Efficient N management technologies for irrigated rice in Asia

Vethaiya T. Balasubramanian

International Rice Research Institute (IRRI), DAPO Box 7777, Manila, Philippines, Email: v.balasubramanian@cgiar.org
Web: http://www.cgiar.org/irri

Abstract

Over 90% of the global rice is produced in Asia, using 93% of the total fertilizer N allocated for the crop. Efficient N use is critical to provide food security for the growing population and protect the environment. Three strategies are discussed for efficient N use in irrigated rice in Asia.

Media summery

Leaf color chart: a simple, popular, and efficient N management method used by more than half a million irrigated rice farmers in Asia.

Keywords

Environmental quality, fertilizer use, food security, N use efficiency, resource base

Introduction

External N application is critical for intensive rice production, because most of the soils are deficient in N. Globally, more than 90% of the rice is produced in Asia, using 93% of the total fertilizer N allocated for rice (FAO 2001). Irrigated rice covers 50% of the total rice area and produces about 75% of the total rice output. Further intensification of the irrigated rice ecosystem is necessary to feed the growing population and to maintain food security in the coming years (Dobermann et al. 2004). Rice crops use only about half of the applied N for producing aboveground biomass (Krupnik et al. 2004). The other half is, for a greater part, dissipated in the wider environment, causing a number of environmental and ecological side effects. Thus, efficient N use is critical to produce enough food for feeding the growing population and avoid large-scale degradation of ecosystems caused by excess N (Tilman et al. 2001). This paper analyzes the relative efficiency of 3 N management technologies for irrigated rice in Asia.

Measurement of fertilizer N use efficiency

In field-scale N management studies, four agronomic indices are commonly used to measure N use efficiency (NUE): (a) partial factor productivity from applied N (PFP_N), expressed as kg grain per kg N applied; (b) agronomic efficiency of applied N (AE_N), calculated as kg increase in grain yield over that of zero-N control per kg N applied; (c) apparent recovery efficiency of applied N (RE_N), defined as the increase in N uptake by aboveground biomass (grain + straw) over that of zero-N control per unit of N applied; and (d) physiological efficiency of applied N (PE_N), defined as the increase in grain yield per unit of N acquired by the crop over that of zero-N control.

Technologies for efficient N use in irrigated rice

Researchers have developed a number of technologies for efficient N management in rice (Table 1). Performance of selected technologies is briefly discussed below.

Real-time N management

Real-time N management strategies synchronize the timing and amount of N application with actual crop demand and soil N supply during the growing season. These strategies must be robust enough to handle high variability in soil N supply within or between fields.

Table 1. On-station N-use efficiency of different N management technologies developed for irrigated rice in Asia (Data source: IRRI-CREMNET, 1998, 2000).

N management technology	No. of cases	Mean yield (Mt ha^{-1})	AE_N (kg increase in grain/ kg N)	PFP_N (kg grain/ kg N)	RE_N (% increase in N uptake)
Bangladesh, BRRI-Gazipur & Comilla, Winter season (Boro), 1997 & 1998					
Farmers' practice	20	5.8	22	58	40
SPAD-35[a]	20	6.0	29	70	54
90% of OF-ref.[b]	20	6.1	27	66	54
CRNF[c]	24	6.6	36	69	67
UB/DP[d]	12	6.8	41	79	79
Bangladesh, BRRI-Gazipur & Comilla, Wet season (T-Aman), 1997 & 1998					
Farmers' practice	8	4.2	12	70	
SPAD-35	8	4.2	23	140	
CRNF	16	4.8	16	57	
UB/DP	8	4.6	19	79	
India, SWMRI/TNRRI/TNAU, Tamil Nadu, Dry season (Kuruvai), 1997 & 1998					
Local rec.[e]	8	7.1	25	57	
STCR rec.[f]	25	6.6	15	37	
SPAD-35/37	48	6.3	36	84	

