A CRITICAL REVIEW ON THE VALIDITY OF CHEMICAL EXTRACTANTS FOR SOIL POTASSIUM WITH SPECIAL REFERENCE TO SUGARCANE AS TEST CROP

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ABSTRACT

Since more than two decades, neutral normal ammonium acetate has been widely accepted as a measure of exchangeable soil potassium, and for sugarcane 100 ppm exch. K has been taken as a critical limit. The other chemical extractants tried were conc. H_2SO_4, boiling O.IN HNO_3, NaOAc at pH 4. 85, conc. HCl, NH_4Cl, and continuous percolation. German workers observe that for high cropping intensity with rye grass, electro-ultra filtration (EUF) for 10 minutes is a better index of K availability. Chemical potential of K (Gok), a fixed soil parameter, has also been taken as an index of K availability to plants. The specific soil K extractant viz. Sodium tetraphenyl boron (NaTPB) partitions the soil K into two categories namely exchangeable and non-exchangeable. Authors opine that any extractant which removes a part of the non-exchangeable K can satisfactorily predict K availability to long duration crops like sugarcane. Hence the Haylock's step K as obtained in successive extractions with IN HNO_3 gains the added importance.

INTRODUCTION

The potash in soil solution is in equilibrium with exchangeable and non-exchangeable portions. BARBER AND HUMBERT (1963) indicate that during cropping period the release of non-exchangeable K varied from zero to 1000 ppm and most soils released less than 200 ppm. They assumed that soils would have to release greater than 300 ppm before a condition is reached when plants do not respond to applied K.

The rate of K release is characteristic of soil type and is of utmost importance to plants, since this will decide the availability of K to plants. Several extractants have been suggested as specific extractments for soil potassium and are used as indices of potassium availability to plants.

For sugarcane 75 to 100 ppm of exchangeable K has been kept as a critical limit (AYERS & HAGIHARA, 1955). DUTOIT (1959), SILVA, DARROCH AND HUMBERT (1960) and INNES (1959) studied the response of sugarcane to potash dressing in relation to soil tests.

The different K extractions are grouped into five broad categories and their usefulness in evaluating potassium availability is discussed.

OBSERVATIONS

1. EXTRACTION WITH BUFFER SOLUTIONS

A large array of solutions such as Morgans, i.e. NaOAC at pH 4.8 (MALEAN, DOYLE & HAMLYN, 1957), NH_4Cl (NELSON, 1959), Mehlich solution (BLANCET & PERIGUAD, 1960), an infusion with $BaCl_2$ and triethanolamine, acid NH_4OAC, pH 4.35 (WIKLANDER, 1961), and normal neutral ammonium acetate have been used as specific soil K extractants.

The most widely used extractant neutral N NH_4OAC has been first tested by SCHOLLENBERGER AND SIMON (1945). The chief defect with NH_4OAC extraction seems to be that NH_4 ions may block the release of non-exchangeable K (WELCH & SCOTT, 1961), since the former will be fixed into the hexagonal holes. To overcome this, WILLIAMS and JENNY (1952) suggested that H, Na, Li, Ca, and Mg are more effective removers of non-exchangeable K than NH_4.

The water-soluble K obtained in the saturation extract, was better correlated with plant uptake in the studies of MACKAY AND DELONG (1955), NEMETH (1975), NEMETH AND GRIMME (1972), and NEMETH, MENGEL AND GRIMME (1970). Similarly, HOOD, BRADY AND LATHWELL (1956) observed water soluble K to be highly corrrelated with K uptake by Ladino clover. The water soluble K, however, does not correlate with plant uptake in long duration crops or in continuous cropping system. SILVA, DARROCH AND HUMBERT (1960) reported the relationship for sugarcane in Hawaii in a summary of 112 experiments. Their data showed the dependance of the increase in yield from added K on the levels of exchangeable K. The relationship is described in a polynomial equation which includes soil K, the square root of applied K and product of these. A variation of a little over 60 per cent was accounted by the three variables.

2. EXTRACTION WITH ACIDS

Better correlations between the extractants and biological data were obtained when the former extracted some portions of non-exchangeable K, hence the acid extraction was first proposed by WOOD AND DETURK (1941) and subsequently by HUNTER AND PRATT (1957), SCHMITZ AND PRATT (1953), WIKLANDER (1961), and PRATT (1951). Boiling in 1 N HNO_3 was used by DETURK, WOOD AND BRAY (1943) and this method has been compared with conc. H_2SO_4 by HUNTER AND PRATT (1957). In the latter procedure (PRATT, 1951), the heat is applied by adding 10 ml of conc. H_2SO_4 to a mixture of 10 g soil and 25 ml of water and the samples are allowed to stand 30 minutes before filtration and washing with 0.1 N H_2SO_4. Potassium in Taiwan soils extracted by HCl of constant boiling point has been extensively studied and reviewed by CHANG (1951). CHAO AND LEE (1953) studied the soil fertility problems of Taiwan sugarcane fields and they found acid extraction as a better indicator of K availability to plants.

