Soil Testing for Phosphorus

Comparing extractants and their ability to detect P responsive soils in Manitoba

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Background

A number of commercial extractants are used to determine phosphorus (P) status of soils in order to make agronomic decisions on fertilization. The traditional extractant for calcareous soils in the Great Plains is the Olsen or sodium bicarbonate test and it was selected for use in 1962 for use at the Manitoba provincial soil test lab (Flaten et al, 2002). Other phosphorus extractants have been developed since that time (see Table 1).

Table 1. Brief description of agronomic soil P extractants

Method	Chemical extractants	Characteristics	Lab use
Olsen (1954)	0.5 M $NaHCO_3$	Suitable on wide range of soils, especially calcareous based soil.	AgVise, A&L Labs, Midwest Labs
Modifed Kelowna 2 (1991)	0.25 M CH_3COOH + 0.015 M NH_4F + 0.25 M CH_3COONH_4	Considered suitable for calcareous and non-calcareous soils. Ability to extract many nutrients at the same time, increases lab efficiency.	Enviro-Test Labs (ETL)
Modified Kelowna 3	0.5 M CH_3COOH + 0.015 M NH_4F + 0.25 M CH_3COONH_4		Norwest Labs (NW)
Bray P1 (1945)	0.03 M NH_4F +0.025 M HCl	Developed for acidic to neutral pH soils. Generally unreliable for calcareous soils due to rapid neutralization of acid by calcium carbonate	AgVise, A&L Labs, Midwest Labs on acidic soils
Mehlich-3 (1984)	0.2 M CH_3COOH + 0.013 M HNO_3 + 0.25 M NH_4NO_3 + 0.015 M NH_4F + 0.001 M EDTA	Ability to extract many nutrients at the same time, increases lab efficiency.	Some Midwest US labs

There is current interest in developing a relationship between the various extractants to:

- Allow for wider use of fertilizer recommendations developed with individual tests (ie provincial phosphorus fertilizer recommendations were based on the Olsen-P test).
- Allow tracking of soil P levels over time if growers/agronomists/labs change analytical procedures, by providing conversion factors.
- Provide conversions for proposed regulations addressing P applications as manure or fertilizer.

Methods

A total of 214 soils from Manitoba were analysed using the 5 extractants in Table 1 (and 5 other methods not discussed here).

- 51 soils had a history of manure application
- 113 soils were from an archive of the distinct soil groups across Manitoba

Soil P was extracted using the above methods, and extracts were determined colorimetrically using the molybdate-ascorbic method. Some commercial labs use the ICP (Inductively Couple Plasma emission spectrometry) method to measure extracted P instead of the colorimetric method. Others have observed that P determination with the ICP method produces higher P values, presumably because organic P in addition to inorganic P is measured (Herman et al, 2004). This current study did not address such differences.

Linear regression analysis was performed to establish relationships between amounts of P extracted.

Development of a relationship between extractants is only a “first-step” in evaluating their effectiveness (Fixen and Grove, 1990). The more useful measure is the ability of the extractant to detect and identify soil where P additions have increased yield or P uptake. So soil from 16 phosphorus response studies on cereals in Manitoba was obtained from researchers to evaluate the effectiveness of various tests in identifying responsive soils. The Cate-Nelson Graphical Method was used at a relative yield of 80% to visually identify the highly responsive soils.

Results – Relationship of various extractants

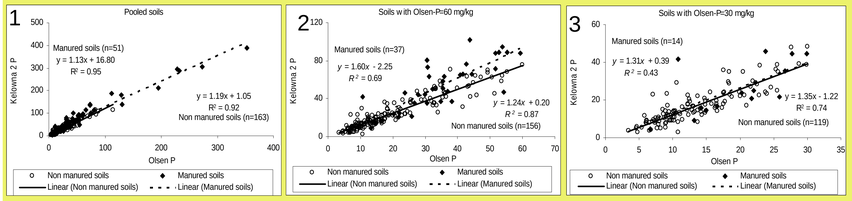
Highly significant correlations were established among all the extraction methods (Table 2).

Table 2. Pearson’s correlation coefficients between different soil P test methods (with all 214 soils).

Soil test P Methods	Olsen P	Kelowna 2-P ETL	Kelowna 3- P NW	Bray P1	Mehlich 3-P
Olsen P	1.00				
Kelowna 2-P ETL	0.97	1.00			
Kelowna 3-P NW	0.94	0.98	1.00		
Bray P1	0.95	0.94	0.93	1.00	
Mehlich 3-P	0.98	0.98	0.96	0.94	1.00

The relationships were very strong (R^2>90) when all 214 soils were included in the statistical analysis, particularly due to the presence of a few extremely high soil test values from manured fields (Figure 1). The relationship between extractants was not as strong when using only those soils in the “agronomic” soil test ranges (0-30 or 0-60 ppm Olsen P) as in Figures 2-3. Similarly, manured soils had a weaker relationship between extractants within the agronomic soil test range.

The extracted P was 180-225% greater on manured fields as compared to adjacent unmanured fields.



