

New age nutrient carriers for rice based cropping systems

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Soil fertility and plant nutrition are remained together in agricultural sciences and play a vital role in sustainable production in rice based growing areas. However, recent interest in attaining sustainability in agriculture made a way to high utilisation of natural resources to enhance the soil fertility and plant nutrition through possible ways that are expected to be increased in near future. Moreover, there is an escalating direct pressure on demand of agricultural production with limited resources, which can be maulled with a combined use of mineral nutrient and natural resources, recycling of waste materials and growing of efficient genotypes. Increasing rice yield under a constraint environment has to be addressed with the rational use of chemical fertilizers including the introduction of multi nutrient mixtures, novel fertiliser materials coupled with the involvement of natural sources of nutrition in the nutrient management in rice based cropping systems. Imbalanced fertilization is causing a major reduction in yield and low nutrient dense grains in rice based cropping areas. Generally, nutrient management is carried out by application of conventional high analysis compounds solely or mixed with other nutrient fertilisers.

Keywords: Imbalanced fertilization, Indo-Gangetic plains, Nutrient, Rice

Essentiality of nutrients

In general, next to sunlight; nutrients are playing a major role in crop growth and metabolism; 16 different nutrients are necessary for normal growth and full development. In general, the most limiting factor for rice growth in inland valleys is nitrogen, followed by phosphorus and potassium (Table 1).

Rice based cropping systems and their nutrient requirement

Nutrient requirements for upland and lowland rice are different due to their inherent capacity of production viz, yield levels and growing conditions. A major difference in low land and upland rice is that environmental conditions are most stable and favourable for plant growth and high fertilizer application can ensure higher yields in low land rice whereas in upland rice, inadequate water particularly around flowering period reduces the yield

significantly and at the end there is little or no differences in yield between well fertilized and unfertilized crops. Intensive rice based cropping systems removes the nutrients in substantial quantities from the soil due to continuous cultivation. Basic principle of maintaining the fertility status of soil under high intensive cropping system is to replenish or add those declined nutrients in the field. In India, sub-tropical climate and efficient tillage practices are leading to loss of major

nutrients especially, nitrogen. Nutrient recovery efficiency of existing NPK fertilisers are very low as 40-65, 15-25 and 30-50%, respectively. Here, the study discuss the efficient nutrient use to increase the overall performance of cropping systems by introducing new fertiliser material and minimizing nutrient losses from the field. It can impact greatly on nutrient management as well as soil and plant-water management.

The essential macro nutrients are

Table 1. Essential elements for rice

The macro elements (required in large amounts)	Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulphur (S)	Generally available to plants in sufficient quantities through air, soil, and water	
The micro-elements needed by plants in lesser quantities (trace amounts)	Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn), Molybdenum (Mo), Boron (B), Chlorine (Cl)	Available through soil but mostly not through fertilizers	

Source: IFA (2015)

