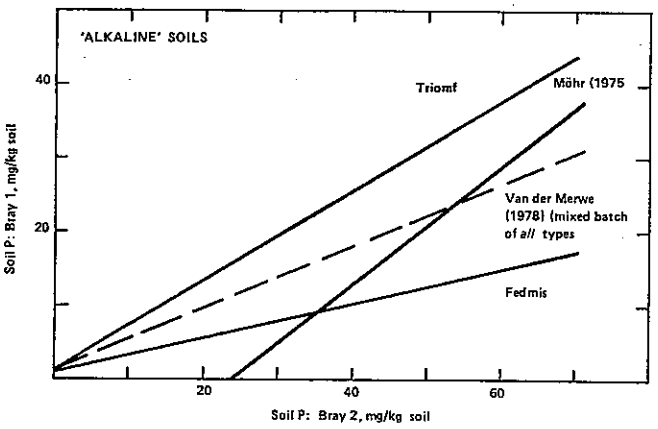

FIG 2 *Regression lines of Bray 1 vs Bray 2 soil P on 'alkaline' soils (pH (KC1) > 6)*

The correlation between the two methods for *alkaline soils* is poor, probably due to erratic pH-dependant Bray 2 values, especially in the high P range (Bray 2). The Bray 1 values are probably more reliable in this case. The few values above 50 mg/kg P, (Bray 2) were not taken into account, but nevertheless fit regression equation fairly well. This suggests that the relationship holds for higher P values, probably up to about 70 mg/kg P, Bray 2.

Triomf, Potchefstroom — farm samples (1979)

The results are given in Table 5.

TABLE 5 *Correlation between soil P extractants — Triomf's routine farm samples : Bray 2(X) vs Bray 1(Y) up to 70/80 mg/kg P, Bray 2*

Soils	Number of samples	Regression equation	Correlation co-efficient, r
Acid soils (See Figure 1)	8 class intervals (10 mg/kg P, Bray 2) 57 weights (1 131 individual samples)	Y =0,92 + 0,737 X	(0,9997)
'Alkaline' soils: pH(KC1) > 60 (See Figure 2)	7 class intervals (10 mg/kg P, Bray 2) 11 weights (109 individual samples)	Y =1,22 + 0,628 X	(0,998)

( ) These r values represent the correlation of data pairs within class intervals.

TABLE 6 *Mean soil P values for P treatments (FSSA Maize trial M3/S/78) (Venter, 1979)*

P treatment		Mean soil P, mg/kg soil (for all N and K levels)		
No	Kg P/ha	Bray 2 (X)	Bray 1 (Y)	Mean yield kg/ha
P0	0	17,6	15,9	6 204
P1	95	33,9	31,7	6 865
P2	190	55,4	52,1	6 884

FSSA Maize trial M3/S/78 (Soetmelk series, Avalon form) (Venter, 1979)

Regression equation for Bray 2 (X) vs Bray 1 (Y) for all 54 plots (3 replications; N, P and K treatments:

$$Y = -0,185 + 0,937X \quad (r = 0,984^{**})$$

The correlation on this acid soil is very good. The experimental results are summarised in Table 6.

The correlation between P extracted and yield was also investigated. The correlation co-efficients are given in Table 7.

TABLE 7 Quadratic correlation co-efficients (r) for P extracted by Bray 1 and Bray 2 vs maize yield for different N treatments (FSSA Maize trial M3/S/78) (Venter, 1979) (n = 54)

kg N/ha	N1	N2	N3
Bray 2	0,595 **	0,681 **	0,480 **
Bray 1	0,510 **	0,657 **	0,453 **

Although it would appear that the quadratic equations fits the data well, none are really good. The correlation between soil P (Bray 2 and Bray 1) and yield is not very good, although statistically highly significant. This may be partly attributable to the fact that the initial P level is not very low.

FSSA Maize trial M1/W/78 (Heidelberg series, Avalon form — acid) (Venter, 1979)

Regression equations for Bray 2, Bray 1 and ISFE (vol) vs one another are given in Table 8.

