



Nutrient Omission Technique for Assessing Crop Nutrient Responses: A Review

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Abstract

Optimum productivity of any cropping system depends on an adequate supply of plant nutrients. Even if, all other factors of crop production are in the optimum, the fertility of a soil largely determines the ultimate yield. The proper rate of nutrients to be given to a crop is determined by knowing the nutrient requirement of crops and nutrient supplying capacity of the soil. Exploitive nature of modern agriculture involving use of high analysis NPK fertilizers, free from micronutrients as impurities, limited use of organic manures and restricted recycling of crop residues are some important factors having contributed towards accelerated exhaustion of secondary and micronutrients from soil. Crop growth and yield are controlled by the nutrient that is most limiting. When a particular nutrient is removed from an otherwise adequately fertilized system, a reduction in plant growth, nutrient uptake, yield components, or final yield may occur. The magnitude of this reduction can be used to estimate the importance of that nutrient. The Nutrient Omission Plot technique is an important field-based approach used in agricultural research to identify which essential plant nutrients are limiting crop growth and yield. The technique involves establishing a series of plots in which all nutrients required by the crop are supplied in adequate quantities, except for one nutrient at a time. The crop response in each omission plot is then compared with that of a complete or balanced nutrient plot, in which all required nutrients are supplied. Grain yield in the plot with full fertilization and proper crop management can be used to estimate potential yield target. Nutrient-limited yields are determined from plots in which the nutrient of interest is not added. The omission plot technique can help to identify the nutrient(s) that are limiting crop growth and yield. This information can be used to adjust fertilizer application rates to optimize crop growth and yield. The present review documents and summarizes the cause, procedure and yield responses of nutrient omission plot techniques.

Keywords: nutrient omission, nutrient-use efficiency, nitrogen, phosphorus, potassium, yield response, crop response, indigenous nutrient supply, limiting nutrient, missing element.

1. Introduction

Increasing crop production is imperative to meet the growing demand of the population in terms of food, fodder, fiber, fuel, timber and industrial raw material. A continuous increase in the yield performance and enhanced technical quality has been achieved through progress in breeding and improvements in crop management systems. Despite earlier steady increase

in productivity, presently there is either a plateau or decline in the productivity of many crops across the country. The stagnation in crop productivity has been found due to deficiency of some micro and secondary nutrients (Sakal, 2001). Exploitive nature of modern agriculture involving use of high analysis NPK fertilizers, free from micronutrients as impurities,

limited use of organic manures and restricted recycling of crop residues are some important factors having contributed towards accelerated exhaustion of secondary and micronutrients from soil. At several places, normal yield of crops could not be achieved despite balanced use of NPK due to micronutrient deficiency in soils. Deficiency of micronutrients may either be primary, due to their low total content of elements or secondary, caused by soil factors reducing their availability to plants. The emergence of micronutrient deficiency has generally been considered as secondary (Takkar, 1996). Optimum productivity of any cropping system depends on an adequate supply of plant nutrients. Even if, all other factors of crop production are in the optimum, the fertility of a soil largely determines the ultimate yield. Soil fertility refers to nutrient supplying capacity of a soil for crop growth. It describes available nutrients status of the soil and its ability to provide nutrients for optimum plant growth (Dev, 1997). When the soil does not supply sufficient nutrients for normal plant development and optimum productivity, application of supplemental nutrients is required. Fertilizer is one of the most important sources to meet this requirement. Indiscriminate use of fertilizers, however, may cause adverse effect on soils and crops both regarding nutrient toxicity and deficiency either by over use or inadequate use (Ray et al., 2000). The proper rate of nutrients is determined by knowing the nutrient requirement of crops and nutrient supplying capacity of the soil. Diagnostic techniques including identification of deficiency symptoms, soil and plant analysis and biological tests are helpful in determining specific nutrient stresses and quantity of nutrients needed to optimize the yield (Havlin et al., 2007). Soil fertility evaluation, thus, is the key for adequate and balanced fertilization in crop production. A thorough and proper understanding of morphological, physical and chemical characteristics of the soils gives greater insight of the dynamics of the soil. The nutrient omission trials provide a visible order of crop response to nutrient application. It aims to find out the most limiting nutrients to the growth of a crop plant. If any element is omitted while other elements are applied at suitable rates and plants grow weakly, then the tested element is a limiting factor for crop growth. Conversely, if any element is omitted but plants are healthy, then that element is not a limiting factor for crop production (Gami et al., 2001).