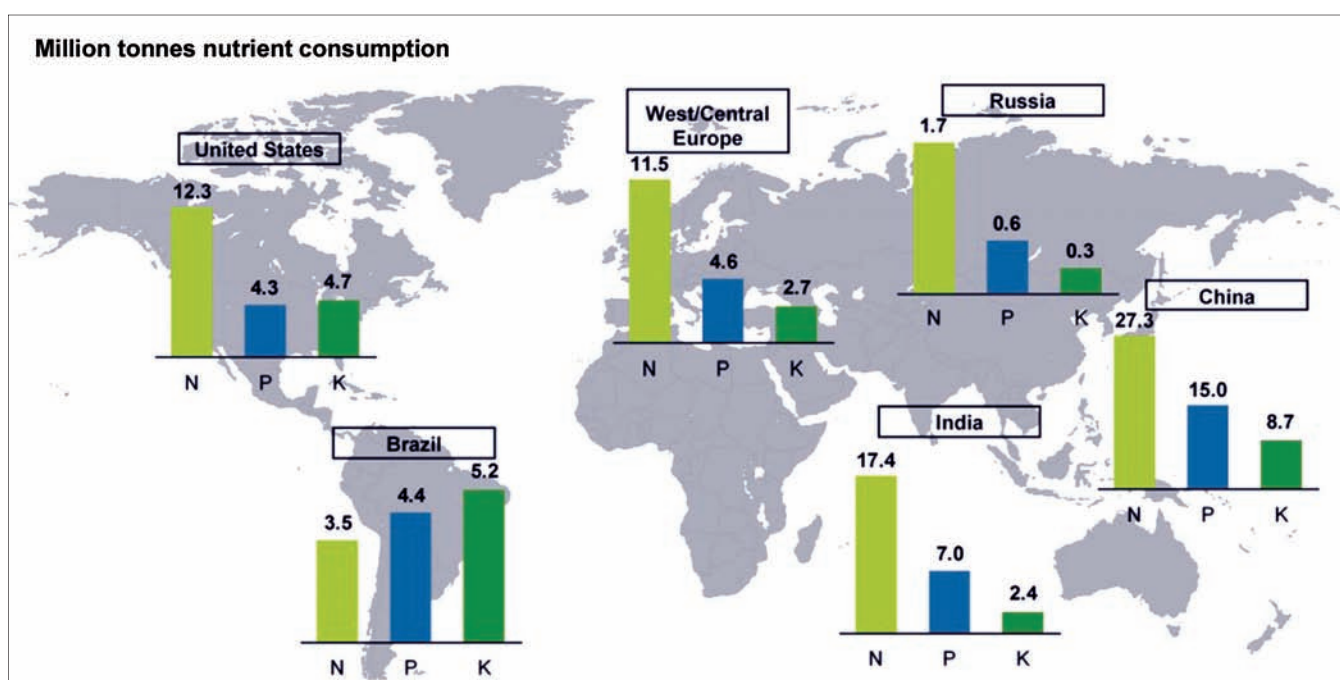


Fig. 1. Fertilizer consumption by region - 5 key markets. Source: IFA (2015)

supplemented through different fertilisers like urea, di ammonium phosphate (DAP), single super phosphate (SSP) and Muriate of potash (MOP). Consumption of the above fertilisers has been increased in multi-folds due to high requirement and cultivation of high yielding varieties of rice and other fallow crops. Overall, fertiliser consumption of N, P and K were 34,208,000 Mt, 3,730,000 Mt and 2,866,000 Mt, respectively in 2020, as reported by FAI. Rice is the most important crop in India in terms of both area and fertilizer use. As per the available data, rice alone occupy an area of 44.7 million ha, it accounted for more than 32% (5.34 million tonnes) of consumption in total fertilizer consumption. Fertilizer use on irrigated rice (155 kg/ha) is double than that on rain-fed rice (77.6 kg/ha). The shares of irrigated and rain fed paddy in total fertilizer consumption were 22.2 and 9.6%, respectively. The average per-hectare use of fertilizer on rice was 119.1 kg (81.7 kg/ha N, 24.3 kg/ha P_2O_5 and 13.1 kg/ha K_2O). Overall fertiliser use pattern in Indo-Gangetic plains in rice crop has been displayed here in the Table 2.

NEW NUTRIENT CARRIERS IN NUTRIENT MANAGEMENT

Increasing peer pressure on land to

produce more crop from the limited area is creating a shift to new novel fertilizing material from the conventional fertilisers is being created. Crop yield and economy of cultivation are highly influenced by efficient uptake of nutrients from soil and as a result higher nutrient use efficiency is expected.

Water soluble fertiliser

Water soluble fertilizers (WSF) are fertilizers that can be dissolved in water easily and control the precise amount of nutrients available to plants. Being readily soluble in water, it releases essential plant nutrients at the root zone from where they are

readily absorbed and used elsewhere in the plant system. Moreover, deficiency of essential micronutrients in soil coupled with increasing demand for micronutrients such as Zn, Fe, etc., to support plant growth is positively influencing the demand for water soluble fertilizers in the country. Indian water soluble fertilizers market stood at \$ 12.7 billion in 2018 and is projected to reach \$ 20.6 billion by 2028. Furthermore, Indian government is promoting drip irrigation as it reduces the cost of cultivation by 30% and this factor is further likely to push the demand for water soluble fertilizers in the coming years of

Table 2. Fertiliser use pattern under rice-wheat cropping system in the Indo-Gangetic Plains

Region	Crop	Fertiliser usage (kg ha ⁻¹)			Total	Yield (tonnes/ha)
		N	P ₂ O ₅	K ₂ O		
Lower Gangetic plain	Rice	85.9	9.9	32.8	128.5	2.34
Middle Gangetic plain	Rice	111.9	36.4	9.8	158.1	2.22
	Wheat	111.6	42.4	11.6	165.6	2.60
Trans Gangetic plain (Haryana)	Rice	163.2	52.8	0	216	3.60
	Wheat	171.3	56.9	0	228.2	4.55
Trans Gangetic plain (Haryana)	Rice	141.3	58.5	0	199.8	3.68
	Wheat	143.2	58.7	0	201.9	4.73
Upper Gangetic plain	Rice	108.3	44.6	2.2	155.1	2.92
	Wheat	109.8	52.2	2.1	164.1	4.48
Indo-Gangetic plains	Rice	117.3	35.2	11.8	164.2	2.95
	Wheat	120.3	38.2	11.1	169.7	3.95
	Rice + Wheat	237.6	73.4	22.9	333.9	6.9

Source: Sharma, S.K., Subba Rao, A.V.M. & Murari, K. 2004. Atlas of rice-wheat cropping system in Indo-Gangetic Plains of India. Modipuram, India. Bulletin No. 2004-I, PDCSR (ICAR), pp. 110.

