COMPARISON OF MEHLICH-3, OLSEN, AND BRAY-P1 PROCEDURES FOR PHOSPHORUS IN CALCAREOUS SOILS

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INTRODUCTION

Fertilizer recommendations for P generally are based on soil testing. Although a variety of soil tests are reliable for evaluating plant available P of neutral or slightly acid soils, there is still uncertainty about appropriate soil tests and soil-test interpretations for calcareous soils. The Bray-P1 and Olsen methods are the most widely used soil-test P methods in the North Central region. Extensive research has shown that the Bray-P1 test is reliable on neutral or acid soils but that it tends to underestimate available P on calcareous soils. The Olsen test is more reliable for calcareous soils. Because of this problem, many routine soil testing laboratories often use both methods, and base fertilizer recommendations on one or the other method depending on the pH of the sample.

The increasing demand for soil testing (because of the introduction of grid sampling methods and other site-specific management practices) necessitates the use of more efficient methods for soil testing. One possibility for improving laboratory efficiency would be to use a single extractant for multiple purposes. The Mehlich-3 extractant has been proposed as a "universal" extractant and is an attractive method for routine soil testing. This test seems to be a reliable test for neutral or slightly acid soils, and amounts extracted seem to be similar to amounts extracted by the Bray-P1 method. Little information of correlations and crop-response calibrations for the Mehlich-3 has been published for soils of the North Central region, however. The information is especially lacking for a variety of calcareous soils. The objective of this research was to correlate amounts of P extracted from soil samples varying in soil pH by the Bray-P1, the Olsen, and the Mehlich-3 methods and to obtain field calibrations over a wide range of Iowa soils varying in pH and calcium carbonate content.

METHODS

The Bray-P1, Olsen, and Mehlich-3 methods were compared by using two approaches. In one approach, the amounts of P extracted by these methods were compared by analyses of 240 soil samples submitted by farmers to the Iowa State Laboratory. The samples were selected among samples for which information about field location and soil type was provided. The pH values ranged from 5.3 to 8.2, and the calcareous soils represented soil series of western and north central Iowa. In the other approach, numerous (48 site-years) field P-response studies with corn were conducted on farmers' fields and experimental research farms from 1989 to 1994. The trials included several replicated P rates and were established on 14 different soil series. The calcareous soils corresponded mostly to soils of the Clarion-Nicollet-Webster soil association.

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Soil and crop management practices (except N. P. and K fertilization) were those normally used by the farmers. Nonlimiting rates of N and K were applied to all plots. All fertilizers were broadcast in the fall or spring and incorporated by disking or chisel plowing except at sites managed with no-till or ridge tillage.

Soil samples (0-6 inches depth) were dried at temperatures less than 100 °F. Soil analyses were performed at the Iowa State University Soil Testing Laboratory following suggested procedures for the North Central region (North Dakota Agric. Exp. Stn., 1980). The procedure used to determine P by the Mehlich-3 extractant was that described by Mehlich (1984). Briefly, P by the Bray-P1 and Mehlich-3 extractants were determined by using a 1:10 (w/v) soil:solution ratio and an extraction time of 5 min, and P by the Olsen extractant was determined using a 1:20 (w/v) soil:solution ratio and an extraction time of 30 min. All extractions were performed in duplicate. Relative yields shown were defined as the mean yield of the nonfertilized plots expressed as percentages of the mean yield of statistically similar highest yielding treatments for each site.

RESULTS

Correlations between amounts of P extracted.