2. Soil Site Characteristics

Properties and development of soils is closely related to their position on the landscape. In upper part of the

landscape the soils remain shallow, young with less developed features and are usually highly eroded. Down the slopes, the soils had more developed features. The change in soil properties indicates the difference in drainage conditions, transport of eroded material and translocation and deposition of mobile soil constituents. Moving down the slope, there is an increase in soil depth, water holding capacity, cation exchange capacity and preponderance of calcium and magnesium ions on exchange sites. Along the same direction, there is gradual change of color from red to dark gray and brown, texture from sandy loam to clayey, consistency from non-sticky to very sticky, mineralogy from illite to montmorillonite and calcium carbonate from almost none to abundant. The topographical variations have marked influence on regulating hydrological conditions and there by on pedogenic processes responsible for morphological features as well as physical and chemical properties of the soils. The soils so developed differ in their production potential and management requirements (Biswas and Gawande, 1962; Gawande et al., 1963; Gawande and Biswas, 1967; Gawande et al., 1968)

2.1 Physical Properties of Soils

Soil texture is an intrinsic attribute of the soil and the one most often used to characterize its physical make-up, having a bearing on soil behaviour. Differences in parent material, physiography, *in situ* weathering and translocation of clay can cause wide variations in soil texture (Basava Raju et al., 2005). Sandy clay loam to sandy clay texture may be observed at the surface and clay to sandy clay in subsurface horizons. A decrease of sand fraction up to certain depth indicates weathering of these fractions to finer particles as evidenced by increase in clay content with concomitant decrease in sand fraction. However, irregularities in relative proportion and distribution of sand and silt with depth have also been reported. Argillaceous parent material gives rise to fine textured soils. Therefore, soils developed over basaltic parent material or partly laterized basalt contain higher amount of clay. The content of clay is found to increase with depth (Pardeep and Verma, 2005) which is an indication of vertical migration or translocation of clay (Sarkar et al., 2002). Higher clay content may also be due to such topographic positions, which favour accumulation and retention of bases and thus promoting formation of smectite. Soils of plain contain more clay as compared to uplands and hill slopes (Basava Raju et al., 2005) which are related to deposition of finer fractions in the plains from uplands

and hill slopes. The vertical distribution of sand and silt content in a profile is affected by illuviation process (Swarnam et al., 2004). A gradual increase in bulk density down the profile is related to rise in sand fraction and decrease in organic matter content moving down the profile. Increase in bulk density with depth is due to lower organic matter, more compaction and less aggregation in lower horizons (Singh and Agrawal, 2005). The lower layers in soil profiles supporting rice-wheat system become compact with time causing increase in bulk density with depth.

2.2 Chemical Characteristics of Soils

A high level of organic matter and leaching of bases lower the pH value (Mahapatra et al., 2000) whereas parent material containing appreciable amounts of basic cations and calcareousness favours high pH condition (Tamgadge et al., 2003). A pH range of 8.1-8.9 in some problematic *Vertisols* of Maharashtra plateau has been observed which increased with depth in the profile indicating the progressive development of alkalinity (Bhupendra et al., 2018). Electrical conductivity is directly related with the amount of soluble salts present in different horizons of the profile (Singh et al., 2000). Higher values of electrical conductivity may be observed in sub-surface layers compared to surface layers due to accumulation of salts in the lower layers (Balwant et al., 2018; Krishna et al., 2018). Surface horizon contains higher amount of organic carbon which decreases with depth (Marathe et al., 2003) and it is primarily related to leaf fall and accumulation of crop residues. But under tropical climatic conditions, oxidation loss of organic matter results in low organic carbon. Manorama Thampatti and Jose (2000) did not notice any definite pattern of organic carbon content in horizons of acid-saline rice soils of Kerala. The presence of sand layers, differential accumulation of organic matter and sedimentary nature of parent material were responsible for the heterogeneity in organic carbon distribution. Many scientists have reported a variable range of CEC in the profile. This variation is related to content and nature of organic and inorganic colloids in soils (Mahapatra et al., 2000). Low content of clay in the horizon can cause decrease in CEC with depth. However, in some profile, CEC increases with depth due to higher clay content in the lower layers (Chaudhary et al., 2006)