Indian agriculture.

Benefits

- With the use of WSF, saving of 5-30% of recommended dose of fertilizer can be achieved.
- WSF is suitable for different methods of application *viz.*, foliar and fertigation. They are also suitable for soil application depending on requirement.
- Essential nutrients can be applied uniformly to each and every plant even on daily basis.
- Wide range of nutrient grades are available.
- As it is applied on crop requirement, it reduces accumulation of salts in soil.

Customized fertilisers

Customized fertilisers are manually prepared multi nutrient carrier designed to contain macro and /or micro nutrient (both from inorganic and/or organic sources), manufactured specifically to crop and soil. These fertilizers are considered as the best available option to correct site specific multi-nutrient deficiencies of soils to attain the maximum crop production through improved nutrient use efficiency. Customized fertilisers are manufactured to provide site specific nutrient management for achieving maximum fertilizer use efficiency with multi nutrient mixture. Customized fertilizers are a combination of nutrients like sulphur, zinc, boron added to the key items such as urea and diammonium phosphate (DAP) and potash, in a proportion that suits specific crops and soil patterns. Efficiency of customized fertilizers depends on soil properties, crop, water and specific nutrients. Manufacture of customized fertilizers involves mixing and crushing of urea, DAP, MOP, ZnS, bentonite sulphur and boron granules for obtaining the desired proportion of N, P, K, S and micronutrients.

Benefits

- It can be comfortably accepted by the farmers due to their higher nutrient content and easy handling.
- It can supply all the major and micronutrients in a timely interval

- Farmer need not buy micronutrient separately at extra cost, thus reducing the total cost.
- Mixed fertilizers with micronutrients provide recommended micronutrient dose for the agricultural crops.

Constraints

- High cost of customized fertilizers.
- Necessity of investing heavy capital in the state of art manufacturing facility for customized fertilizer.
- Limited awareness and very low affordability of customized fertilizers among the farmers.
- Uncertainty in response when fertility is restored in the field.

Nano particle fertilisation/nano formulation

Nano fertilizers are now being used in specific concentrations, in accordance with the nutritional requirements of the crops, ensuring minimal differential losses. This will act as alternative to conventional fertiliser. The unique properties of nanoparticles, such as high sorption capacity, high surface area, more surface to volume ratio, and controlled-release kinetics to targeted sites, make them a potential nutrient carrier or supplier to the rice crop. Nano-fertilizers are released very slowly in comparison to conventional fertilizers. This approach improves nutritional management, *i.e.*, increasing the nutrient-use efficiency and decreasing nutrient leaching into

groundwater. Many researchers proved that using nano materials can enhance agricultural productivity by improving seedling growth, germination etc. (Fig. 2).

Usages of nano formulations or nano fertilisers are restricted to few compounds such as urea, phosphate and metal oxide compounds. Nano nitrogen fertilizers (prepared as a result of deposition of urea on calcium cyanamide) are very instrumental in enhancing the productivity of rice. This nano-fertilizer offers a slow and gradual release of nutrients for a more extended period. Nano fertilizers can also be classified based on their actions: control or slow-release fertilizers; control loss fertilizers; magnetic fertilizers or nanocomposite fertilizers. As per the recent study, the application of nanoparticles carrying NPK (nitrogen, phosphorus, and potassium) to wheat showed an increase in grain yield and reduced the crop cycle of wheat by 40 days. Even conventional fertiliser can be encapsulated within nanoparticles which may be having a greater absorption and targeted releasing capacity and nutrient use efficiency. Few companies in India like Nano-Micro Nutrient (Shan Maw Myae Trading Co., Ltd., India) and Nano Green (Nano Green Sciences, Inc., India) have already started the production of nano micro nutrient fertilisers for commercial use in agriculture.

