



Relationships between soil phosphorous extraction tests

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INTRODUCTION

TO COMMONLY USED SOIL P EXTRACTION TESTS

Soil phosphorous extraction tests

P extraction tests simulate availability of P to plants under various conditions

Some tests are believed to work best for certain soil types

- i. Acidic soil = Bray I, Bray II
- ii. Calcareous soils = Olsen

Some tests are believed to be effective under a wide variety of conditions (Mehlich III & Ambic 1)



Types of extractants used

Some extractants reflect P quantity and others reflect P intensity (1:2 water, Olsen).

Water/unbuffered salt solutions

- Reflect P intensity and not quantity

Dilute organic acid extracts

- Mimic plant organic acid exudation to enhance P solubility
- **Citric acid**

Dilute strong acid extracts with complexing agents (F⁻ & EDTA)

- Promotes solubility of P through complexation of Al³⁺ and Fe³⁺
- **Bray I, II and Mehlich III**

Buffered alkaline solutions **with** and **without** complexing agent

- **Olsen, Colwell and Ambic I (also contains EDTA & F)**

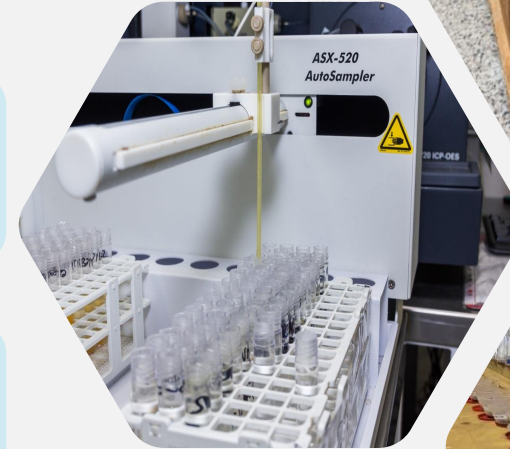


Table 1 Summary of soil P extraction tests solution properties and extracting conditions used in this study.

P Test	Extracting solution ingredients	Solution pH	Soil:solution ratio	Extraction time	Method used
Bray I	0.03M NH ₄ F, 0.025M HCl	2.0	1:7	60s	The Non-affiliated Soil Analyses Work Committee (1990)
Bray II	0.03M NH ₄ F, 0.1M HCl	1.0	1:7	40s	The Non-affiliated Soil Analyses Work Committee (1990)
Mehlich III	0.2M CH ₃ COOH, 0.25M NH ₄ NO ₃ , 0.015M NH ₄ F, 0.013M HNO ₃ , 0.001M EDTA	2.5	1:10	5min	Mehlich (1984)
Citric acid	1% citric acid	1.0	1:10	1h	The Non-affiliated Soil Analyses Work Committee (1990)
Olsen	0.5M NaHCO ₃	8.5	1:20	30min	The Non-affiliated Soil Analyses Work Committee (1990)
Colwell	0.5M NaHCO ₃	8.5	1:100	16h	Colwell (1963)
Ambic I	0.25M NH ₄ HCO ₃ , 0.01M (NH ₄) ₂ EDTA, 0.01 M NH ₄ F, 0.05 g L ⁻¹ Superfloc N100	8.3	1:10	30min	The Non-affiliated Soil Analyses Work Committee (1990)
Water	Distilled water	7.0	1:2	1h	Kuo (1996)
Total P	70% perchloric acid	<1.0	1:100	16h	Kuo (1996)

The background features a light green gradient with several green leaves. Some leaves are partially obscured by white hexagonal outlines. A dark grey rectangular box is centered horizontally, containing the title text.

PHOSPHOROUS NORMS

Table 2. Critical soil P concentrations (mg/kg)