Successive extractions with boiling IN HNO_3 has been used as an index of K availability (MOSS & COULTER, 1964; MACLEAN, 1961; BISWAS, 1974). Successive extractions with nitric acid partitions the non-exchangeable K portion into two, namely the 'step K' (HAYLOCK, 1966) and the constant rate K (CRK). It is argued that the Haylock's step K is that portion of non-exchangeable K which is available to plants.

In their review, BARBER AND HUMBERT (1963) concluded that exchangeable K extracted with neutral normal NH_4OAC in field moist soil is a reliable indicator of K availability and this may further be improved by taking into account soil variables, such as organic C, CEC, pH, soil texture, and the K level of soil layers.

3. PERCOLATION TECHNIQUES

Prolonged cropping methods have been used to measure the availability of non-exchangeable soil K to plants (REITEMEIER, 1951). Since the cropping intensity influences the relative release of non-exchangeable K, an inclusion of greater portion of non-exchangeable K has been recommended for high cropping intensities (BINNIE, 1958). In other words, with high cropping intensity, exch. K alone may not predict the K release. In this context, the percolation technique may have greater relevance. MATHEWS AND SMITH (1957) used CO_2 saturated water percolation technique. GARDNER (1960) used 0.1 N HCl percolation while GARMAN (1957) used 0.01 N HCl percolation technique. SCOTT AND WELCH (1961) used 5 to 10 extractions with N NH_4OAC and N NaCl + 0.1 N HCl. In this technique, a plot of cumulative K extracted against time at a constant rate of leaching gives curves consisting of an initial linear portion with a steep slope followed by a curviliner portion with a small slope. The slope of the first part of the curve is highly correlated with exchangeable K and the slope of the third part of the curve is an index of K release from non-exchangeable forms.

4. EXCHANGE RESINS

PRATT (1951) incubated soil with a quantity of hydron saturated cation exchange resin and then determined the K content of the resin. He related K extracted by the resin to the biological measurement. In the opinion of the authors, exchange resin is a poor indicator of K availability to plants.

5. OTHER MEASURES OF K AVAILABILITY

(*a*) *Electrodialysis*—AYERS, TAKAHASHI AND KANEHIRO (1947) used prolonged electrodialysis to predict the K release.

(*b*) *Electro-ultra filtration*—Recently, NEMETH (1975) observed good correlation between the yield of perennial rye grass grown in pots and the amounts of K dissolved after 10 minutes of electro ultra filteration (EUF) even though the nature of soils differed widely. This method is thus found satisfactory for assaying the K availability in soils.

(*c*) *Sodium tetraphenyl boron*—In the recent past, an emphasis has been laid on sodium tetraphenyl boron (NaTPB) as a specific extractant for soil potassium. The preliminary studies by SCOTT, HUNZIKER AND HANWAY (1960) and further studied by SCOTT AND REED (1962) indicated that NaTPB extracted much of the non-exchangeable inter layer K. Moreover, the data of SCOTT AND WELCH (1961) indicated that extraction with NaTPB was akin to successive percolation either with NH_4OAC or 1 N NaCl+0.1 HCl. SCHULTE AND COREY (1965) treated soil with NaTPB, then determined the K extracted and related it to biological measurement. Another approach had been to separate several fractions such as exchangeable and non-exchangeable portions.

(*d*) *Activity ratio*—Since the cations in soil solution are in equilibrium with K, the percentage saturation of CEC with K has been taken as an index of K availability. More specifically the activity ratio of K with divalent ions has been suggested to indicate the K releasing capacity of soils (SCHEFFER AND ULRICH, 1962; MOSS, 1968; EHLERS, MEYER AND ULRICH, 1967; ADDISCOTT AND TALIBUDEEN, 1969). Mathematically expressed as:

$$AR^{K} = \frac{aK}{a\,(Ca + Mg)^{\frac{1}{2}}}$$

The chief defect with the activity ratios is the extent to which they may change as plants absorbed K, hence may not be good indicators of K availability to plants (MACLEAN, 1961).

(*e*) *Chemical potential*—The best measure of K availability to plants is to find out potash potentials in soils (BECKETT, 1971, ADDISOTT AND TALIBUDEEN, 1969; TALIBUDEEN, 1974). WOODRUFF (1955) has suggested the use of energy of exchange between K and Ca as a measure of K availability to plants. The response to applied K is above 2.5 to 3.0 K cal/mole when the Gibbs Free energy change ($\triangle Fo$) is calculated as:

$$\triangle Fo = - RT \ In \ K$$

CONCLUSIONS

The authors are of the opinion that none of the chemical extractants can predict satisfactorily K availability to long duration crops such as sugarcane or in continuous cropping system as in sugarcane ratoons. Hence the potash potential in soil ($\triangle$Gok) a fixed parameter, will possibly indicate its availability to plants. To be of practical importance, regression may be worked out for each soil type between K potential and the K extracted by any specific soil extractant. Further, the exchangeable K *per se* obtained by different extractants is not a satisfactory index of its availability. Hence a portion of non-exchangeable K should be included. The specific soil extractants such as sodium tetraphenylboron (NaTPB) or boiling N HNO_3 are, therefore, considered suitable indices of K availability to sugarcane including its ratoons.

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