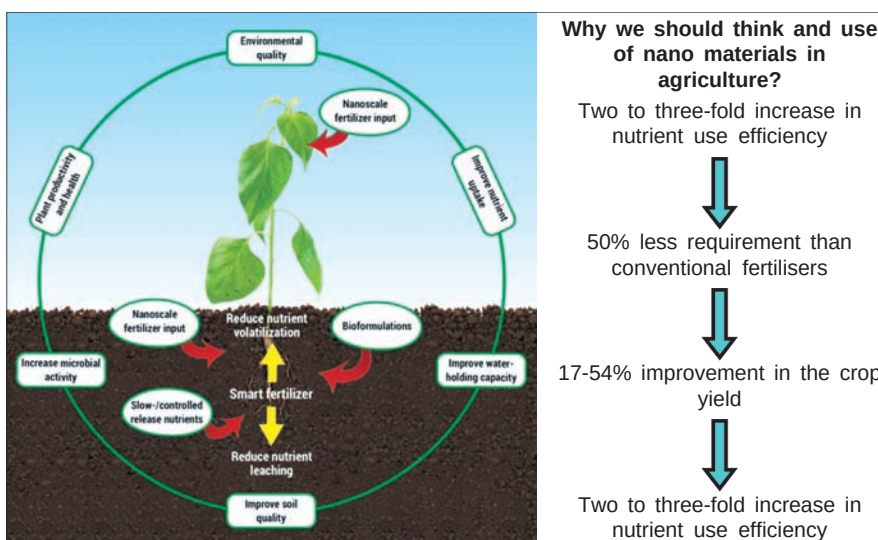


Fig. 2. Schematic diagram of potential smart fertiliser in plant system. Source: Calabi-Floody, M. *et al.* 2017. Adv. Agron. 147:119-157.

Setbacks of using nanoparticle in agriculture

- Lack of risk management system.
- Lack of production and availability of nano fertilizers in required quantities. This limits the wider scale adoption of nano-fertilizers as a source of plant nutrients.
- High cost of nano fertilizers.
- Lack of standardization in the formulation process.

Polymer based nutrient suppliers (capsulation)

Encapsulation is a process of coating materials (liquid, solid and gas) using thin wall materials over the homogeneous or heterogeneous matrices to form small capsules. Encapsulation is used to protect active ingredients that are sensitive to environmental influences. Another function is to control the release of a core material with a certain concentration and time so that it can improve the efficiency of nutrient use. Wall material used for encapsulation is usually from polymers/bio polymers (carbohydrates and proteins). Precision delivery of microbial strains for nutrient solubilization and delivery with higher load by encapsulation is called bio capsules. Encapsulation with organic materials increases the residence time of the material in the rhizosphere zone and ensures the quick resolution, faster mobilization of nutrients and positive plant growth and yield in the targeted crops. Bio capsules are easy to handle, have a higher shelf life and with more inoculant count that makes them efficient bio fertilisers in the field.

Bio-capsules are generally used for promoting plant growth by

supplementing fertilizer nutrients and also for considerable reduction in use of conventional fertilisers by 20-30%. Inducting capsule technology in fertilizer nutrient management is easier and cost effective (cost benefit ratio 1:3) compared to conventional formulations. Moreover, this encapsulation technology will significantly deliver all possible nutrients by using nitrogen fixers, nutrient solubilisers, plant growth promoting rhizobacteria (PGPR) etc. This may play a vital role in upcoming generation of innovative agriculture in the farming community. Bio-capsule technology will also promote the use of organic input in agriculture by reducing the requirement of chemical inputs.

Bio-enrichment of chemical fertilizer

There is an urgent need of enriching an existing fertiliser with the organic compound as witnessed by the researchers towards soil health. The urgency to enriched chemical fertilizer with organic and biological material is unavoidable. An economically feasible and environmentally safe product of fertilizer is desirable. Soil microbiology, no doubt holds the keys to unlocking some of the important new opportunities for enhancing nutrient management and crop production. Bio organo fertilizer is the most promising solution to harness a nutrient requirement in high nutrient requirement crops. Even clay mineral also loaded with bio inoculants to enhance the nutrient availability in soil. For example, organo-zeolitic bio-fertilizer is composed of nutrient and crushed zeolitic rock, containing clinoptilolite

functions biologically in initiating nitrification. Zeolite has high pore area which can be utilised for effective nutrient stabilization, loading of metal elements etc. Loaded nutrients present in the zeolite framework will improve the residence time in the soil and control the nutrient delivery. Combination of microbial carriers and chemical fertilizers such as urea, diammonium (DAP), potassium chloride mixing with bio inoculants will increase the fertilizer use efficiency.

Conclusions

Expanding global population has to ensure the availability of food for survival of the humankind with the existing agricultural practices. But the deteriorating soil quality, crisis of agricultural inputs has increased the pressure on crop production. In such an agro-critical scenario, efficient fertilization with efficient fertiliser product is important to sustain the soil quality and nutrient cycling effectively in soil. Chemical, organic/microbial fertilizer or combination of either through encapsulation has its advantages in terms of effective nutrient supply and management. Addressing the nutrient requirement in rice based cropping system through the existing suitable nutrient carriers integrated with the use of these kinds of fertilizers may be a viable alternative to maximise the nutrient use efficiency without disturbing the soil health.

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