Review Article

Indian Journal of Plant and Soil
Volume 3 Number 2, July - December 2016
DOI: http://dx.doi.org/10.21088/ijps.2348.9677.3216.5

Evolution of Plant Nutrition (Manuring) Concepts

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Abstract

The evolution ofPlant Nutrition (manuring) conceptsfrom the early ones confined to application of organic wastes followed byinclusion of major nutrients N,P and K and thenof micro nutrients as and when their deficiencies occur and ,to the application of all nutrientsrequired for growth in ratios found in whole plant analysis and to the targeted productivity is traced .

Keywords

Plant Nutrition; Evolution over the years.

Introduction

The manure is froma Middle English word "manuren" meaning "to cultivate land," and has its origin from *French* "main-oeuvre"/ "hand work" alluding to the work manuring, the spreading of it on the land. Manure originallyis organic matter of any origin used as fertilizer to sustain soil fertility and increase productivity in agriculture. With the advent of time, manure is defined as any material used to improve productivity. The early additions to this category are the N,P and K fertilizers whose deficiencies and importance are recognized with the rapid growth of organized cultivation with emphasis on productivity to feed and clothe the increasing population. Now it is defined as application of all nutrients required for plant growth to get a desired level of quality and productivity.

Nuutrients for Plant Growth

Plants require about sixteen nutrient elements essential for growth. Out of them seven elements , Carbon Hydrogen, Oxygen, Nitrogen, Sulfur, Phosphorus, and Calcium enter the chemical composition of organic bio-mass.

The other nine elements namely Potassium Magnesium,Copper, Iron, Manganese, Zinc, Boron, Molybdenum, and Chlorine occur as free ions and are recovered in ashes and hence are known as 'Mineral' nutrients. Potassium ions regulate osmotic pressure in cell sap and helps in water balance in tissues. Chloride ions act as buffer to the cationic concentration in tissue cells. Other mineral nutrients are co- enzymes in various enzymatic bio-cycles for synthesis of various chemical constituents of biomass and sustaining metabolic process which are involved in growth of plants and manifestation of their specific characteristics for which they are valued and grown. Each micro-nutrient has specific role(s) to play in sustaining theholistic growth of plants and,their deficiency leads to malfunction of the bio-cycle(s) which theycontrol leading to crop loss, compounds responsible for their quality or both.Thus all the nutrients are required in quantities in proportion to targeted productivity level for optimum expression of quantity and quality in the end products for which the plants are grown.

Some nutrient elements (Fluorine, Cobalt Selenium and Sodium) which are essential for sustaining life activitiesof animals and humans which feed on them are also taken by the plants. Plants also develop adaptive mechanisms for passive accumulation of certain elements found in abundance in the eco systems where they are evolved .Plants evolved in base deficient acidic soils in humid zones accumulate Aluminum as in Tea.

Carbon, Hydrogen, and Oxygen are obtained from atmosphericCarbon dioxide and soil water. All other nutrients are taken from the soil- derived either from

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weathering of rock minerals or the decomposition of organic wastes by soil bioactivity. Lightening to some extent fixes Nitrogen as oxides and ammonia and further transformations of them to available forms are carried by soil microorganisms. Plants utilizemostly ionic forms and synthesize the compounds which make up the biomass on their own. Since soil is the main source of nutrients for plants to grow, some crop specific nutritional preferences could be traced to soil nutrient contents in their natural habitat as influenced by geological and environmental factors.

Soil Based Agriculture

In soil based agriculture, itacts not only as a medium for anchorage but also as a source of nutrients. Weathering of rock minerals and mineralization of recycled organic wastes maintain a certain equilibrium levels of nutrient elements which support a minimum level of productivity known as 'threshold level of productivity' with further increases dictated by most deficient nutrient. The plant responds to increasing levels of application of this nutrient till another element becomes most deficient one. Inclusion of this element increases the response further until a third one takes its place. Like this at every stage ofstagnationinresponse, nutrient limiting the crop is added to the schedule of nutrients to be applied. Chasing the productivity to get nearer to theoretical limits requires adding new nutrients which is most deficient at each and every stage of stagnation in productivity until the genetic potential is reached. This is the basic objective of manuring programs in the pursuit of sustainable of agriculture.

