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# THE SSNM CONCEPT AND ITS IMPLEMENTATION IN RICE

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# The SSNM concept and its implementation in rice

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**Abstract**

The site-specific nutrient management (SSNM), as developed for rice through partnerships of the International Rice Research Institute (IRRI) with organizations across Asia, provides scientific principles for optimally supplying rice with essential nutrients. It enables rice farmers to tailor nutrient management to the specific conditions of their fields, and it provides a framework for nutrient best management practices for rice. The total fertilizer N needed by rice to achieve a profitable yield target is determined from the anticipated crop response to applied fertilizer N and a targeted efficiency of fertilizer N use. Fertilizer N is supplied at critical growth stages, especially active tillering and panicle initiation, to match the crop needs for supplemental N. Fertilizer P and K are applied in sufficient amounts to overcome deficiencies and sustain soil fertility. The widespread implementation of SSNM by farmers requires transforming science-based principles and information into locally adapted guidelines enabling extension workers, crop advisors, and farmers to rapidly develop and implement best management practices tailored to specific fields and growing conditions. Decision support software, videos, quick guides for fertilizing rice, and the leaf color chart (LCC) are among the tools now facilitating the uptake by farmers of best management practices based on the SSNM concept.

## Introduction

Much of the essential nutrients taken up by rice come from soil and crop residues, but high yields require the input of supplemental nutrients. Rice farmers often apply fertilizer N at rates and times not well matched to the needs of the crop for supplemental N. Site-specific nutrient management (SSNM) as developed through partnerships of IRRI with national organizations across Asia provides the principles and guidelines that enable farmers to apply fertilizer to optimally match the needs of their rice crop in a specific field and season. It aims to achieve high rice yield and high efficiency of nutrient use by rice, leading to high cash value of the harvest per unit of fertilizer invested.

The SSNM approach was developed across diverse irrigated rice-growing environments through more than a decade of research in Asia. Researchers developed the concept of SSNM in the mid 1990s. It was then evaluated and refined from 1997 to 2000 on about 200 irrigated rice farms in eight major rice-growing areas across six countries in Asia (Dobermann et al., 2004). From 2001 to 2004, the initial SSNM concept was systematically transformed to provide farmers and extension workers with simplified plant-need-based management of N, P, and K. This included the use of the leaf color chart (LCC) for N management. Since 2005, increased emphasis has been placed on the dissemination of SSNM through expanded partnerships with research and extension organizations, non-government organizations (NGOs), and the private sector. Recent efforts in 2008 and 2009 have particularly focused on providing extension workers, crop advisors, and farmers with appropriate tools to quickly develop and implement nutrient best management practices for specific rice fields and growing conditions.

**Principles of nutrient management for rice**

The fertilizer N needed by a rice crop can be estimated from the anticipated crop response to applied fertilizer N and the expected efficiency of fertilizer N use by the crop. The crop response is the increase in grain yield due to fertilizer N, which is the difference between a yield target and yield without fertilizer (i.e., N-limited yield). The yield target is the rice grain yield attainable by farmers with the recommended nutrient management, their crop management practices, and typical climatic conditions. The yield without fertilizer N indicates the ability of the soil to supply N to the crop. It can be determined with an N omission plot receiving no fertilizer N but sufficient quantities of other nutrients to ensure that they do not limit yield (Witt et al., 2007).

Only a fraction of the fertilizer N applied to rice is taken up by the crop. Hence, the amount of fertilizer N required depends on the efficiency of fertilizer N use by rice, which is defined as the agronomic efficiency of fertilizer N (AEN) or the increase in grain yield per unit of applied fertilizer N. The fertilizer N needed by a rice crop can be estimated as shown in the table below from the expected yield increase or response due to application of fertilizer N and the expected AEN.

| AEN (kg grain increase per kg applied N) → | 15 | 18 | 20 | 25 |
|---|---|---|---|---|
| Expected yield response (t/ha) ↓ | Fertilizer N rate (kg/ha) | | | |
| 1 | 65 | 55 | 50 | 40 |
| 2 | 130 | 110 | 100 | 80 |
| 3 | | 165 | 150 | 120 |
| 4 | | | 200 | 160 |

Experiences in Asia indicate an AEN of 18 to 20 kg grain increase/kg applied N is achievable in the tropics with good management in low-yielding seasons in which crop response to fertilizer N typically does not exceed 2 t/ha. This corresponds to a fertilizer N need of about 50 to 55 kg N for a one ton increase in grain yield. An AEN of 25 is often achievable in the tropics with good crop management in high-yielding seasons with very favorable climatic conditions and a crop response to fertilizer N of up to 3 to 4 t/ha. This corresponds to a fertilizer N need of 40 kg N for each one ton increase in grain yield. An AEN of 15 is a realistic target for environments where existing fertilizer N management practices are very inefficient with AEN in farmers' fields of about 10 or less.

In order to achieve high yield farmers should apply fertilizer N several times during the growing season to ensure that the N supply matches the crop need for N at critical growth stages. Young rice before the tillering stage grows slowly and does not need much N. Therefore, with SSNM only a small to moderate amount of fertilizer N is applied to young rice within 14 days after transplanting or 21 days after direct sowing. Rice requires sufficient N at early and mid-tillering stages to achieve an adequate number of panicles and at panicle initiation stage to increase grain number per panicle.

