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Efficient Nutrient Management Practices for Sustainable Rice Production and Soil Health

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Abstract

Most of the Indian soils have shown symptoms of fatigue with respect to secondary and micro nutrients due to the sub-optimum application of fertilizers to cereals and taking heavy harvests year after year. Crop productivity is directly influenced by the nutrient availability in the soil and their use efficiency. Considering the low productivity of many agricultural commodities, there is a need to increase fertilizer consumption and also the productivity of agricultural crops. Agro-climatic-region and crop specific fertilizers application should be offered to the farmers to overcome nutrient deficiencies particularly secondary and micronutrients for better crop response and higher productivity. Use of precision farming technologies that consider spatial variability and help conserve natural resources should be promoted. We require a clear-cut and comprehensive long-term fertilizer policies to improve productivity and generate marketable surplus by improving the nutrient use efficiency.

1. INTRODUCTION

Rice (*Oryza sativa*) requires 17 essential elements to complete its life cycle including macro-nutrients *viz*., C, H, O, N, P and K; secondary nutrients *viz*., Ca, Mg and S; micro-nutrients *viz*., Fe, Mn, Zn, Cu, B, Mo, Ni and Cl. Excess or deficit of any nutrient is harmful to rice plants. The deficiency or toxicity is specific to the element and can be prevented or corrected only by supplying that element. Once the first limiting factor is eliminated, the second limiting factor will appear (Liebig's law of minimum). The movement of nutrients inside the rice plant influences the appearance of its symptom. Nutrients are classified into three categories based on their movements inside the plant. (i) Mobile nutrient in plant *viz.*, Cl, Mg, Mo, N, P, K. (ii) Immobile nutrient in plant *viz.*, B, Ca. (iii) Moderately mobile Cu, Fe, Mn, Zn, S. The deficiency symptom of mobile elements appears in the bottom leaves, immobile elements symptom appears in the top leaves while

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moderately mobile elements produce its symptom in the middle leaves. The common deficiency and toxicity symptoms of nutrients in rice are presented in Table 1.

Table 1: The common deficiency and toxicity symptoms of nutrients in rice

Nutrients	Deficiency	Excess
N	Chlorosis of older (bottom) leaves	Dark green leaves
P	Anthocyanin accumulation in lower leaves. Reddening of lower leaves.	Zn deficiency in rice
K	Marginal burning of older leaves starting from tip of the leaves.	Mg deficiency in rice
B	Abnormal development of growing tips, becoming stunted and dying, fruits will abort	Leaf tips and margins will turn brown and die
Cl	Younger leaves will be chlorotic and wilt	Premature yellowing of lower leaves
Cu	Slow growth, stunted plants, distortion of the young leaves and death of the plant	Fe deficiency may occur, and roots will have stunted growth
Fe	Interveinal chlorosis of young leaves	Older leaves show brown spots surrounded by a chlorotic zone
Mo	Similar to N deficiency. Older and middle leaves become chlorotic, and leaf margins are rolled	-
Zn	Upper leaves show interveinal chlorosis with a whiting of the affected leaves, rosette formation	Fe deficiency will develop

Iron (Fe) deficiency is often reported in Calcareous silt and clay soil. Similarly, Mn deficiency often occur in Calcareous silt and clay with high organic matter. Zn deficiency common in highly leached acidic soils, calcareous soils, and in the soil with high levels of Ca, Mg, and B deficiency found in sandy soils, naturally acidic leached soils, alkaline soils with free lime. Mo deficiency found in highly podzolized soils and well drained calcareous soils (Vijayakumar et al., 2022). The favourable soil pH for the development of various micro-nutrient deficiencies is presented in Figure 1. The sufficiency, toxicity and critical level of various micro-nutrient for rice plant are presented in Table 2.

