Phosphorus effectiveness in fertilized soils evaluated by chemical solutions and residual value for wheat growth

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Abstract

Nineteen soils from the south east of the Province of Buenos Aires (Argentina) that had been fertilized with moderate amounts of P (10–40 kgP/ha) during the last 10 years were used to investigate the effect of time on the decline of P availability as measured by three soil tests (Bray 1, Bray 2, Olsen) and the null-point method. Differences in rates of P decline among soils and chemical methods were characterized by an exponential coefficient for time ($b_2$) in equations which describe the changes of the added P retained by the soil ($Pr = ac^{b_1} t^{b_2}$). The rate of decline of P for the nineteen soils calculated for the soil test methods was ordered decreasingly as: null-point > Olsen > Bray 1 > Bray 2. The ability of the chemical methods for assessing the residual value of P for wheat growth (RV) was tested in a pot experiment on seven of the soils that differed in their individual rates of reaction with P. Differences between soils in the rate of reaction with P as measured in the laboratory by the null-point method and by the Olsen test were reflected in different residual values for P fertilizer for wheat plants. Thus the value of $b_2$ for these methods was well correlated with the observed residual values. The soil properties commonly associated with the retention of P were not related to the value of $b_2$ suggesting that more than one soil property may be involved in the measure of $b_2$. The exponent for time $b_2$ may be used as an index of the ability of the soil test to reflect the decline of P availability with time.

Introduction

Phosphate (P) applications to soils do not remain fully available with time and therefore repeated additions are needed to maintain an adequate supply of plant available P. The decline in effectiveness of added P with time is mostly a consequence of the slow reaction between soil and P [2]. The measure of P decline should reflect the availability of previously added P relative to its initial availability. Although an absolute value for the availability of P is difficult to measure [12], relative availability in soils can be measured by comparing the effects of two applications of fertilizers either as yield or uptake [8].

Laboratory measures of relative effectiveness for P have been done with various chemical solutions [11, 15, 22] and, more recently measuring the rate of reaction between soil and P [3, 19]. Chemical solutions cannot be expected to always give the correct balance to the numerous factors which affect uptake of P by plants. The amount of P already present in the soil (either native or added), the ability of the soil to retain P, the period of contact between soil and P, and the different age of the P which is actually present in the soil affect measurements of relative effectiveness of previous addition of P [22]. Soil tests do not necessarily reflect the separate effects of any of those factors; hence the changes with time in extracted P may not indicate changes in P status. Sharply [27] showed that the
Bray 1 reagent extracted a high proportion of residual-P from a soil which had been successively fertilized with moderate amounts of P for three years. Barrow and Shaw [11] found that extracted P by sodium bicarbonate solutions decreased more quickly with time in soils of high buffering capacity; these alkaline tests also overestimated P availability in those soils [20].

There do not appear to have been sufficient attempts to select or modify Soil-P tests using the criterion of whether they reflect the decline in availability of P with time. For obtaining this information is required a measure of the decline in availability of P with time after application, and the changes of soil test with time [2, 11]. In this paper some results are presented on the effect of time on the decline of P availability as measured by three soil tests and the null-point method. The reliability of these methods for assessing the residual value of P for wheat growth was tested on fertilized soils that differed in their individual rates of reaction with P. The null-point method does not measure the concentration of extracted P from the soil, but rather the solution concentration of P that is just high enough to prevent desorption from the soil and just low enough to prevent further adsorption. This concentration is measured in a solution of constant ionic strength in order to eliminate effects of P treatment on ionic strength [23].

Theoretical

The decline in P availability is estimated by the change with time of either the amount or the concentration of P in a solution in contact with the soil for a specific period of time, depending on the method used. If it is assumed that those changes are able to reflect the product of the reaction between soil and P with time, then it would be possible to relate those changes with changes in P availability.

If P is added to a soil that contains an appreciable amount of P already present and the soil is subsequently extracted by some soil test reagent, a basic equation is

\[ Pa - Pe = Pr - Q \]  

where \( Pa \) is the amount of P added to the soil, \( Pe \) is the amount of P extracted by a reagent, \( Q \) represents an amount of P already present. Formally \( Q \) may be defined as the amount of P present in the soil that has the same status at a given time as the added P. Finally, \( Pr \) is the amount of added P that is retained by the soil.

Another possibility to estimate the decline of P availability is by measuring and describing the rate of reaction of P with soil using the null-point method [3, 23]. The use of this method is convenient for the slow reactions [6]. A range of approaches has been used to describe the rate of reaction of P with soils and they have been appropriately discussed by Barrow [7]. An approach that has proved to be effective involves two assumptions. One is that adsorption is rapid and that the equilibrium between the adsorbed form and the concentration in solution (c) can be adequately described by the Freundlich equation. The other is that the amount that remains in the adsorbed form decreases with time \((t)\) according to \( Pr t^{-b_2} \) (where \( Pr \) is the sorbed form which includes the adsorbed form and \( b_2 \) is a coefficient). Thus, \( ac^{b_1} = Pr t^{-b_2} \) (where \( a \) and \( b_1 \) are coefficients).

If the soil contains an appreciable amount of P already present — this seems to be the case, the simplest approach is to let this be represented by \( q \)

\[ Pr = a c^{b_1} t^{-b_2} - q \]  

where \( q \) represents the amount of P already present in the soil that could be desorbed if the solution concentration could be reduced to zero [23]. Total retained P is therefore \( Pr + q \). This approach was previously used by Mendoza and Barrow [23] in soils that contained a high amount of native P.

In the case of the extraction of P by soil tests, the term \( Pr \) of Eq. (1) has also two components: one accounts for the P that is adsorbed by the soil during the extraction even in presence of the soil test reagent, the proportion of this adsorbed P depends of the level of addition and is independent of the period of reaction [22]. This adsorbed P is related to concentration of P in solution by an adsorption equation. The other component is P that is more firmly held and its amount increases with increasing period of con-