Scientific registration n° : 2443
Symposium n° : 12
Presentation : poster

The nutrient buffer power concept - a conceptual change for precise quantification of soil nutrient bioavailability
Le concept de pouvoir tampon en nutriments, un nouveau concept pour une quantification précise de la biodiponibilité des nutriments du sol

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A successful agricultural system denotes that the crop species grown for food, fibre and fuel produce the maximum of their genetic potential in a given set of conditions. The primary task of Soil Scientists is that such success is obtained with reference to the soil substrate, without needless abuse of the same, in which these crop species grow. Despite the complexity of soil science and the emergent soil management practices, the basic concept of soil as a medium of plant growth can be expected to persist for an indefinite length of time. However, of late, it is becoming increasingly clear that the earlier views of soil as merely the "*supportive medium*" for plant growth is giving place to the newer ones on "*managerial concepts*" of this supportive medium. The emphasis on "*sustainable agriculture*", beginning the early eighties, as opposed to the "*green revolution*" phase of the early and mid seventies, remarkably illustrates this shift in focus. The Earth Summit in Rio in Brazil in June 1992 and the Rio plus five years later in Denver, USA reflect this shift in focus. Disconcertingly, however, despite the inclusion of six chapters on soil management in Agenda 21 in the 1992 Summit Proceedings, not much of consequence, has been done on a global scale. The focus of this paper will be to highlight a revolutionary shift in soil management, with specific reference to soil testing and fertilizer recommendation, that is already making a great impact on the "managerial concepts", as explained earlier, and is expected to provide an unchartered course in the coming millennium inasmuch as soil management is concerned. The new concept has been christened as "***The Nutrient Buffer Power Concept***".

Basic concepts

Without going into the needless controversies and confusions surrounding the definition of the ubiquitous word "availability", it is proposed, that the nearest to accurate definition of it is "An available nutrient is one when the plant decides to make use of the same from the soil". It is, rather, a loose manner of definition, but, it is submitted that, in the final analysis, it is the plant and plant alone that will decide whether or not a nutrient is "available" notwithstanding the myriad of definitions, not to speak of the multitudes of procedures to quantity "availability" that are littered on the pages of the text books on soil fertility and plant nutrition. Agricultural soils, for the most part, are in a state of disequilibrium owing both to fertilizer input, on the one hand, and plant uptake, on the other, and this, to a very large extent, complicates the precise definition of the word "availability". Despite these limitations, if we have to move forward in devising accountable "prescriptive soil management practices", we must sieve the available information to locate one or more than one key factor which will crucially affect nutrient "availability" and uptake. Predicting mobility of dissolved chemicals, such as fertilizers, is crucial to an intelligent management of fertilizer applications. Soil testing, in principle, aims to achieve this. Though modeling transport and retention of ions from thermodynamic, kinetic and mechanistic angles could be very informative, the importance of translating this information into practically feasible procedures in crop production calls for an understanding not only of the basic concepts, but, of their intelligent application as well. Among the different factors which decide plant uptake, from the soil substrate, the mean concentrations of the nutrient on the root surface is most critical, but, in a dynamic state of plant growth it is nearly impossible to quantify this, in a field soil. Using Fick's first law, F = -D (dC/dx) where F = the flux, dC/dx = concentration gradient across a particular section, and D = the diffusion coefficient, Nye (1979) suggested an operational definition for soil systems, which are inherently complex, to quantify the diffusion coefficient as follows:

$$D = D_1 \quad \mathbf{f}_1 \, (dC_1/dC) + D_E$$

where

D_1 = diffusion coefficient of the solute in free solution

= the fraction of the soil volume occupied by solute and gives the cross section for diffusion

f_1 = an impedance factor

C_1 = concentration of solute in the soil solution

D_E = an excess term which is zero when the ions or molecules on the solid have no surface mobility, but, represents their extra contribution to the diffusion coefficient when they are mobile. Only in rare instances will D_E play any role in plant nutrient diffusion and so can generally be neglected.

When we consider plant nutrient availability, dC_1/dC where C_1 = concentration of the nutrient ion in the soil solution and C = concentration of the same ion species in the entire soil mass assumes considerable significance in lending a practical meaning to nutrient availability, as we shall presently see. If the term "capacity" or "quantity" is ascribed to C and "intensity" to C_1, we have in this term an integral relationship between the two parameters which will crucially affect nutrient availability. Since the concentration gradient of the nutrient depletion profile in the zone of nutrient uptake depends on the concentration of the ion species in the entire soil mass (represented by "capacity" or "quantity") in relation to the rate at which this is lowered on the plant root surface by uptake (represented by "intensity"), it could be argued that a quantitative relationship between the two should represent the rate at which nutrient depletion and/or replenishment in the rooting zone should occur (Nair, 1984). Nair and Mengel (1984) functionally quantified this relationship for 8 widely differing European soils and derived a factor b which they expressed as the soil's "buffer power" for the nutrient in question. In this case, it was for the important nutrient phosphorus.