Figures 1-3. Relationship between Olsen P and Kelowna 2-P (ETL) at different levels of Olsen P. Note: mg/kg = ppm

The following graphs show the relationship of the extracted P from other methods to Olsen P . (Figures 4-6).

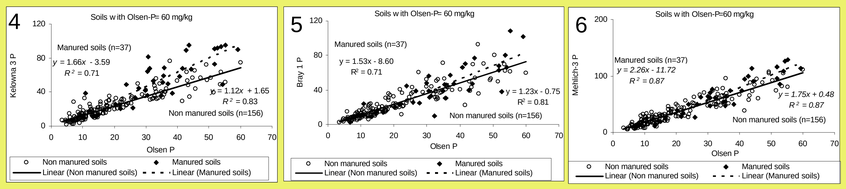


Figure 4-6. Relationship between Olsen P and modified Kelowna 3-P (NW), Bray P1 and Mehlich 3P extractants within the agronomic range of 0-60 ppm Olsen P . Note: mg/kg = ppm

The amount of soil P extracted differed among methods, but was well correlated as indicated by the R^2 value. However, there is still considerable scatter of data points. Within this agronomic soil test range (0-60 ppm Olsen P), the relationships between methods were not as strong as those in Table 2.

The Olsen test extracted less P than the others. In the range of 0-60 ppm Olsen P, the extracted levels were 24%, 12%, 23% and 75% greater with the modified Kelowna 2-P (ETL) and 3-P (NW), Bray P1 and Mehlich 3-P tests, respectively.

Results – Identification of Responsive Soils

The ability of the different P tests to identify responsive soils in Manitoba is shown in Figures 7-12. The relative yields are those with no added P compared to the fully P fertilized treatments. All trials were seeded to cereals; 9 to spring wheat (Grant, Tomasiewicz), 6 to oats (Mohr) and 1 to winter wheat (Westco).

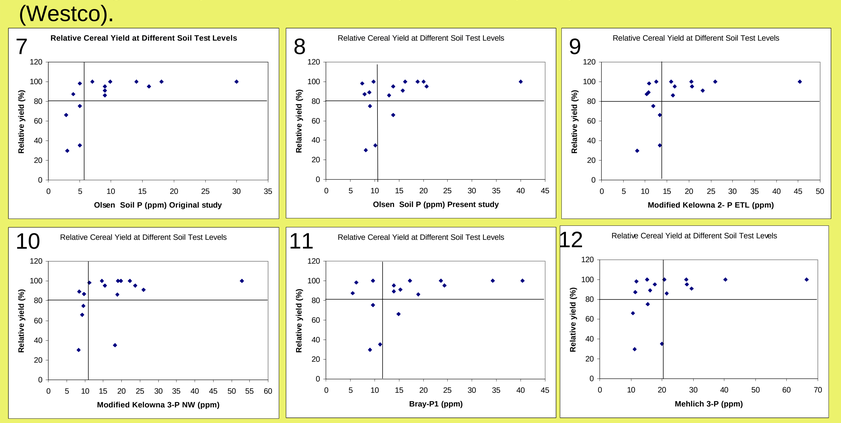


Figure 7-12. Relationship between soil test extractants and crop yield response to applied P. Extractants are; Fig. 7 Olsen P as reported in original research study, Fig. 8 Olsen P as measured in this study, Fig. 9 modified Kelowna 2-P (ETL), Fig. 10 modified Kelowna 3-P (NW), Fig. 11 Bray P1 and Fig 12 Mehlich 3-P.

The extractant that best identified the highly P responsive soils was the Olsen P test; with the original Olsen P value more discerning than the Olsen test conducted in this study. The Bray P1 test was least discerning of the responsive soils.

Summary

Agronomists or growers wishing to relate other extractants to the Olsen P test may consider using the following conversion factors, based on unmanured soils in the range of 0-60 ppm Olsen P.

Olsen P = Kelowna 2-P x 0.81 Olsen P = Kelowna 3-P x 0.89

Olsen P = Bray P1 x 0.81 Olsen P = Mehlich 3-P x 0.57

Extractants were generally able to differentiate between P responsive and sufficient soils. The Olsen test appeared most discerning and the Bray P1 test the least.

References and Acknowledgements

Fixen, P.E. and J.H. Grove. 1990. Testing Soils for Phosphorus. P.141-180. *In* Soil Testing and Plant Analysis. SSSA Book Series:3. Madison, Wi.

Flaten, D., G. Racz and C. Grant. 2002. Development of soil fertility tests for Manitoba: A historical perspective. *In proc* Manitoba Society of Soil Science, 2002. pp 1-15.

Herman, J.C., J.R. Massey, D.F. Leikam and S. Harrold. 2004 Relationship of Mehlich-3-ICP and Mehlich -3-Colorimetric phosphorus determinations with the Bray-P1 extractant. 2004. In proc. NC Extension-Industry Soil Fertility Conference. Des Moines, Iowa. Pp 166-172.

Full report available as:

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