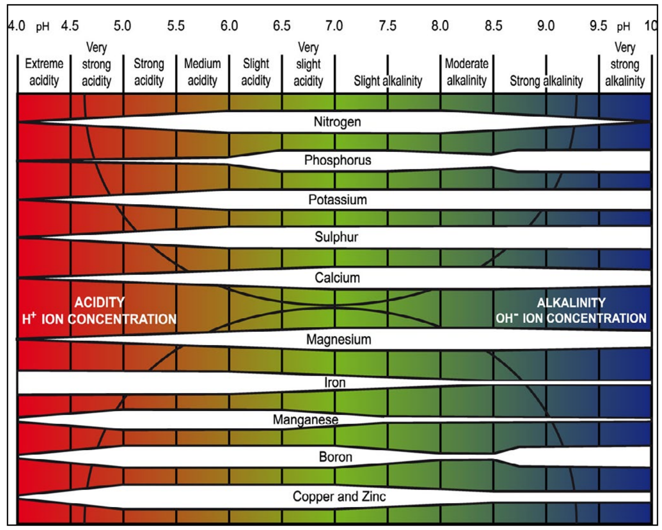

Figure 1: Ideal soil pH for optimum nutrient availability to plants (Anonymous, 2005)

Table 2: Guideline for critical, sufficient and toxic levels of plant nutrients

Element	Critical level	Sufficient level	Toxicity level
Fe (ppm)	<50	50-250	>250
Zn (ppm)	15-20	20-100	>400
Mn (ppm)	10-20	20-300	>300
Cu (ppm)	3.0-5.0	5.0-20.0	>20
B (ppm)	<10.0	10-100	>100
Mo (ppm)	<0.1	0.1-0.5	>0.5
Cl (%)	<0.2	0.2-2.0	>2.0

(Source: Seenappa et al., 2019)

2. Major Nutrient Management Problems

- Inadequate and unbalanced use of fertilizers
- Increasing native soil nutrient mining
- Decreasing fertilizer use efficiency/ factor productivity
- Sub-optimum state fertilizer recommendations
- Poor performing soil and low productivity
- Non-availability of secondary and micro nutrients and

even P and K

• Lack of durable fertilizer policies

• Inadequate availability of FYM and other organic inputs

Nutrient deficiencies in soils and plants are found increasing over the year. In Pre-Green Revolution Era (before 1960s) the practice of subsistence agriculture leads to lower production and limited nutrient removal. Introduction of high yielding varieties, assured irrigation and inorganic fertilizer use during Green Revolution Era (1966-1990) improved crop yield. Increasing population pressure is compelling to produce more and more food grains from available land without proper replenishment of nutrients and ultimately soil fertility got depleted (Vijayakumar et al., 2019). Green Revolution helped in achieving higher yields but led to multi-nutrient deficiencies. Unfortunately, during Post Green Revolution Period (after 1990) the total factor productivity declined due to the emergence of second-generation problem.

3. Consequences of Mining of Soil Nutrients

✓ Decline of soil nutrient reserves

✓ Decline in the fertility of even well supplied soils

✓ Occurrence of more widespread and more acute nutrient deficiencies

✓ Lower efficiency of nutrients applied

✓ Lower returns from money spent in fertilizers and other inputs

✓ Very high remedial cost of improving depleted soils

✓ Jeopardizing the sustainability of high yields to meet future needs.

4. The Consequence of Nutrient Deficiency in Rice

• Complete crop failure in case of severe deficiency.

• Stunted plant growth.

• Internal abnormalities such as clogged conductive tissues.

• Delayed or abnormal maturity.

• Reduce or increased uptake of other nutrients.

• Reduced tolerance to various biotic and abiotic stress.

• Poor quality of crops, including differences in protein, and starch content.

• Yield reduction.