With the SSNM approach, fertilizer P and K are applied in sufficient amounts to overcome deficiencies and sustain soil fertility. Total P and K needed by the crop are determined from the yield target and an established optimal reciprocal internal efficiency (kg nutrient in above-ground dry matter per ton grain) for each crop (Witt *et al*. 1999). The portion of total P or K supplied from sources other than the fertilizer applied to the crop — the indigenous nutrient supply — is estimated from the sum of the nutrient contained in returned crop residues, organic inputs, irrigation water, excess fertilization of the previous crop, and deposited sediment from floods. The difference between the total P or K needed for the yield target and the indigenous P or K supply provides a nutrient balance to estimate P or K deficit. This deficit reflects the amount of fertilizer P or K required to maintain a nutrient balance with no net removal of P or K from soil.

The SSNM approach uses both maintenance levels of P and K estimated from the nutrient balance and expected crop response to the nutrient to determine fertilizer P and K rates. When crop response to P or K is negligible, the rates of nutrient addition are based solely on the estimated nutrient balance. When the crop responds to P or K, the anticipated crop response to applied nutrient and an efficiency of nutrient use are used to determine fertilizer P or K needed to achieve a profitable yield target.

## Nutrient best management practices for rice in Asia

Nutrient management is implemented by crop growth stage.

*Early vegetative phase*

This phase covers the period from before crop establishment up to 14 days after transplanting (DAT) for transplanted rice or up to 21 days after sowing (DAS) for wet-seeded rice. During this period apply:

- Only a moderate amount of fertilizer N because the need of rice for supplemental N is small during this period of slow initial plant growth.
- All of required fertilizer P because P is important for early crop growth especially root development and tillering.
- At least half the required fertilizer K because it can contribute to greater canopy photosynthesis and crop growth.

Use the following guidelines for the early application of N:

- Typically apply about 20 to 30 kg N/ha in seasons with yield response to N between 1 and 3 t/ha.
- Apply about 25 to 30% of the total N in seasons with yield response to N >3 t/ha.
- Eliminate early application when yield response to N is ≤1 t/ha.
- Do not use the LCC with the early N application.
- Reduce or eliminate early N application when high-quality organic materials and composts are applied or the soil N-supplying capacity is high.
- Increase the N application to 30 to 50% of the total N for transplanted rice when old seedlings (>24 days old) and short-duration varieties are used.

Apply all fertilizer K before 14 DAT or 21 DAS when the total fertilizer K requirement is relatively low (<40 kg $K_2O$/ha). On sandy soils or when larger amounts of fertilizer K are required, apply about 50% of the required fertilizer K before 14 DAT or 21 DAS.

*Active tillering and panicle initiation*

Rice requires N during the tillering stage to ensure a sufficient number of panicles, and rice requires N at panicle initiation to ensure a sufficient number of filled spikelets per panicle to achieve a yield target. The critical time for N application at panicle initiation is about 60 days before harvest of tropical rice. The critical time for N application at active tillering is about midway between 14 DAT or 21 DAS and panicle initiation. The need for fertilizer N at active tillering and panicle initiation increases in proportion to the response in grain yield to fertilizer N.

The leaf N content of rice is closely related to photosynthetic rate and biomass production, and it can serve as an indicator of N status by the crop during the growing season. The leaf N content is directly related to the relative greenness of a rice leaf. Dark green leaves have ample N, whereas yellowish green leaves are deficient in N. The more yellowish green the leaf color, the greater the need of the crop for fertilizer N.

The leaf color chart (LCC) is an inexpensive and simple tool for monitoring leaf greenness and guiding the application of fertilizer N to maintain an optimal leaf N content for achieving high rice yield with effective N management (Witt et al., 2005). A standardized plastic LCC with four panels ranging in color from yellowish green to dark green has been developed and promoted across Asia (IRRI, 2009b).

An insufficient supply of K at panicle initiation can result in loss of yield and profit through reduced grain number per panicle and reduced filling of grain. Apply at panicle initiation up to 50% of the total fertilizer K requirement when the total fertilizer K requirement is ≥40 kg $K_2O$/ha. In the case of sandy soils typically apply up to 50% of the total fertilizer K requirement even when the requirement is <40 kg $K_2O$/ha.

*Early heading*

Nitrogen absorbed during the ripening phase, in the presence of adequate solar radiation, enhances the grain filling process. Inbred rice normally does not require fertilizer N at heading or flowering if the N application at the critical growth stage of panicle initiation was adequate. Hybrid rice in high-yielding seasons can require a fertilizer N application at early heading in the particular situation when leaf color is yellowish green. As a general guideline, apply about 20 kg N/ha at early heading to hybrid rice when the expected response to fertilizer N is ≥3 t/ ha and leaf color is yellowish green.