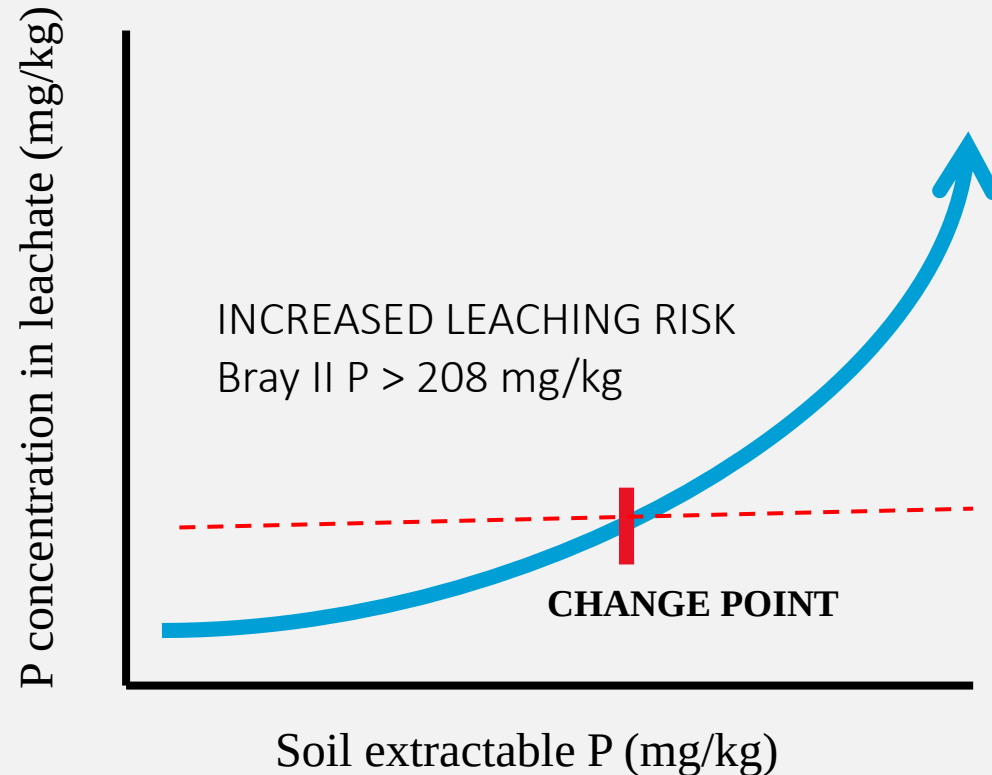
TEXTURE	pH _{KCl}	EXTRACTANT					
		Olsen	Citric Acid	Mehlich III	Bray I	Bray II	Ambic I
		Mg kg ⁻¹					
Sand	< 5.0	-	25	25	20	20	20
Loam		-	30	30	25	25	25
Clay		-	35	35	30	30	30
Sand	5.0 - 6.0	12	25	20	15	20	20
Loam		16	30	25	20	25	25
Clay		16	35	30	25	30	30
Sand	6.0 – 7.0	10	25	20	10	20	10
Loam		12	30	25	12	25	15
Clay		15	35	30	15	30	20
Sand	> 7.0	10	25	18	10	15	10
Loam		12	30	21	12	18	12
Clay		15	35	25	15	21	15

Table 3. Maximum soil P concentrations (mg/kg)

TEXTURE	pH _{KCl}	EXTRACTANT					
		Olsen	Citric Acid	Mehlich III	Bray I	Bray II	Ambic I
		Mg kg ⁻¹					
Sand	< 5.0	-	80	80	80	80	80
Loam		-	100	100	100	100	100
Clay		-	120	120	120	120	120
Sand	5.0 - 6.0	20	80	80	70	80	80
Loam		25	100	100	90	100	100
Clay		30	120	120	110	120	120
Sand	6.0 – 7.0	20	100	100	70	100	70
Loam		25	120	120	90	120	90
Clay		30	140	140	110	140	110
Sand	> 7.0	20	140	120	70	120	70
Loam		25	160	140	90	140	90
Clay		30	180	160	110	160	110

How much is too much?

- The point at which P concentration in leachate exceeds extracted P = **change point**
- When the change point concentration is reached the risk for leaching losses is greatest
- Change point = $40 - 61.5 \text{ Olsen P (mg/kg)}$ (Heckrath *et al.* 1995, Wang *et al.*, 2012, Zhong *et al.*, 2004)
- **208 – 375 Bray II P (mg/kg)**





