FUNCTIONAL RELATIONSHIPS BETWEEN YIELD RESPONSE AND SOIL PHOSPHORUS SUPPLY

I. CHOICE OF THE INDEPENDENT VARIABLE
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SUMMARY

In greenhouse pot experiments, four wheat varieties were grown on four different soils enriched with various levels of added P. Several integrated expressions, derived from a first-order rate differential equation similar to that proposed by Mitscherlich, were used to evaluate yield response expressed in terms of P added or of NaHCO₃-soluble P. The latter value was a more reliable estimate of available soil P, but it was not consistent for all four soils. Thus the operational range of a functional model relating yield response of a crop to soil P supply can depend in part upon the quantity chosen as the independent variable. To be useful this value must provide a consistent estimate of the available soil P for a range of soils and crop conditions.

INTRODUCTION

Attempts to relate quantitatively plant yield response and the supply of a growth-limiting nutrient, such as P, generally have been based on the hypothesis that, where all other growth condition variables can be taken as constants, or nonlimiting, the following functional relationship holds:

\[ y = f(x) \]  \hspace{1cm} [1]

where \( y \) = yield response, and \( x \) = soil-P supply.

The hypothesis appears to be experimentally confirmed. Thus a considerable body of evidence 2 4 5 11 15 19 20 21 26 27 indicates that when the rate of P application or some soil test value is plotted vs yield response, the resultant

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curve can be expressed mathematically. Also, it conforms with the diminishing yield returns concept, i.e., as the amount of nutrient supplied is increased the yield increment per unit of nutrient decreases. Mitscherlich described this relationship by a first-order rate differential equation. Both integrated and modified forms of the Mitscherlich equation have been used in practice. Also, polynomial equations have been adapted to describe particular sets of experimental data. In all cases the value used as the estimate of soil P supply, commonly designated 'x', has been treated as the independent variable of the equation.

Irrespective of the mathematical approach adopted, an extension of applicability of a yield response equation to describe sets of data, other than the one used to derive the equation, requires that x is a common independent variable for all these sets of data. Theoretically, this requirement would be satisfied only if x were a true estimate of available soil P. In practice, however, x is expressed in terms of nutrient added or determined by some soil test, and it represents only an estimate of the true value. In practice also, the relationship between an estimate and the true value may be different from soil to soil and from crop to crop, and unique only for a particular soil-plant system. Under these conditions x would not be an independent, but rather a dependent variable.

Failure to satisfy adequately the requirement that x be an independent variable could therefore be a major cause of the limited predictive ability of the several yield response-to-phosphorus equations proposed. Steenbjerg and Jakobsen pointed out that the values designated as constants in these equations are not actually constants, because the variables of the formulas are not independent variables; but no direct experimental evidence has been provided to support their view.

This paper reports studies conducted to test the applicability of the two quantities, nutrient P added and NaHCO₃-soluble P, in mathematical models for predicting yield response to varying P supply. The experiments were designed so that proper account could be taken of the likelihood that any functional relationship examined with these quantities as independent variables might be limited to a given range of experimental conditions.

MATERIALS AND METHODS

Four mineral soils (Table 1) with NaHCO₃-soluble P concentrations less than 6 ppm were used. These particular soils were selected because the addition of P resulted in a growth response when the soils were planted to wheat, and their textures were favorable for pot experiments. The soils, which had been collected from the top 15 cm, were air-dried, screened to pass a 2-mm sieve, mixed thoroughly, and stored. The Wyo soil was used as the standard soil material, the three other soils were used in comparative studies.