5. Efficient Nutrient Management Practice for Sustainable Soil Health

5.1. Balanced Fertilization

There is no greater threat to sustaining high crop yields than the alarming rate at which Indian soils are being mined of their nutrients. Balanced fertilization is a key to break yield barrier and enhance farmer's profits. Balanced nutrition will continue to be NPK – driven but not restricted to NPK only. Large-scale efforts will be needed to provide S, Zn and B with NPK. Policies and products are needed to improve fertilizer supply plans and nutrient use efficiency for high yield, quality, profits and environment protection. '4R' nutrient stewardship (Right source, right rate, right time, in the right place) is the key to achieve balance fertilization and higher nutrient use efficiency in rice based cropping system (Surekha et al., 2023). To realize the maximum benefit of every nutrient management practices the identification of 4R nutrient stewardship for each nutrient and in every crop is crucial. The adoption of identified 4R nutrient stewardship practice will improve the yield and quality of economic produce, minimize the negative impact of inorganic fertilizer and improve environmental quality, reduce the production cost and maximize net return, maintain and improve soil health, reduce the emission of greenhouse gas (Vijayakumar et al., 2021). Creating adequate awareness about the importance of 4R nutrient stewardship, providing on-farm training to farmers and appropriate government policy will improve the soil health and system productivity and ensure the sustainability of rice-based system.

5.2. Customized Fertilizers

Site-specific and crop-specific customized fertilization practice caters to the nutrient need of crops and correcting the deficiency of soil nutrients will help in addressing the nutrient management issues in the context of climate change. As per Fertilizer (Control) Order, 1985 customized fertilizers are "multi-nutrient carrier designed to contain macro and /or micronutrient forms both from inorganic and/or organic sources, manufactured through a systematic process of granulation, satisfying the crop's nutritional needs, specific to its site, soil and stage, validated by a scientific crop model capability developed by an accredited fertilizer manufacturing/marketing company". Use of customized fertilizers would enhance nutrient-use efficiency which is currently 40% for N, 15-20% for P, 50-60% for K, 2-5% for other micronutrients (Gobinath et al., 2021). Addition of micronutrients along with granulated NPK fertilizer ensures balance fertilization which, in turn increases the uptake of macro and micronutrient uptake by plant and prevents nutrient deficiency in plants. agriculture. Customized fertilizers reduce the burden of farmers by excluding workloads like separate applications, saving time and cost, overcome the problem of non-uniformity in application of small quantity of nutrient in field (Dass et al., 2017).

5.3. Site Specific Nutrient Management (SSSNM): A Plant Based Approach

Site-specific nutrient management (SSNM) involve the use of principles and tools for supplying nutrients to plant to achieve higher yield by synchronizing the demand and supply after considering climatic yield potential, yield target, and availability of nutrients from all possible indigenous sources which generally vary from site to site. The recommendations using SSNM ensure the application of the right amount of fertilizers at a time when it is required by the plant so that the losses are minimized (Nayak et al., 2020).

• SSNM provides an approach for 'feeding' crops with nutrients as needed.

• Make optimal use of existing nutrients, such as from soil, residues, and manures

• Apply N, P, K and other nutrients based on soil testing and crop need to achieve preset yield target.

Advantage of SSNM

• Improve profitability by increasing crop yields

• Reduce input costs by minimizing input requirement

• Improve marketable crop quality

• Improve environmental stewardship

5.4. Real Time Nitrogen Management Using Leaf Colour Chart

Changes in rice leaf colour is a sensitive indicator of leaf nitrogen status within a growing season. The change in leaf colour can easily be determined by the leaf colour chart (LCC), which is a low-cost and user-friendly real-time N management tool (Figure 2). This tool assists farmers in deciding the right time and dose of N fertilization. It contains four or more colour panels that vary from yellowish-green to dark green. These color bands match the color range of rice leaves encompassing a continuum from leaf N deficiency to excessive leaf N concentration.