Correlation coefficients between methods were strongly dependent on the soil pH of the samples included in the analyses. Correlations involving the Bray-P1 method were very low when all soil samples were included in the analyses but improved when calcareous soils were dropped. Figure 1 shows these relationships for three pH classes and for all samples. The low correlation coefficient between the Bray-P1 and the Olsen methods across all soil samples was expected because other research has shown that the Bray-P1 tend to underestimate available P on calcareous soils. The correlation between the Bray-P1 and the Mehlich-3 methods across all samples was very low, and the correlation between the Olsen and Mehlich-3 methods was highly independent of soil pH. These results were not expected because of the common belief that the Bray-P1 and the Mehlich-3 would result in similar evaluations of available P. Moreover, the slopes of linear relationships between the Olsen and Mehlich-3 methods were similar for the different groups of samples. These results suggest that in many calcareous soils the Mehlich-3 method is comparable to the Olsen method. It is clear from Fig. 1, however, that none of the three methods correlate well for some calcareous soils. Information about soil type, calcium carbonate content, and organic matter content (not shown) is being studied to explain this disagreement.

Data from Fig. 1 suggest that the use of a single factor or equation to express amounts of P extracted by one method based on amounts extracted by another often would yield wrong estimates. This is mostly the result of the different ability of the methods to estimate P on calcareous soils and of unexplained variability. It is very clear that this problem would occur especially for comparisons between amounts of P extracted by the Olsen or Mehlich-3 methods with the Bray-P1 method. Elimination of calcareous soils would not solve the problem entirely because (from Fig. 1) it seems that there is no clear soil pH value that could be used to identify problem soils. The relationship between the Olsen and Mehlich-3 methods were only slightly affected by the inclusion of calcareous soils (the slope of lines and intercepts tended to be similar for the different pH classes). It is obvious from Fig. 1, however, that there is much unexplained variability and the prediction ability of these equations would be questionable.