TABLE 8 Correlation between Bray 2, Bray 1 and ISFEI (volume) soil P extractants. (FSSA Maize trial M1/W/78) (Venter, 1979) (n = 54)

Methods	Regression equation	Correlation co-efficient, r
Bray 2 (X) vs Bray 1 (Y)	Y = 0,14 + 0,966 X	0,998 **
Bray 2 (X) vs ISFEI (vol) (Z)	Z = −0,64 + 0,958 X	0,951 **
Bray 1 (Y) vs ISFEI (vol) (Z)	Z = −1,70 + 1,022 Y	0,983 ***

The correlations between pairs of the three methods are good. So is the numerical agreement, especially between Bray 1 and ISFE (volume). The experimental results are summarised in Table 9.

TABLE 9 Mean soil P values for P treatments (FSSA Maize trial M1/W/78) (Venter, 1979)

P treatment		Mean soil P, mg/kg or litre soil (for all N and K)			Mean yield kg/ha
No	kg/Pha	Bray 2 (X)	Bray 1 (Y_1)	ISFEI(vol) (Y_2)	
PO	0	2,5	2,5	1,5	5 115
P1	95	21,4	21,1	19,9	8,017
P2	190	51,8	49,9	48,3	8 168

These relationships are near-perfectly linear and correspond closely with regressions given in Table 8.

Correlation co-efficients for correlations between extract P and the respective yields are given in Table 10.

TABLE 10 Quadratic correlation co-efficients (r) for P extracted by Bray 1, Bray 2 and ISFEI (vol) vs maize yield for different N treatments (FSSA Maize trial M1/W/78) (Venter, 1979) (n = 54)

kg/N/ha	N1	N2	N3
Bray 2	0,807**	0,925**	0,787**
Bray 1	0,803**	0,923**	0,788**
ISFEI (vol)	0,825**	0,941**	0,771**

These correlations are all equally good, which shows that for acid soils with no sedimentary phosphate there is little to choose between these methods of P extractions. The low initial P is probably partly responsible for the 'good' responses.

FSSA Wheat trial W19/NWV/78 (Dijkhuis, 1979)

Acid soil; four cultivars; N and P treatments
Regression equation (all 48 data pairs of one replication); Bray 2 (X) vs Bray 1 (Y):

Y = 2,30 + 0,716 X (r = 0,897**)

The correlation is good and applies between 20 and 40 mg/kg P, Bray 2.
Experimental results are summarised in Table 11.

TABLE 11 Mean soil P values for P treatments (FSSA Wheat trial W19/NWV/78), (Dijkhuis, 1979)

P treatment		Mean soil P, mg/kg		Mean Yield
No	kg P/ha	Bray 2 (X)	Bray 1 (Y)	kg/ha
PO	0	27,1	21,3	1 899
P1	20	28,0	22,4	1 966
P2	40	27,2	22,0	1 915

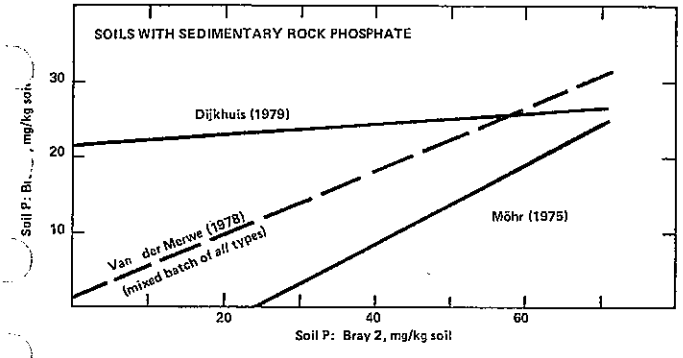

FIG 3 Regression lines of Bray 1 vs Bray 2 soil P on soils to which sedimentary rock phosphate had been applied

The correlation between the two methods for the mean P values is reasonably good, but does not correspond well with the regression of all individual data pairs. (It applies to Bray 2 P values between 30 and 60 mg/kg.

FSSA Wheat trial W20/NWV/78 (Dijkhuis, 1979)

Very acid soil; four cultivars; N and P treatments; sedimentary rock phosphate previously applied.