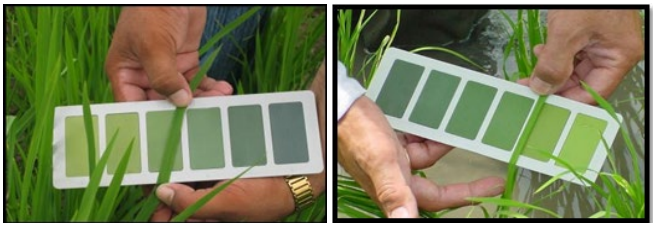

Figure 2. Use of LCC for N stress identification in rice

5.5 Brown Manuring

Brown manuring is a technique of growing *Sesbania* between two rows of standing rice crop and its knockdown with the help of herbicide for manuring. Generally, the seeds of *Sesbania* spp @ 20 kg ha^{-1} are broadcasted three days after rice sowing and allowed to grow for 30 days, and then killed by spraying 2,4-D. Due to 2,4-D spray, leaves turn brown in colour because of loss of chlorophyll, and hence termed as brown manuring. Desiccated *Sesbania* crop is left standing in the field along with the main crop without incorporation/ *in-situ* ploughing till its residue decomposes itself in the soil. Hence it is simply a 'no-till' version of green manuring, where an herbicide is used to desiccate the crop before the flowering stage. This practice can supply upto 35 kg N ha^{-1}, and increase yield by 4-5 q ha^{-1} due to the addition of organic matter in low fertile soils (Sharma et al., 2014). Over and above its beneficial effect on soil fertility, brown manuring also helps controlling weed growth through its weed smothering effect at the early vegetative stage of rice. Bispyribac sodium @ 25 g a.i/ha can also be used to knock down *Sesbania* at 25-30 DAS in direct seeded rice (Keerthi et al., 2022).

Advantages of brown manuring

❖ Improve nutrient use efficiency

❖ Increase soil organic matter content

❖ Improve soil physical condition along with microbial activity and nutrient availability

❖ Decrease NO_3-N leaching

❖ Curb weed population

5.6. Integrated Plant Nutrient Supply

Integrated Plant Nutrient Supply (IPNS) is a holistic approach to managing plant nutrition that aims to optimize nutrient availability and utilization while


Figure 3: Brown manuring in rice

minimizing environmental impacts. It involves the integration of various nutrient sources and management practices to ensure balanced and sustainable crop nutrition. IPNS takes into account both organic and inorganic sources of nutrients, such as chemical fertilizers, organic manures, crop residues, and green manures, to provide a well-rounded and efficient nutrient supply for plants.

Bottlenecks in adoption of IPNS

✓ Competitive uses of cattle dung and crop residues

✓ Quality of FYM/compost is poor due to inappropriate compositing method

✓ Transport and handling costs of bulky organic manures is very high vis-à-vis fertilizers

✓ *In-situ* decomposition of crop residues causes temporary immobilization of N

✓ The cost of raising a green manure crop is high.

✓ Short window period for green manure inclusion in the cropping system.

✓ Lack of government policies to promote IPNS

✓ IPNS recommendations are highly location specific and not available for many regions.

5.7. Efficient Genotypes

Cultivating nutrient-efficient genotypes of rice in nutrient stress situations will provide good yield. Several varieties have been identified/ developed for different nutrient stress environments are presented in Table 3.

Table 3: Variety for different nutrient stress environment

Stress	Genotypes
Low N	Swarna, Ranjit, Sarjoo-52, Bejhary, Pranava, Salivahana
Low P	Kasalath, Rasi, RPA 5929, MTU 2400, Vikramarya, DRR Dhan 60, DRR Dhan 65, DRR Dhan 66
Low Zn	CSR 10, Sarjoo-52, Vikas, IR-30864
Fe toxicity	Mahsuri, Phalguna, Dhanrasi

6. Conclusion

Adopting nutrient management techniques such as SSNM, IPNS, customized fertilizer, brown manuring, and balanced crop nutrition helps in correcting nutrient deficiency, enhance crop yield and soil fertility while preserving the environment. Implementation of '4R' principles of nutrient stewardship and improved crop management practices is essential to enhance crop productivity and nutrient use efficiency.

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