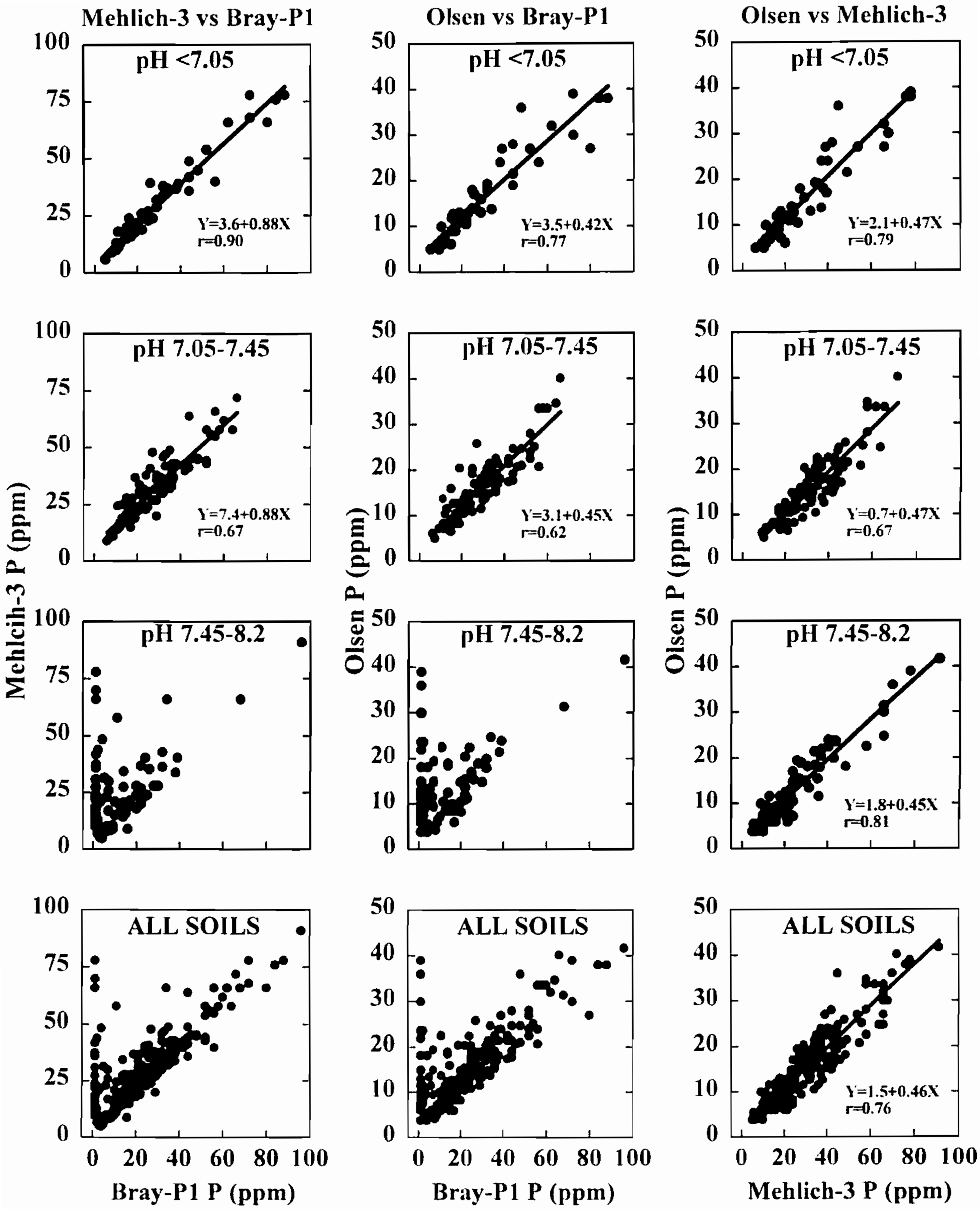

Figure 1. Relationships between amounts of P extracted by the Bray-P1, Mehlich-3, and Olsen methods for 240 Iowa soils varying in pH.

Field calibration studies with corn.

Field calibrations studies that account for local variations in soil types and other site variables should provide the basis for soil test interpretations. The variety of growing conditions in this study resulted in grain yields that ranged from 90 to 220 bu/acre. Timely rainfall usually was a major factor affecting crop growth during most growing seasons. The lowest yields were observed for the 1993 season due to excess soil moisture or flooding, and yield data for this season were not included in the results shown. Phosphorus fertilization resulted in statistically significant yield increases at approximately one third of the sites.

The three extractants tended to agree when evaluating available P in one soil relative to that in other soils (Fig. 2). There were a few important disagreements, however, that tended to occur on highly calcareous soils. The Mehlich-3 and Olsen extractants indicated more available P than did the Bray-P1 extractant for these calcareous soils. This finding is consistent with earlier reports (Olsen et al., 1954; Eik et al., 1961; Smith and Pesek, 1962; Wolf and Baker, 1985; Sen Tran et al., 1990; Mallarino and Blackmer, 1992) suggesting that the Bray-P1 extractant often underestimates available P in calcareous soils. The disagreements among extractants were small for other soils. Seemingly small disagreements, however, may be important for soils that test near the critical concentrations.

The relationships shown in Fig. 2 (with the addition of recently collected 1995 yield data which were not available at the time this article was submitted) are being analyzed by different statistical methods to estimate critical concentrations for the three methods and to develop complete soil-test interpretations. Visual inspection of data on Fig. 2 for the Olsen method suggests that soil-test interpretations for this method would be very similar to interpretations used in other states of the North Central region. Inspection of data for the Mehlich-3 method would indicate that critical concentrations and boundary values for potential soil-test classes would be near but slightly higher than those normally used for the Bray-P1 method. This observation tends to agree with equations shown in Fig. 1 for relationships between amounts of P extracted by these methods. The use of available soil-test interpretations for the Bray-P1 method for soil P data obtained with the Mehlich-3 method would give preliminary approximations but specific calibrations are needed.

The results of this study show the Olsen and the Mehlich-3 methods are more reliable tools than the Bray-P1 method for estimating available P on Iowa calcareous soils or across soils varying in soil pH. Because these methods seem to have similar ability to the Bray-P1 for estimating available P on neutral and slightly acid soils the results suggest that either the Olsen or Mehlich-3 methods would be much better than the Bray-P1 test when a single soil-test for P is used for routine analysis of Iowa soils. It is noteworthy, however, that there was a small proportion of calcareous soils in which estimations of available P by any of the three methods were unsatisfactory. Further research is being conducted to explain these results.

