

# 4R Nutrient Stewardship in Indian Agriculture

By T. Satyanarayana, Kaushik Majumdar, and Sudarshan Kumar Dutta

Agriculture is an integral part of the overall economic development in India. More specifically, agriculture and its allied activities contribute to nearly 50% of India's national income. Ensuring food security for India's growing population, expected to be around 1.33 billion by 2020 (Anonymous, 2014), continues to be a major challenge. IFPRI (2012) summarized several studies that showed foodgrain demand in India will reach 293 million (M) t by 2020 and 335 M t by 2026. The declining per capita land availability and limited scope for horizontal expansion of cultivated area requires the intensification of agricultural production through higher crop yield per unit area.

Increasing food demand from limited land resources in the coming decades requires increased use of fertilizers. Application of fertilizers following proven scientific principles is required to ensure improved productivity of crops without adding to environmental concerns. The contribution of fertilizers to total grain production in India has increased from 1% in 1950 to 58% in 1995 (Subba Rao and Srivastava, 1998). However, imbalanced fertilizer application in crops is identified as one of the major reasons for decreasing crop response to fertilizer application, and the consequent lower crop production growth rate in the country (Majumdar et al., 2014a). Despite the proven economic, social, and environmental benefits of balanced fertilization, its adoption at the farm level is low. The lack of appropriate tools and implementation mechanisms restricted its wide-scale adoption by farmers. The generally unbalanced fertilizer use by farmers in India has raised concerns about the environmental sustainability of such practice.

Fertilizer Best Management practices (FBMPs), are agricultural production techniques and practices developed through scientific research and verified in farmer fields to maximize economic, social, and environmental benefits (IFA, 2009). FBMP is aimed at managing the flow of nutrients in the course of producing affordable and healthy food in a sustainable manner, that protect the environment, conserve natural resources, and at the same time become profitable to producers. With FBMPs, farmers implement, under specific site, crop, and soil conditions, the concepts and elements of balanced fertilization, site-specific nutrient management (SSNM), integrated plant nutrient management (IPNM), among others (Bruulsema et al., 2009). On a broader scale, FBMPs are components of product stewardship and integrated farming. The benefits that can be derived from fertilizers are maximized through FBMPs, while the losses and negative effects of over/under/or misuse of fertilizers are minimized. The application of such scientific principles of FBMPs form the basis of the globally accepted concept called **4R Nutrient Stewardship**.

## What is 4R Nutrient Stewardship?

The concept of 4R Nutrient Stewardship is defined as applying the **right** source of plant nutrients at the **right** rate, at the **right** time, and in the **right** place, for sustainably managing

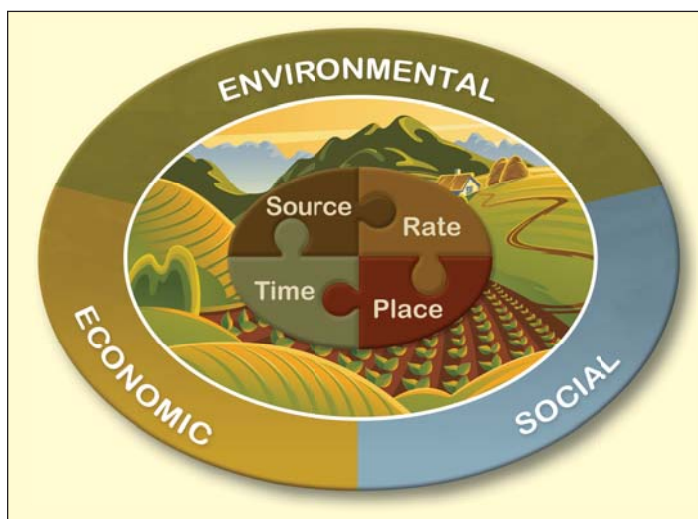


IPNI agronomist (left) promoting the concept of applying the right sources of plant nutrients for cotton.

plant nutrients and increasing crop productivity (**Figure 1**). The 4Rs encompass FBMPs within cropping systems that are proven to optimize production potential, input efficiency, and environmental protection. The idea of 4Rs was first introduced to the fertilizer industry in 2007, and the concept, developed by the global fertilizer industry, is now considered as an essential tool towards sustainable agricultural systems.