P TEST EFFICIENCY & CONVERSION

Relative effectiveness of soil P tests

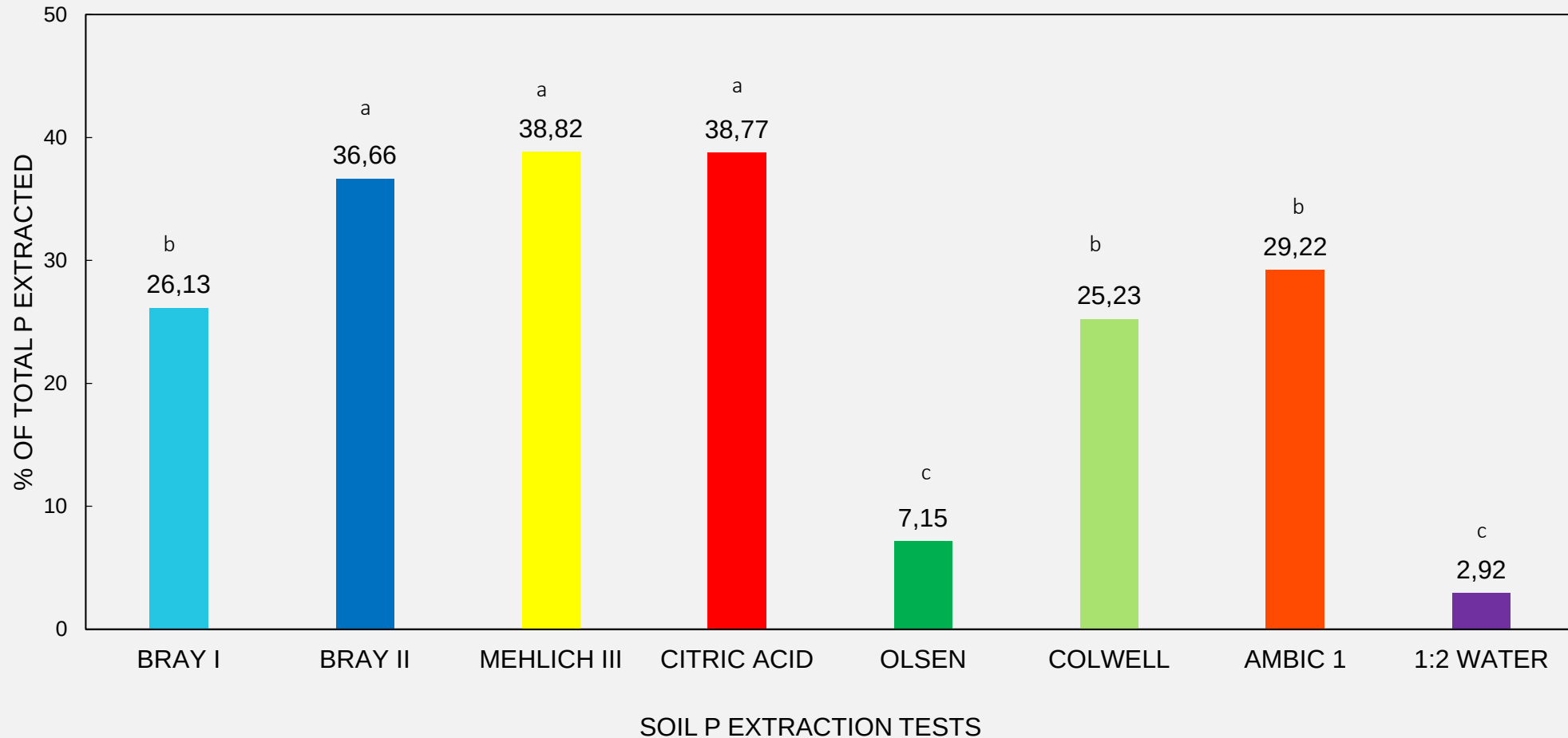


Figure 1 Mean percentage of total soil P extracted by the various soil P extraction tests ($n = 48$). Where letters are the same, they represent a lack of statistical difference between tests at $p < 0.05$

Correlation with total P at two pH(KCl) groups

Table 4 Pearson correlation coefficients (r) between available P extraction tests and Total P at $\text{pH}_{\text{KCl}} > 5.5$ (n=22) and $\text{pH}_{\text{KCl}} < 5.5$ (n=25) (*p < 0.05; **p<0.001).



Soil P test	$\text{pH}_{\text{KCl}} > 5.5$	$\text{pH}_{\text{KCl}} < 5.5$
Bray I	0.61**	0.75**
Bray II	0.79**	0.77**
Mehlich III	0.72**	0.78**
Citric acid	0.69**	0.53*
Olsen	0.65**	0.73*
Colwell	0.34	0.52*
Ambic I	0.68**	0.55*
1:2 water	0.52*	0.64**

Correlations between P extraction tests

- All tests correlated significantly ($p < 0.05$)
- Strongest relationship between Bray I, Bray II and Mehlich III ($r = 0.92 - 0.99$)
- Olsen correlated strongly with Bray I, Bray II and Mehlich III
- Ambic I correlated strongly with Citric acid, Bray II, Mehlich III and Bray I
- 1:2 water P correlated with Olsen P



Correlations between P extraction tests

Table 6 Pearson correlation coefficients (r) between the soil P extraction tests (n = 48) (* = $P < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$; $r > 0.70$ are highlighted).