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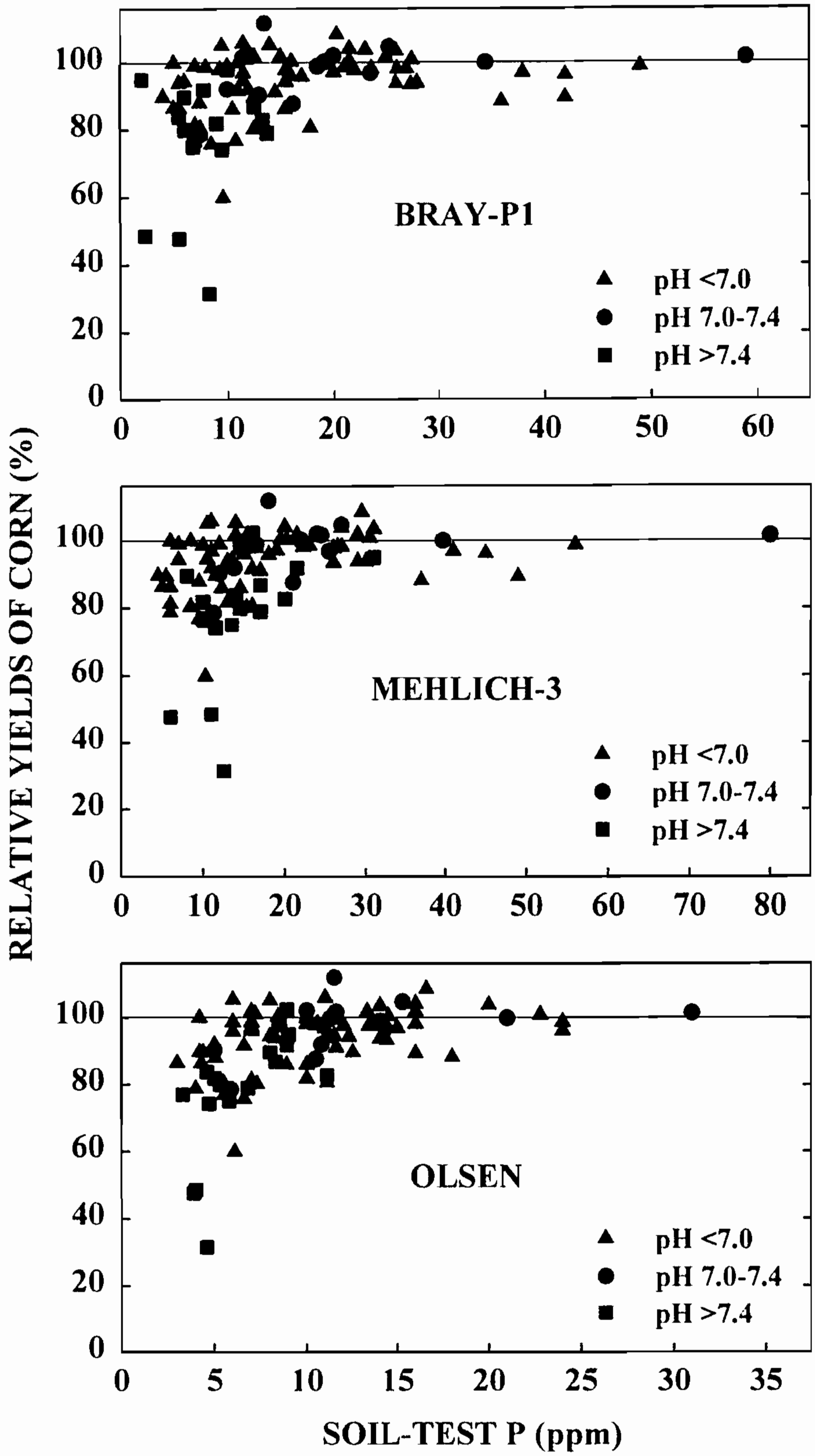

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