Soils differ widely in their ability of supplying nutrients due to geological, environmental and topographical factors. Soils in hilly terrain lose lot of nutrients by leaching away as there is one-waymovement of nutrients i.e., away from the fields. Contrary to this, a dynamic equilibrium of soil nutrient contents exists in plains and alluvial basins arising from the balance of nutrients a) released in situ thru natural recycling processes, b) losses thru percolation and leaching away by surface and sub-soil runoff water and c) gains by deposits from runoff water from uplands carrying soil and nutrients.Thethreshold level of productivity is thus higher in foot hills and in plains.

Asssesment of Nutrient Requirements

For any agriculture systems in vogue or planned, soil analysis and field experiments give information on the amount of nutrients available in the soil that could be taken by the plantin a unit time .The quantity of nutrient(S) to be applied is the difference between what is required and what is available. It looks simple but interaction of inorganic ions with soil colloids, losses that occur in the soil, fixation tounavailable forms and physicochemical properties that control their retention and availability, kinetics of nutrient movements in the soil and the rhizhosphereleads to a factor termed as 'utilization factor'. On an average only 40% of soil available and applied Nitrogen is utilized by plants; it is 80% for K, while Phosphorus accumulates in soil as sparingly soluble phosphates. The available phosphorus levels are maintained by the solubility product of soil phosphate system dominating at a given pH and REDOX potentialgrid. Micro nutrients are retained as chelates by organic acids from decomposing organic matter and their hydrolysis constants bestows elasticity in maintaining their concentration in soil solution. All these factors make plant nutrition a complex subject requiring knowledge of soils and their physicochemical properties. Source of nutrients to be used and method of applications depend on sol factors.

The growth of plants is not uniform throughout the year and pattern of seasonal changes also vary from year again due to climatic vagaries. The requirement and timing of application of fertilizers varies from season to season and year to year. Climate, thus, decides the finer aspects of applications - timing of them, number of splits, and apportioning the quantity in the various splits. The ability of roots to absorb nutrients to meet the demands of the growing plants depends on the health of plant; hence the good plant protection measures against pests and diseases and good crop husbandry practices improve the efficiency of fertilizer application.

Besides the roots, leaves and stems also absorb some nutrients from solutions of them as they come in contact with their surfaces. Foliar application of nutrients is viable in plants with well-developedphloem transport from the foliar tissues for distribution to other parts. This is mostly true in plants where osmotic regulations in leaf-tissues are controlled by theinorganic ions absorbed through roots or foliage. Further the vacuolar loading andunloading help in controlling osmotic regulations by buffering ionic concentration in leaf tissues. In absence of vacuolar loading and unloading of inorganic ions, foliar applied nutrients increase the ionic concentration dislocating osmotic regulations affecting photosynthesis and vital functions related growth.

Plants evolved in humid zones low in bases have developed osmotic regulations using the photosynthatesfor osmotic regulations by retaining them inthe leaf tissues beforetransporting them to roots for further processing. When inorganic salts are applied to foliage they increase the salt concentration dislocating osmotic regulations; and unless the salt concentration is regulated by vacuolar loading, salt injury occurs. Assuch, thesetypes of plants do not respond to foliar application of nutrients except the ones which are required in small quantities and that too in growing points such as zinc and their major requirements of course are met through absorption by the roots.

Fertilizer Recommendations

As the Soil play an important role in the retention and release of nutrients, be they are inherent from natural recycling process or added as fertilizers,soil tests are developed to estimate the quantity of available nutrients during the cropping season. Field experiments helped to fix economic doses by critical analysis of responses obtained in relation to soil test values. Lot of Research had gone in designs of experiments and theirstatistical interpretations taking into account heterogeneity associated with their growth determinant factors (soil, climate and water).At high yield levels where the uptake in unit time is high, kinetic factors on the movement of ions in the soil and rhizhosphere have a say in assessing nutrient requirements.

As the growth of plants depends on availability of nutrients, lot of investigations has gone in to use plant analysis as a diagnostic tool for predicting nutrientdeficiencies and ways of correcting them. The mean composition of plants varies within a narrow range and it is kept so by buffering biomass production to keep the chemical composition within optimal limits for efficient functioning of life processes.As such the chemical composition of plant tissues fail to show the initial stage of deficiency as they are kept within the optimal limits by reducing the biomass production. Only in extreme cases of deficiency, dislocations of metabolic processes occur and this leads to expression of deficiency symptoms. Similarly with increasing nutrient inputs, biomass production increases and the chemical composition is kept at optimal limits. Attempts have also been made to a combined use of a vegetative growth index and chemical composition of plant tissues to evaluate mid-term correction ofapplication rates of nutrients already planned. The chemical composition is normally expressed on dry matter basis and it doesn't give a correct picture of *in situ* nutrient status under field conditions. The chemical composition expressed on moisture basis is found to be a better index than that based on dry matter (dm) basis particularly for Potassium and mineral nutrients which are highly mobile and occur in ionic state. The critical level of K on hydration basis is O.25 % in sugarcane sheaths(3rd to 6th) and fourth leaf in Tea shoots