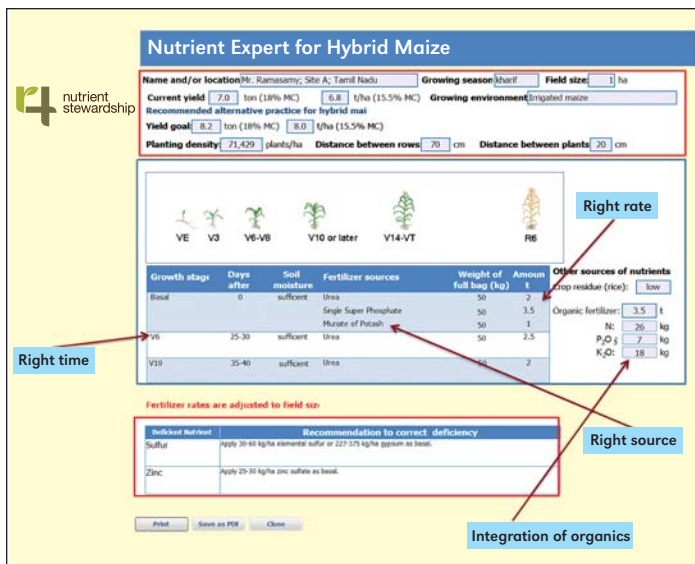
## Importance of 4R in Indian Agriculture

The smallholder farmers of the intensively cultivated areas in India often over or under use nutrients or apply them in an imbalanced manner, at an inappropriate time, or by wrong methods. Such practices result in low crop productivity and economic returns and often leave a large environmental footprint of fertilizer use. Several reviews of research (Johnston et al. 2009; Majumdar and Satyanarayana, 2011) demonstrated



**Figure 1.** The 4R Nutrient Stewardship concept defines the right source, rate, time, and place for fertilizer application as those producing the economic, social, and environmental outcomes desired by all stakeholders to the plant ecosystem.

Abbreviations and notes: N = nitrogen; N<sub>2</sub>O = nitrous oxide.



**Figure 2.** Example of a 4R compliant Nutrient Expert® based fertilizer recommendation, providing guidance on the application of fertilizer application to maize.

limitations of blanket fertilizer recommendations commonly used in India. Such blanket recommendations, made for large areas, have resulted in inefficient use of fertilizer, low crop productivity, and farm profitability. On the contrary, the 4R Nutrient Stewardship framework promotes the application of nutrients to ensure higher crop yields, better nutrient use efficiency, and profitability of small holder farmers through the above stated four “rights” of nutrient management (Majumdar et al., 2013).

### Relationship between 4R and Climate Smart Agriculture

Climate smart agriculture (CSA) has recently achieved much prominence in India, given the adaptation and mitigation challenges facing humanity. CSA is defined by three objectives: firstly, increasing agricultural productivity to support increased incomes, food security and development; secondly, increasing adaptive capacity at multiple levels (from farm to nation); and thirdly, decreasing greenhouse gas emissions and increasing carbon sinks. Fertilizer, particularly fertilizer N use, is often cited as a causal factor of climate change, while its adaptive or mitigation potential to climate change impacts have often been overlooked. For example, negative effects of N fertilizers on increased N<sub>2</sub>O emissions is well highlighted while its role in promoting carbon sequestration (i.e., removing CO<sub>2</sub> from the air) by stimulating plant growth leading to greater carbon storage in plant residues and roots is less discussed. Evidence across the globe suggests that research and extension efforts on precise 4R recommendations in crops and cropping systems have provided rich dividends in terms of increased crop productivity and farm income, while adapting and mitigating climate change.

### IPNI Initiatives in Promoting 4R Nutrient Stewardship

The International Plant Nutrition Institute (IPNI) has incorporated the concept of 4Rs into the institute’s strategic planning, and has invested significant resources towards capacity

building of stakeholders and partners around the world. Some of the significant outcomes of IPNI efforts on 4R is given below:

- The Institute has developed a comprehensive *4R Plant Nutrition Manual* that is considered as a very significant contribution towards 4R education. The manual is available in hard copy and electronic formats, and has been translated into eight different languages.
- The Certified Crop Adviser (CCA) program of the American Society of Agronomy has created a *4R Nutrient Management Specialization* within the CCA program and IPNI is soon to release a training manual to help CCAs prepare for the exam.
- The North American 4R Fund, through generous support by the fertilizer industry, has created a network of 40 leading scientists engaged in 4R research across North America.