Regression equation (all 48 data pairs of one replication); Bray 2(X) vs Bray 1(Y):

$$Y = 21,45 + 0,1032\ X\ (r = 0,271\ NS)$$

The correlation is poor, and applies between 30 and 70 mg/kg P, Bray 2 (See Figure 3).

Experimental results are summarised in Table 12.

TABLE 12 Mean soil P values for P treatments (FSSA Wheat trial W20/NWV/78) (Dijkhuis, 1979)

P treatment		Mean soil P, mg/kg		Mean Yield
No	kg P/ha	Bray 2 (X)	Bray 1(Y)	kg/ha
PO	0	42,5	24,1	2 583
P1	20	46,0	26,1	2 940
P2	40	47,0	28,1	3 163

Conclusions

(i) Bray 2 gives much higher values than either Bray 1 or ISFEI (vol) for alkaline soils and soil treated with sedimentary rock phosphate. The correlation between the methods for such soils is not as good as for acid soils.

(ii) For acids the correlations between the three methods are good.

(iii) The regression equations indicate that for acid soils where no sedimentary rock phosphate had been added the P values obtained by Bray 1 and ISFEI (volume) are similar. Both these methods yield slightly lower values than Bray 2.

(iv) Bray 1 extractable P is possibly pH dependent in the alkaline range because the regression equations for the very alkaline soils (Fedmis' samples) are different from that of moderately alkaline soils (Triomf's samples). Further investigation is required.

(v) The correlation between Bray 2 and Bray 1 extractable P is also possibly dependent on the quantity of sedimentary rock phosphate applied and/or time ('contact/reaction' time in the soil). This could possibly explain the large difference between regression equations obtained by Möhr (1975) and Dijkhuis (1979). It could also explain why both the Fedmis and Triomf data give lower Bray 1 values with respect to Bray 2 values than the acid soils with no sedimentary phosphate history. (FSSA maize trials).

(vi) Routine laboratories using the Bray 2 method of analysing soil samples from farmers with a view to fertilizer recommendations can immediately and confidently change over to either Bray 1 or ISFEI(volume) for all types of soil, since good correlations exist for acid soils and all the FSSA fertilization calibration work had been done on acid soils with no sedimentary rock phosphate. Both these methods are more

acceptable for the alkaline and rock phosphate treated soils, although no calibration work had been done with them. Further investigation is required on these soils, using Bray 1 and/or ISFEI (vol).

Acknowledgement

The authors wish to express their sincere appreciation to the Summer Grain Centre of the Department of Agriculture and Fisheries for the ISFEI (vol) analyses reported in this article.

References

BRAY, R.H. & KURTZ, L.T., 1945. Determination of total, organic, and available forms of phosphorus in soils. *Soil Sci.* 59, 39–45.

DIJKHUIS, F.J., 1979. Tussentydse verslag: Koringprogram 1979. Internal unpublished FSSA report.

FERTILIZER SOCIETY OF SOUTH AFRICA, 1974. Soil Analysis Methods: Manual of Laboratory Procedures of the Fertilizer Society of South Africa. 3rd Edition.

HUNTER, A.H., 1974. Tentative ISFEI soil extraction procedure. International Soil Fertility Evaluation and Improvement Project, North Carolina State University, Raleigh, North Carolina, USA.

MÖHR, P.J., 1975. Unpublished internal FSSA report.

OLSEN, S.K., COLE, C.V., WATANABE, F.S. & DEAL, L.A., 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate USDA Cir. No. 939.

VAN DER MERWE, A.J., 1978. Evaluasie van verskeie beskikbaarheidsparameters van P in grond. Paper presented at symposium on fertilization of small grain, Bethlehem.

VAN DER MERWE, A.J., 1980. 'n Evaluering van fosforekstraksiemetodes vir Suid-Afrikaanse gronde met die oog op standaardisering. Paper read at the Soil Science Society of Southern Africa session of the Combined Congress, Durban, January.

VENTER, G.C.H., 1979. Verslag oor 1978/79 Proewe. MVSA Publikasie nr 72. *And*: Individual trial results; unpublished.