CRNF	25	6.5	26	66	
India, SWMRI/TNRRI/TNAU, Tamil Nadu, Wet season (Samba), 1997/98 & 1998/99					
Local rec.	8	5.0	15	33	
SPAD-35/37[a]	30	5.3	23	55	
CRNF	20	4.9	20	54	
India, KVK-Pondy & DRR-Hyderabad, Wet & Dry seasons, 1997/98 & 1998					
Local rec.	10	5.2	32	55	20
SPAD-35	4	6.4	63	91	
CRNF	28	6.2	45	72	66
Neem oil-coated urea	10	6.2	35	67	57
Gypsum-coated urea	6	5.3	37	62	65
Indonesia, IIRR, Wet & Dry seasons, 1998 & 1999					
Local rec	33	5.5	19	49	57
SPAD-35/37	21	6.0	47	86	83
CRNF	48	5.7	27	64	78
UT/DP	21	6.1	29	65	66
Philippines, PhilRice-Maligaya, Dry season 1999 & 2000 (inbred & hybrid rice varieties)					
Farmers' practice	16	7.1	19	60	
UT/DP	16	7.1	24	68	

CRNF	32	7.1	27	82
Philippines, PhilRice-Maligaya, Wet season 1999 & 2000 (inbred & hybrid rice varieties)				
Farmers' practice	16	4.6	7	51
UT/DP	16	4.5	10	78
CRNF	32	4.7	12	79

[a] SPAD-35 or SPAD-35/37: Chlorophyll meter method with critical values set at 35 to 37
[b] OF-ref.: Over-fertilized reference plot's SPAD value
[c] CRNF: Controlled release nitrogen fertilizer (urea)
[d] UB/DP: Urea briquette/urea tablet/urea super granule deep placement
[e] Local rec.: Local recommendation
[f] STCR rec.: Soil test crop correlation research recommendation (Tamil Nadu, India)

Figure 1 shows the two methods available for real-time N management in irrigated rice fields: chlorophyll meter (SPAD or Soil-Plant Analysis Department) and leaf color chart (LCC) (Balasubramanian et al 2003). Both tools are used to monitor crop N status *in-situ* in the field and to determine the right time of N topdressing. The amount of N per application is decided based on physiological demand of the crop for N at different growth stages.

Figure 1. (a) Chlorophyll meter and (b) leaf color chart (LCC) for monitoring crop N status *in situ* in the field and applying N as per actual crop demand.

Both the SPAD and LCC methods were more efficient in N use than fixed split N recommendations over large areas. For example, the AE_N ranged from 23 to 63 for chlorophyll (SPAD) meter method in contrast to 7 to 22 for farmers' practice, 15 to 32 for local (research) recommendation, and 15 for soil-test-crop-correlation (STCR) recommendation (Table 1). The PFP_N values followed a similar trend as that of AE_N (Table 1). Since chlorophyll meter is expensive, farmers use the simple and inexpensive LCC for N management in rice in Asia (Balasubramanian et al. 2003).

Deep point placement of urea and modified urea materials

Deep point placement of urea super granule (USG), urea tablet (UT) or urea briquette (UB) is highly efficient compared to surface broadcasting of prilled urea in flooded rice (Kumar et al., 1989). The AE_N of

UB deep point placement (UB/DP) method was 24 to 41 in dry/winter seasons (DS) and 10 to 19 in wet season (WS), compared to 19-22 in DS and 7-15 in WS for split application of N (Table 1). By adopting the UB/DP method, farmers in Bangladesh produced on an average 1 Mg ha^{-1} more yield and reduced urea input by 20% to 30% (IRRI-CREMNET 2000; Mathot, 2003). Farmer adoption is limited due to the lack of suitable methods to deep place the UB in anaerobic subsoil (8-10 cm depth). Simultaneous change from transplanting to dry drilling in rows and placement of UB adjacent to seed row is being tried to overcome the difficulty of manual deep placement.

Controlled release N fertilizer (CRNF)

Urea or other nitrogen source is coated with a polymer so that the N release pattern is regulated to match crop N demand. CRNF is highly efficient in use, because of its regulated N release and its ease of placement with seed that enhances crop N uptake (Shoji et al. 2001). CRNF produced more grain yield per unit of N applied (26 to 45 kg additional grain per kg N in DS and 12 to 20 in WS) than conventional split N application with AE_N values of 19-22 for DS and 7-15 for WS (Table 1). However, the high cost of CRNF prevents its widespread use by farmers.

Conclusions

Matching N application with crop demand by real-time N management, deep point placement of N, and controlled release N fertilizers (CRNF) are the three efficient N management strategies for irrigated rice in Asia. To maximize benefits from these technologies, crop management must be optimum and nutrients other than N must be applied in the right balance. While farmer adoption is poor for N deep placement due to its high labor need and CRNF due to its high cost, the simple and inexpensive LCC method is attractive to farmers. Adequate training and follow-up technical support are needed to improve farmers' knowledge and proper use of these new technologies.

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