	Bray I	Bray II	Mehlich III	Citric acid	Olsen	Colwell	Ambic I	1:2 water
Bray I								
Bray II	0.92***							
Mehlich III	0.95***	0.99***						
Citric acid	0.68***	0.85***	0.82***					
Olsen	0.89***	0.86***	0.85***	0.57***				
Colwell	0.62***	0.66***	0.66***	0.74***	0.59***			
Ambic I	0.73***	0.85***	0.84***	0.96***	0.56***	0.72***		
1:2 water	0.68***	0.63***	0.64***	0.33*	0.75***	0.35*	0.34*	
Total P	0.68***	0.78***	0.76***	0.60***	0.69***	0.58**	0.60***	0.58***

Convert between norms

Table 7 Simplified direct conversion factors between the various P extraction tests

Soil Test (Y =)	(X =)	BRAY I	BRAY II	MEHLICH III	CITRIC ACID	OLSEN	AMBIC
BRAY I							
BRAY II		$Y = 1.29X$ ($R^2 = 0.82$)					
MEHLICH III		$Y = 1.46X$ ($R^2 = 0.90$)	$Y = 1.10X$ ($R^2 = 0.97$)				
CITRIC ACID		$Y = 1.05X$ ($R^2 = 0.34$)	$Y = 0.87X$ ($R^2 = 0.70$)	$Y = 0.77X$ ($R^2 = 0.63$)			
OLSEN		$Y = 0.22X$ ($R^2 = 0.80$)	$Y = 0.16X$ ($R^2 = 0.72$)	$Y = 0.14X$ ($R^2 = 0.72$)	$Y = 0.15X$ ($R^2 = 0.24$)		
AMBIC		$Y = 0.83X$ ($R^2 = 0.47$)	$Y = 0.59X$ ($R^2 = 0.71$)	$Y = 0.59X$ ($R^2 = 0.71$)	$Y = 0.75X$ ($R^2 = 0.92$)	$Y = 1.32X$ ($R^2 = 0.52$)	

Including pH

Table 8 Generalized least squares model including a pH interaction accuracy metrics (mae = mean absolute error).

Model type	Y	Predictor (X)	mae	R ²
GLS	BRAYI	BRAYII	8.86	0.95
GLS	BRAYI	MEHLICHIII	8.90	0.94
GLS	BRAYI	OLSEN	16.47	0.82
GLS	BRAYI	AMBIC	22.27	0.63
GLS	BRAYII	MEHLICHIII	8.28	0.98
GLS	BRAYII	OLSEN	24.14	0.77
GLS	BRAYII	AMBIC	25.10	0.71
GLS	MEHLICHIII	OLSEN	31.52	0.71
GLS	MEHLICHIII	AMBIC	27.74	0.72
GLS	OLSEN	AMBIC	6.96	0.27

Conclusions

❖ *The relative effectiveness of the P tests in extracting total soil P was found to be as follows:*

1:2 H₂O < Olsen < Colwell < Bray I < Ambic I < Bray II < Mehlich III $\approx$ citric acid.

❖ CBD Fe oxide and clay% has the most significant negative effect on soil extractable P

❖ Strong acid extraction tests correlated significantly with total P at pH > 5.5 and < 5.5

❖ *Conversion is possible between*

i. Mehlich III, Bray I , Bray II and Olsen

ii. Ambic I and Citric acid

❖ Conversions were created using **SANAS** accredited labs (Bemlab, Labserve and Elsenburg)

❖ Work is required to validate conversions and further improve prediction accuracy





P FERTILISER RECOMMENDATIONS



Considerations regarding P application

- **Soil pH (KCl):** acidity needs to be addressed.
- **Soil P sorption capacity:** applied P will become less available over time.
- Typically, 4.5 kg P/ha will increase soil P by 1 mg/kg
- P removal by the crop should be considered.



P application with lime ?

- P sorption is kinetically biphasic – first part is rapid, and the second part is slow
 - FIRST PART** involves non-specific ligand exchange (still labile)
 - SECOND PART** involves precipitation reactions
- *Applied P will eventually react with soil Ca or applied lime, but the reaction is slow*
- Soil P should be determined annually and readjusted in these cases.
- Over liming should be avoided



Plant response

Is soil P concentration within the norm ?

Is leaf P concentration within the norm ?

- No reaction to applied P if leaf P and soil P concentration is sufficient.





Thank You



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