The South Asia program of IPNI has strongly emphasized the 4R concept in its research and education program. A total of 40% of the research projects are aimed at developing 4R nutrient management guidelines for predominant cereal-cereal cropping systems of India. About 20% of the projects are focused on determining the right rate and right timing of nutrient application in soybean and cotton. The outcome of such studies also provided additional information on right sources of nutrients, based on the nutrient limitations identified through soil testing during the course of the implementation of the projects. The remaining 40% of projects promote dissemination of improved 4R fertilizer recommendations to farmers through on-farm demonstrations and education through training. Some of the significant outcomes of the above research and education programs are given below:

**Development of Nutrient Expert® fertilizer decision support tools:** The site-specific fertilizer recommendation tools for rice, wheat, and maize are 4R compliant, and provides recommendations to individual farmers on right source, right rate, and right time of application that are tailored for his/her farm (**Figure 2**). The recommendations from Nutrient Expert® for rice (Mandal et al., 2015), maize (Majumdar et al., 2014; Satyanarayana et al., 2014) and wheat (Dutta et al, 2014; Bhende et al., 2014) have significantly improved the cereal yields, farm profits, and nutrient use efficiency when compared to existing nutrient management practices.

**Collaboration with NARES and regional stakeholders to develop and promote 4R nutrient management strategies through research and education:** The IPNI South Asia program is strongly engaged with partners from National Agricultural Research and Extension System (NARES), State Agricultural Universities (SAU’s), Government Departments of Agriculture (DOA), industry, NGOs to disseminate 4R Nutrient Stewardship in diverse crops and cropping systems.

**Videos developed for disseminating information on 4R nutrient management:** IPNI South Asia program staff has developed crop and nutrient specific 4R videos in different Indian regional languages. These simple videos are expected to help fertilizer industry and public extension systems to convey simple messages about the importance of specific nutrients as a part of balanced fertilization, or the right ways of managing nutrients for specific crops for higher yields, farmer profit-



ability, and better environmental stewardship of nutrients. 4R videos on sugarcane, rice, wheat, and cotton are available in multiple regional languages

**Awareness on 4R Nutrient Stewardship through workshops/seminars:** IPNI staff demonstrated 4R as a means of practicing efficient nutrient management for improving soil health and outlined 4R Nutrient Stewardship principles for adaptation and mitigation of climate change impacts on agriculture at the events organized in commemoration of International Year of Soils during 2015. In the training workshops, principles of 4R Nutrient Stewardship were thoroughly discussed citing examples of each R and explained the importance of practicing 4R in a crop nutrient management program. Scientists recognized the importance of 4R and convinced to design the nutrient management program of a crop integrated with the 4R perspective while addressing researchable issues of crop nutrient management.

**Scientific papers and publications on 4R:** IPNI staff, in collaboration with partners, has published book chapter on 4R (Majumdar et al., 2014b) and scientific articles (Dutta et al., 2015; Pattanayak et al., 2015; Sapkota et al., 2014; Majumdar et al., 2013; Jat et al., 2013; Satyanarayana et al., 2011; Johnston et al., 2009) that discussed the scientific principles and application of the 4Rs. Such initiatives help in improving the understanding of 4R Nutrient Stewardship across wide range of stakeholders.

**Ownership of 4R Nutrient Stewardship by partners:** Partners of IPNI research and education programs in South Asia has contributed significantly to the dissemination of the 4R concept. NARES partners has adopted the concept and application tools in their research and extension program. The International Maize and Wheat Improvement Centre (CIMMYT), development partner of the Nutrient Expert® tool, has recognized the concept of 4R Nutrient Stewardship, and the Nutrient Expert® fertilizer decision support tool is currently being used by CIMMYT in their global flagship programs such as CRP MAIZE and CCAFS. A recent video (<https://www.youtube.com/watch?v=BAtwJALZpql>) developed by CIMMYT India on smallholder precision nutrient management is a practical example of endorsing 4R through the use of Nutrient Expert® in conjunction with GreenSeeker® technology.

## Summary

Nutrient management within the framework of the 4R Nutrient Stewardship promotes the application of nutrients using the right source at the right rate, right time, and right place and is aimed at ensuring the economic, social, and environmental goals of sustainable farming in India. The concept is well recognized among the stakeholders of Indian agriculture; it is such a rare occasion in any meeting where fertilizer or nutrient management issues are discussed and the 4Rs are not mentioned in the program. Going forward, there still exists a need for bringing nutrient management under the 4R perspective. Continuous efforts of developing and promoting 4R guidelines in diverse crops through research and education programs and strengthening effective partnerships in this dimension would be the way forward for successful implementation of 4R Nutrient Stewardship in Indian Agriculture. **ICSA**



**Educating a farmer** (left) on using the right rate for potash application.

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