## Dissemination of nutrient best management practices

The SSNM approach is a relatively knowledge-intensive technology in which optimum fertilizer management is tailored to field-specific conditions for crop yield, crop residue management, historical fertilizer use, use of organic materials, nutrient inputs in irrigation water, and in the case of rice the growth duration of the variety. This knowledge intensity of SSNM has slowed the wide-scale promotion and uptake by farmers of best management practices based on SSNM principles. Uptake by farmers can also be constrained by confusion arising from contrasting recommendations for nutrient management received from different organizations and technical experts.

The widespread uptake by farmers of improved nutrient management requires transforming science-based information into locally adapted guidelines that enable extension workers, crop advisors, and farmers to rapidly develop and implement nutrient best management practices for specific fields and growing conditions.

IRRI in partnership with organizations across Asia and in Africa is developing computer- and internet-based decision support software capable within 15 minutes of providing farmers with nutrient management guidelines for specific fields with minimized risk and high likelihood of increased profit. The decision software entitled *Nutrient Manager for Rice* is tailored to local rice-growing conditions. Distinctive versions of the software are developed, verified, and released by country or regions of a country in the case of some large rice-growing countries. The decision software utilizes results from more than a decade of research on SSNM for rice, and it forms the basis for development of additional locally adapted tools for facilitating dissemination such as videos and quick guides for fertilizing rice.

Decision software entitled *Nutrient Manager for Rice: Philippines* was released on CD in 2008, and from 2009 it was available on the internet in English and five dialects of the Philippines (IRRI, 2009a). A partnership of organizations in Indonesia similarly developed decision support software tailored to rice production for Indonesia. It was released on CD in Bahasa Indonesia with the title *Pemupukan Padi Sawah Spesifik Lokasi* (*Location Specific Rice Fertilization*) in 2008. The experiences of the Philippines and Indonesia with rice are being replicated across Asia with rice, maize, and wheat. As of November 2009, decision tools for providing field-specific nutrient management based on SSNM were under development and verification for rice in Bangladesh, China, India, Sri Lanka, Vietnam, and West Africa; wheat in India; and maize in Bangladesh (IRRI, 2009b).

The *Nutrient Manager for Rice* decision tools are designed to help extension workers, crop advisors, and farmers quickly formulate fertilizer best management for specific rice fields. Each tool consists of 10-15 questions easily answered by an extension worker or farmer. Based on responses to the questions, a fertilizer guideline with amounts of fertilizer required by crop growth stage is provided for the rice field. Fertilizer rates and timing are adjusted to accommodate a farmer's use of organic sources of nutrients. These tools accommodate transplanted and direct-seeded rice, including inbred and hybrid varieties with a range of growth durations. These tools help farmers increase their yield and profit by applying the right amount of fertilizer at the right time.

Computer and internet-based decision tools are supplemented by a suite of additional locally adapted tools including videos, quick guides for fertilization, and the LCC for managing fertilizer N. In the Philippines in 2009, *Nutrient Manager for Rice* decision support software was used to develop locally adapted fertilizer guidelines for the most common rice-growing conditions (i.e., crop establishment method, yield level, duration of rice varieties, and crop residue management) in 75 provinces. These guidelines were transformed in local dialects into provincial one-page quick guides for fertilizing rice that were distributed, demonstrated, and promoted in the provinces (IRRI, 2009b). As of November 2009 this approach of developing and disseminating quick guides for fertilizing rice was being replicated in Indonesia.

In 2009, a video entitled *Proper Nutrition Makes Healthy Rice Plants* was released in the Philippines to provide farmers with guidelines on nutrient best management for rice (IRRI, 2009b). The script was subsequently adapted to Indonesian conditions and a comparable video was released for farmers in Indonesia in the local language. As of November 2009 additional videos were under development. Scripts from the videos will be circulated to encourage development of locally adapted videos for farmers in other countries.

## Looking ahead

Experiences from the Philippines and Indonesia in transforming the scientific principles and research findings of SSNM for rice into tools such as decision support software, videos, and quick guides for accelerating uptake of nutrient best management serve as a model for replication in other countries and with other crops (i.e., maize and wheat). Experiences with *Nutrient Manager for Rice* highlight the opportunities to consolidate considerable information from research on SSNM into easy-to-use tools addressing needs of a specific target group. Initial experiences with videos highlight their considerable potential, especially when combined with decision tools in either electronic or printed form, to reach farmers.

Building upon the experiences and achievements with *Nutrient Manager for Rice*, a suite of decision support software for specific target groups is planned through 2010-2012 for rice, maize, and wheat. *Nutrient Manager* decision software for specific countries or rice-growing regions of large countries will provide extension workers, professional agronomists, and farmers with field-specific guidelines on nutrient best management. *Nutrient Expert* decision software for specific crops will enable researchers and scientists to identify crop and nutrient management practices to attain yield goals. *Nutrient Teacher* decision software will enable educators and policy makers to better assess on-farm benefits based on fertilizer prices, farm gate prices of produce, seasonal variation in climate, and new technologies. Multi-institutional partnerships within the Cereal Systems Initiative for South Asia (CSISA) and the Irrigated Rice Research Consortium (IRRC) together with emerging public-private sector partnerships across Asia provide opportunities for accelerating development, verification, dissemination, and uptake of locally adapted nutrient best management practices.

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