3. Nutrient Status of Soils

3.1 Status of Primary Nutrients in Soils

Nitrogen (N) is one of the most yield limiting primary nutrients among N, P and K required for optimum crop production. Usually fine textured (heavy) soils contain more N than the coarse textured (light) soils. Indian soils are found to be low in available N content (Motsara, 2002; Ravikumar et al., 2014; Kumar et al., 2015; Singh et al., 2018). Phosphorus (P) is the second most important nutrient after N among the three primary nutrients required in crop nutrition. Information on P fertility status of soils is of great importance, since it helps determine the level of P fertilizer to be applied to crops. Indian soils have been found to be low in available P content (Verma et al., 2005; Kumar et al., 2017; Sen et al., 2018). Potassium (K) is the third most important primary nutrient after N and P required for proper growth and development of the plants. Available K content in Indian soils on an average is considered to be medium (Arora and Chahal, 2003; Harsha and Jagadeesh, 2017; Rashmi et al., 2018)

3.2 Status of Secondary Nutrients in soil

Calcium, magnesium and sulphur are conventionally classified as secondary nutrients. Their requirements by plants are quantitatively less than those of primary nutrients (NPK). Calcium and magnesium are the most abundant cations occupying the exchange sites of soil colloids. Thus, most soils, with possible exception of highly weathered, leached acid soils, contain enough Ca and Mg for crop growth (Pasricha and Sarkar, 2002). The importance of Ca and Mg as plant nutrients is more realized in acid and alkali soils than in neutral soils (Patil et al., 2017). In acid soils, lime-loving crops do not give high yields unless these are suitably fertilized with Ca and Mg. Similarly in alkali soils, crops suffer due to lack of Ca and excess of Na. Sulphur is an essential component of three essential amino acids viz. cystine, cysteine and methionine. As a part of each living cell it is necessary for the formation of chlorophyll and aids in the biosynthesis of carbohydrates and proteins. It promotes nodulation for biological nitrogen fixation in legumes. It is necessary for oilseed crops (Prasad et al., 2017; Dameshwar et al., 2018)

3.3 Status of Micronutrients in soil

The micronutrient cations are involved in enzyme system as cofactors with the exception of Zn. These are capable of acting as 'electron carriers' in the enzyme systems which are responsible for oxidation-reduction reactions in plants (Padhan et al., 2016). Zinc, copper and manganese are involved in the synthesis of some growth promoting hormones and in the reproductive process of many plants which are very vital for grain formation (Verma et al., 2013; Malik et al., 2017). Molybdenum is associated with nitrogenase and nitrate reductase enzyme and is essential for nitrogen fixing plants and microorganism. Boron is associated with the rate of water absorption and translocation of sugar in plants (Chavda et al., 2018)

4. Nutrient Omission Plot Technique

The omission plot technique is used to estimate fertilizer requirements. In an omission plot, adequate amounts of all nutrients are applied except for the nutrient of interest (the omitted nutrient). The yield in such an omission plot is related to the indigenous soil supplying capacity of the omitted nutrient. The yield gap between a target yield and the yield in the omission plot is then used to calculate fertilizer requirements. Omission plots make any nutrient limitations visible. Separate omission plots are needed for each nutrient. It is better to get a good yield average for each nutrient from several omission plots placed in a larger area than to use a single plot in one farmer's field or research plot.

General steps involved in using the omission plot technique

1. Site selection: Select 10 - 20 representative farmers' fields for a larger area that shares similar soil conditions, consistent topography and a common crop history.

2. Plot layout: Divide the field into plots of equal size omission plots. Bunds between plots be maintained to limit nutrient movement between plots.