$$K_{H2O} = K_{dm} * (100-m)/mK_{H2O}$$

K% on hydration basis, K_{dm} is K% on dry matter basis and m is moisture percentage It is generally applicable to K contents in all tissues and to some extent to all crops. Though the results of using plant diagnostic techniques have given mixed responses, the regular plant analysis isuseful to track the effectiveness of a system of manuring and toplan mid-term corrective measures to sustain productivity.

Agro-biological Laws

Metabolic processes and growth of plants are controlled by physicochemical laws and hence could be understood by applying them as and when bottlenecks are encountered which stagnate theongoing efforts to achieve targeted yield.

- *Law of Limiting Factors*

It is also known as Liebig's Law of 'minimum.' When a process is controlled by number of factors, the rate of process is limited by the one which is slowest of all. This gives the qualitative prediction of the factor which is limiting the process. This has been discussed elsewhere whiledescribing theconcepts used inpushing the productivity upward in the beginning of organized cultivation in earlier days.

- *Law of Diminishing Returns*

Mitscherlich gave a mathematical expression to the law of minimum and defined it as "*the increase in crop for each additional incrementof the lacking factor is proportional to decrement from the maximum possible yield*".

Baule's percent yield concept further widened the scope of application of the laws of Liebig and Mitcherlich. Ranganathan further developed methods to get the Ymax from manurial trials and to use them for partitioning the responses to varying factors. For example in correcting micronutrient deficiency by foliar sprays and crop increase due to control of pests and diseases, one wants to know the contribution of each factor in the total percentage increase in crop i.e., the direct effect of sprays on improving heath of bushes and the indirect effect on increasing the efficiency of fertilizers. The above concepts are widely used to compare the efficiency of various factors and their economic importance.

- ***Law of Compounding Effect***

This gives the quantitative prediction of the net effect when several factors are limiting the growth to varying degrees. If available N, P and K in the soil could support 80% yield individually, then the net effect will be 51.2% ,compounding effect of three factors:

51.2% ={100*(80*100)*(80*/100)*(80*100)} and not 80% the mean {(80+80+80)/3)}.

If the climate is adverse and can support only 20% yield while nutrient inputs could support 80% yield, the yield achievable is only 16%. (20*80/100).

- ***Principle of Least Abrupt Changes***

Any change in growth process or response to manuring is only progressive and continuous and no abrupt change occurs in nature. Any abrupt change if noticed should be investigated and, extraneous factor eliminated to achieve the goals.

- ***Principle of Least Resistance Path***

Any process having alternate pathways will prefer the path which gives the least resistance. When a nutrient is available in several forms having different energy levels for their attaining equilibrium levels, the one with low energy level will meet the demands as they offer least resistance to attain equilibrium levels in resonance to the rate of uptake by roots

- ***Law of Mass Action***

This has been stated in many ways and helps in understanding the possible effect of presence of one of the substances in large quantities. The presence of one substance in large quantity affect the activity of other substances considerably and even can change the direction of a reaction. The effect is non-specific; many non-specific antagonisms or counter effects could be predictedand quantified thermodynamically.

Toxic effects of excess Sodium in the soil could be overcome by adding large quantities of Potassium. Application of large quantity of Potassium in soils containing low Magnesium content affect Magnesium availability and induces deficiency symptoms and loss of crop. In combined foliar application, the effect of one of the constituents in low quantity will be masked by the other one in large quantity. The benefit derived from combined spray of growth promoting hormones at 1ppm and Zinc at 2000 to 5000 ppm is a moot point. However it is too difficult to prove or otherwise the conclusions as there are too many factors involved in determining the rate of absorption.

Physical and Physicochemical Laws

Retention, release and movement of nutrient ions and water in the soil and rhizhosphere are governed by physical and physicochemical laws. Distribution of various ions on the various exchange sites (Soil colloids, roots of various plants with varying root CEC) in the rhizhosphere followDonnan distribution laws on charged surfaces and explains the competition of various exchange sites for the favorable ionic distribution. Nutrient flux in the rhizhosphere is mainly through diffusion rateswhich are largely dependent on concentration and temperature. Knowledge on these will help to fine tune the fertilizer program to optimize productivity.