The importance of the "buffer power" in precisely predicting availability of important plant nutrients, such as, phosphorus, potassium and zinc have been examined in different soils using different test crops and the results compared with the routine data obtained through soil tests. In the case of "major" nutrients, the first published work was on phosphorus, using summer rye (*Secale cereale* L.) as test crop, where the authors (Nair and Mengel, 1984) obtained a coefficient of determination, which is the most important index of statistical precision, as high as 98% while comparing the "buffer power" method with the routine methods used to quantify availability of phosphorus, such as the Sch **ller's or the EUP** method. Recently, Nair (1995 unpublished) found that by integrating the soil's buffer power, the routine Olsen's test for phosphorus showed an increase in the coefficient of determination from 3% to 59% in the case of African soils (typical laterite from The Republic of Cameroon) using *Trifolium repens* L. (white clover) as the test crop. In the case of potassium the corresponding increase was from 3% to 61% and the routine soil test used was the classical NH_4OAc test. Most recently (Nair, 1997 unpublished) the problem of Zn deficiency was examined in Central Asian soils with regard to wheat nutrition. Central Anatolia in Turkey, which is the primary wheat growing area, has severely Zn impoverished soils and very high doses of Zn (as much as 100 kg $ZnSO_4$ ha^{-1}) are recommended based on the routine DTPA extractable Zn, which characterizes these soil as "severely Zn deficient" having less than 0.1 mg Zn kg^{-1}. Despite the very low "available" Zn, the wheat crop failed to respond positively to massive doses of Zn application, as already indicated above (100 kg $ZnSO_4$ ha^{-1}). On closer scrutiny, it was very clearly established that the crop response was more related to the Zn buffer power of the soil concerned, rather than the routinely extractable Zn.

It is important to examine how the buffer power approach provides a much better alternative to quantifying the plant nutrient availability as opposed to routine soil test data. The following explanation provides the answer. A root growing into the soil will, at first, encounter a relatively high concentration of the nutrient in question at the root surface, being more or less equal to its concentration in the bulk soil solution. On account of the uptake process, the nutrient concentration at the root surface will decrease. This decrease will not only depend on the uptake rate of the root, but also, on the nutrient's buffer power. A high buffer power will mean that the nutrient absorbed from the soil solution is rapidly replenished. In such a case, the concentration of the nutrient at the root surface decreases rather slowly and mean concentration on the root's surface remains relatively high. On the other hand, with soils showing a poor buffer power for the nutrient in question, the reverse is true. In other words, it is the buffer power of the nutrient which specifically regulates nutrient supply and routine extractions will not provide this vital information. Nair (1993) field demonstrated the merit or this concept in large scale on African soils, and the scientific basis of "***The Nutrient Buffer Power Concept***" has very recently been explained (Nair, 1996).

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Keywords : buffer power, nutrient availability, phosphorus, potassium, zinc
Mots clés : pouvoir tampon, disponibilité en nutriments, phosphore, potassium, zinc

The Nutrient Buffer Power Concept, a revolutionary soil testing procedure developed and tested for over more than three decades in European, African and Asian soils, looks at soil testing to devise appropriate and accurate fertilizer recommendations for many field crops, such as, summer rye, wheat, See More Info.Â The Nutrient Buffer Power Concept, a revolutionary soil testing procedure developed and tested for over more than three decades in European, African and Asian soils, looks at soil testing to devise appropriate and accurate fertilizer recommendations for many field crops, such as, summer rye, wheat, and maize among cereals, red gram among pulses, white clover among fodder crops, and black pepper and cardamom. Soil productivity and nutrient availability are interrelated. Soil productivity is the capacity of a soil to produce a certain yield of crops or other plants with a specified system of management. Management of nutrients is an important aspect of maintaining soil productivity.Â Since soil is a continuum, it is a matrix in constant change. It is very difficult under practical conditions to have all crop production factors at an optimal level; hence, most of the crop production factors are usually at a suboptimal level.Â As nutrient concentration in solution (â–µl) decreases, soil A more readily buffers the solution concentration than soil B. Since BCsoil A > BCsoil B, soil A likely contains greater clay and/or OM content, resulting in greater CEC. View chapter Purchase book.