3. Nutrient application: Apply the nutrient solutions to the respective plots according to the desired nutrient omission treatments. In one of the treatments, all the nutrients are applied (T_1) while in others, one of the nutrient elements from all the nutrient treatments i.e. T_1 is omitted. Thus treatments can be formulated as T_1

- All (N, P, K, S, Ca, Mg, Cu, Zn, B, Mo), T_2 - (All - N), T_3 - (All - P), T_4 - (All - K), T_5 - (All - S), T_6 - (All - Ca), T_7 - (All - Mg), T_8 - (All - Cu), T_9 - (All - Zn), T_{10} - (All - B), and T_{11} - (All - Mo). No. of treatments can vary depending upon the soil reaction, soil conditions and soil nutrient status. The rate of nutrient application should be the same for all plots, except for the nutrient that is being omitted *i.e.* Each plot should receive a different combination of nutrient inputs, with one plot receiving a complete nutrient solution, and the others receiving solutions lacking specific nutrients.

4. Crop management: Manage the crop as usual, taking care to ensure that all plots receive the same level of care and attention.

5. Data collection: Monitor plant growth and yield throughout the growing season, taking measurements such as plant height, leaf area and yield. Record any observations of nutrient deficiencies or excesses.

6. Analysis: Compare the growth and yield of the different plots to determine which nutrient(s) are limiting plant growth and yield. Adjust the application rate of the limiting nutrient(s) to optimize crop growth and yield.

5. Crop Responses in Nutrient Omission Trials

When a nutrient is deficient in the soil then the growth of a crop plant and ultimately the yield is affected. A nutrients omission trial aims to find out the most limiting nutrients to the growth of a crop plant.

Long-term permanent plot experiment was conducted by Gami et al., (2001) at the Regional Agricultural Research Station, Parwanipur, Nepal. Experiment consisted of two crops per year (rice and wheat) with 12 treatments. The application of P, K or both P and K along with N did not improve the yield of rice indicating that P and K were not limiting yields. Omission of P, K or both led to yields similar to those of NPK, indicating that wheat did not respond to P and K.

Missing element technique field experiments were carried out by Din et al., (2001) for determining the components of balanced nutrient management in rain fed chickpea and black gram. Omission of nitrogen (N) and potassium (K) in the fertilizer package did not affect production of either crop. However, missing of

phosphorus (P) and boron (B) reduced yield of both crops drastically and omission of zinc (Zn) reduced yield of chickpea only. Concentrations of P, B and Zn in chickpea leaves were reduced appreciably where the respective nutrients were not applied.

On-farm experiments were conducted by Dobermann et al., (2003) at 155 locations in seven domains of Asia to quantify the variability of soil properties, grain yield of rice and nutrient uptake in N, P and K omission plots (0-N, 0-P, and 0-K, respectively). Soil properties showed little association with plant nutrient uptake or grain yield in nutrient omission plots. Mean grain yields in nutrient omission plots increased in the order 0-N (3.9 Mg ha^{-1}) < 0-K (5.1 Mg ha^{-1}) < or = 0-P (5.2 Mg ha^{-1}), grain yield in fully fertilized plots being 5.2 Mg ha^{-1} . N, P and K accumulation in N, P, and K omitted plots were 54, 15 and 83 kg ha^{-1} , respectively. Seven soils were compared using nutrient omission trials by Melter et al., (2004) in Vanuatu using maize as test plant. Relative top dry weight of maize was significantly affected by different treatments. Study revealed deficiencies of phosphorus in all soils tested, of nitrogen in four soils, of potassium in two soils and of sulfur in two soils. No other nutrient deficiencies were detected.

Haefele and Wopereis (2005) reported that in nutrient omission trials rice yield ranged from 2.2 to 6.0 Mg ha^{-1} in N omission plots, from 4.1 to 9.8 Mg ha^{-1} in P omission plots and from 5.3 to 9.6 Mg ha^{-1} in K omission plots. The highest yield in the fully fertilized treatment was 11.6 Mg ha^{-1} .

Experiments were conducted by Mishra et al., (2007) in *Inceptisols* and *Vertisols* at IGKV, Research Farm, Raipur (Chhattisgarh) during *Kharif* 2001, to study the effect of omission of nutrients. Mean grain and straw yields of rice (variety Mahamaya) were significantly reduced with omission of P only in both the soils. Omission of K, S, Fe, Zn and B did not cause any significant reductions in yields as well as uptake of nutrients, indicating that these elements were in sufficient amounts in the soils for rice crop.