Acknowledgements

I fondly remember my conversations with late Dr. B. Ramamoorthy, eminent Soil Scientist of Indian Agricultural Research Institute on applying physicochemical laws to understanding and interpretation of results of experiments on plant nutrition during the in-service training on Soil testing in December 1965 and thereafter in starting one of the eight centers on AllIndia coordinated scheme on soil –test crop correlation studiesat Coimbatore. He was a constant source of inspiration even after I joined UPASI Tea Research institute in1968. I acknowledge with gratitude the support, cooperation and encouragements received from mentors and colleagues at Tamil Nadu Agricultural Department (1956to68), United Planters Association of Southern India (1968to89), M/s RBT Ltd., Kerala (1989to1995) and IMTtechnologies Ltd., Pune(1995to2005). I record my gratitude to Dr. SS Ranade C&MD,M/s IMT Technologies Ltd., Pune for continued support. I am getting till to-day

References

1. Douglas C. Montgomery , Design and Analysis of Experiments Technology & Engineering*John Wiley & Sons, 2008; pp 680*
2. Gomez, Kwanchai A. Statistical procedures for agricultural research. *"An International Rice Research Institute book." "A Wiley-Interscience publication,1984; pp 680.*

3. J. A. Prescott. The Law of Diminishing Returns in Agricultural Exeperiment. *Economic Record.* May 1928; 4(1): 85-89. *DOI: 10.1111/j.1475-4932.1928.tb00553.x*
4. Quirino Paris, The von Liebig Hypothesis *Am. J. Agr. Econ.* 1992; 74 (4): 1019-1028*. doi: 10.2307/1243200*
5. RanganathanV, and Perumal Raja R., Vegetative growth index as a guide to N manuring in sugarcane. *Indian Sugar.* 1959; 9(4).
6. Ranganathan.V, Balasundaram C.S.,Govindaraj,K, and SoundarajanR. : Studies on the applicability of Mitscherlich-Bray equation for crop response studies. *Fertilite,* 1969; 33.
7. Ranganathan. V, Response curve for N fertilization in sugarcane, *Proc. 5th Bien. Conf. Sug. Res. & Dev. Workers,* Coimbatore, Dec. 1964.
8. Ranganathan V, Balasundaram C.S., and Govindaraj K. : Soil test crop response studies with reference to in *Solanumtuberosum*. *Madras Agri. J.,* 1973; 60(8): 957-967.
9. Ranganathan V., Balasundaram C.S., Govindaraj K and SamburnaramanS ; Soil test-crop response studies in rice – a new approach. Int. Rice Comm. Newsletter. 1972; 21(2): 18-27.
10. Ranganathan V, Balasundaram C.S., Govindaraj K,andRatnam L. :Soil test crop response studies in sorghum: L'AGRONOMIE Tropicale. 1974; 29(5) : 587-592.
11. Ranganathan V.: Impact of soil science research to fertilizer recommendations and cultural practices in tea in south India. *Proc. PLACROSYM.* 1982; 5: 345-357.
12. Ranganathan V. and S.Natesan S.: Agronomic pathways of yield response in tea to correction of zinc deficiency and control of pests *Proc. PLACTOSYM.* 1984; 4.
13. Ranganathan V.: Approaching Theoretical Limits of Productivity in Coconut, *Indian Journal of Plant and Soil.* 2015 2(1).
14. Ranganathan V.:Targeting Productivity in Rice (Oryza sativa L.*), Indian Journal of Plant and Soil.* 2015 2(2): 125-131.
15 Ranganathan V. : Chasing the Theoretical Limits of Productivity in Sugarcane (Sacccharum Spp.) *.), Indian Journal of Plant and Soil. 2016; 3(1): 41-46*
16. Ranganathan V., Balasundaram C.S., Govindaraj K. and Samaburnaraman S.: Some studies on the efficiency of utilization of nitrogen in irrigation cotton (*Gossypiumhirustum*Linn.). *Fertilite.* 1971; 38: 23-28, 1971.
17. SchneebergeH. :Critique of Mitscherlich's Law in Agronomy ; Institute of Statistics, *University of Erlangen-Nurnberg, Germany* -2016.
18. Schneeberger Hans.: Mitscherlich's Law: Sum of two exponential Processes Conclusions *Institute of Statistic University of Erlangen Nürnberg, Germany 2009, 1st July*
19. Y Gan, RC Yang. :Advanced statistical tools and their applications to agricultural research: *Canadian Journal of Plant Science*. 2011; 91 (4): 599-601.