Nath et al., (2012) conducted nutrient omission trial on Boro rice and observed that grain yield was highest with NPK treatment (5.64 Mg ha^{-1}). The treatment with NPK gave 9%, 34.4% and 50.7% more performance than that of the treatment with NP, NK and PK, respectively. The K response was outstanding and gave second highest yield (5.13 Mg ha^{-1}). The indigenous N response was very poor and the yield

obtained was 2.78 Mg ha^{-1} . Similarly indigenous P response was found poor 3.7 Mg ha^{-1} . They concluded that N and P are the most limiting factor for rice yield.

Sahu et al., (2017) conducted a pot culture experiment in greenhouse at faculty of Agriculture, IGKV, Raipur during the *Kharif*, 2015 with soil collected from Bemetra district. They observed that the rice grain and straw yields were significantly reduced with the omission of N, P and S compared to the treatment that received all the nutrients. The yield reductions were more pronounced with omission of N and P (54.76 and 44.73%, respectively). The percent reductions in rice yields were recorded as 11.63% with omission of S, 8.99% with omission of Zn and 6.51% with omission of B. Yield limiting nutrients identified were in the order of $\text{N} > \text{P} > \text{S} > \text{Zn} > \text{B}$.

Balwant et al. (2018) conducted experiment at Shaheed Gundadhar College of Agriculture and Research Station, Jagdalpur with the objective of identifying specific limiting nutrients through rice response with nutrient omission. Omission of N and P significantly reduced the different parameters of growth, yield and nutrient content of rice compared to all the nutrients. The maximum grain yield of 67.1 g pot^{-1} was registered in all the nutrients. Reduction of 40.8% in the yield of the rice grain from the maximum yield was recorded in the pots omitted with N, followed by P omission (23.7% reduction). Other nutrients did not significantly reduce grain yield, indicating that only N and P were yield-limiting nutrients. In field verification during the *Rabi* season, there was an increase of 17.8% in wheat grain yield and an increase of 20.9% in net yield due to the optimal dose of identified limiting nutrients.

Bhupendra et al., (2018) conducted pot experiment, during *kharif* 2017 with transplanted rice, at Shaheed Gundadhar College of Agriculture and Research Station, Jagdalpur (Chhattisgarh). The highest grain yield 66.4 g pot^{-1} was recorded under the treatment receiving all the nutrients and that of lowest grain yields 34.8 g pot^{-1} were recorded under omission of N, followed by omission of P (42.5 g pot^{-1}) and omission of S (56.3 g pot^{-1}). The limiting nutrients so identified were in the order of $\text{N} > \text{P} > \text{S}$.

Singh et al., (2018) carried out nutrient omission experiments in pots at Krishi Vigyan Kendra Farm, Raigarh (CG) during *Kharif*, 2015 for identification of limiting nutrients for rice. In *Inceptisol*, the omission of N, P and S reduced grain and straw yields

significantly compared to the treatment that received all the nutrients. Omission of nitrogen, phosphorus and sulphur reduced grain yield with 47.64%, 40.82% and 19.51% respectively. Limiting nutrients were in the order of Nitrogen > Phosphorus > Sulphur.

Sushma et al., (2018) evaluated the effect of omission of nutrients in rice through pot culture study in two soil types. The yield reductions were more marked with omission of N (43.2%), P (41.7%) in *Vertisols* and N (34.1%), P (31.8%) in *Inceptisols*. The rice grain and straw yields in *Inceptisols* were significantly reduced with the omission of N, P and S compared to the treatment that received all the nutrients.

6. Conclusion

The nutrient omission plot technique is widely used in agricultural research work. The trials provide a powerful bridge between soil fertility diagnosis and site-specific fertilizer recommendations. It is a valuable tool for determining the amount of fertilizer required for attaining a yield target. The principal value lies in quantifying the yield penalty associated with omission of individual nutrients under otherwise adequate nutrient supply. This approach enhances fertilizer use efficiency by optimizing nutrient management practices and maximizes the crop yields by minimizing the nutrient waste and environmental impact. By identifying the limiting nutrient(s) and adjusting nutrient application rates accordingly, farmers can maximize crop production and productivity.

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