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Highlight

Water and Nitrogen Use Efficiency of Rice under System of Rice Intensification

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Nitrogen (N) is a key nutrient determining the yield of rice. Paddy crop utilizes hardly 30-40 percent of applied nitrogen to the soil while the remaining portion is lost in various ways.

SRI which is efficient in absorption and utilization of both water and nutrients greatly enhances the efficiency of applied fertilizers, reduces the cost of inputs and prevents the losses of nutrients to eco-systems. Application of controlled release nitrogen (CRN) either delays nutrient availability or extends it significantly with synchronous nitrogen supply for crop demand. It reduces environmental hazards, improves rice yields and nitrogen use efficiencies

Water and Nitrogen Use Efficiency of Rice Under System of Rice Intensification[1]

Research Highlight Based on a Paper with the Same Title

Water is a scarce resource in India. Projections show that India will have severe water problems by 2025. It is estimated that the water supply-demand gap for irrigated crops will be about 21 BCM in 2025 in India. Agriculture is the biggest consumer of water and nitrogen (N) fertilizers. In India, agriculture accounts for 83 percent of annual water withdrawal, against 49 percent in North and Central America and 38 percent in Europe. Irrigated rice, in particular, is a heavy consumer of water. Around 5000 litres of water is needed to produce 1 kg of rice. Tamil Nadu state in India has about 2 million ha under rice and 70 percent of this area is irrigated. Transplantation of seedlings is a common practice under irrigated rice system. Under this system, maintenance of 5 cm depth of water throughout the crop growth period is a recommended management practice. Under the circumstances, water savings in irrigated rice production is of paramount importance.

Agriculture accounts for 83 percent of annual water withdrawal in India. Irrigated rice, in particular, is a heavy consumer of water that takes around 5000 litres of water to produce 1 kg of rice.

Rational fertilizer application, especially N under intensive agriculture, has increased crop production but has created serious negative impact on soil, aquatic and atmospheric components. Paddy crop utilizes hardly 30-40 percent of N applied to the soil while the remaining portion is lost by ways such as leaching, de-nitrification and volatilization. In this background an experiment in irrigated rice with slow release nitrogenous fertilizer under the system of rice intensification was carried out with the objective of reducing irrigation water requirement and increasing N use efficiency.

Methodology

Rational fertilizer application, especially nitrogen under intensive agriculture, has increased crop production but has created serious negative impact on soil, aquatic and atmospheric components.

Field experiments were conducted at the Agricultural College and Research Institute, Killikulam during rabi, 2003-04 in transplanted rice with the two methods of transplanting: [1] SRI, and [2] conventional rice cultivation as main plot and various N management of (a) absolute control (no nitrogen), (b) 50 percent recommended N as prilled urea, (c) 100 percent recommended N as prilled urea, (d) 50 percent recommended N as CRN, and (e) 100 percent recommended N as CRN as a subplot in split plot design replicated four times. Prilled urea was applied as basal and topdressing but CRN was applied as basal only. Under SRI, 14 days old seedlings were square planted 20 x 20 cm apart. Under the conventional rice cultivation method 21 day old seedling were transplanted 15 x 10 cm apart. The depth of water maintained under SRI was 2.5 cm with alternate wetting and drying practice up to panicle initiation stage and flooded with same depth of water from panicle initiation

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to harvest. Under conventional rice cultivation the field was flooded with water to a depth of 5 cm throughout the standing crop. A conoweeder was used under SRI to incorporate weeds into the soil instead of hand weeding at 30, 45, and 60th days after transplanting as followed in the conventional method. The experimental soil was classified as *Typic ustropept* (it is a taxonomical class of soil showing a texture of sandy clay loam soil) with pH 8.2, EC 0.35 dS/m, organic carbon 0.87 percent, cat ion exchange capacity (CEC) 37.5 c mol (p^+)/kg with the available NPK of 175, 19 and 250 kg/ ha respectively. The test rice crop grown was ADT 43 (Aduthurai-43, name of paddy variety).

Based on the crop area and number and depth of irrigation water, water productivity was measured. N use efficiencies such as partial factor productivity, agronomic efficiency, physiological efficiency and apparent recovery efficiency were derived from grain yield, total biological yield,

Table 1: Grain (14 Percent Moisture) and Straw Yields (Kg/Ha) as Influenced by Method of Cultivation and N Management in Irrigated Rice

Treatment	Grain yield	Straw yield	Total	Fertile tillers (no./m²)
Main effect				
Method of cultivation				
S_1- System Rice Intensification	3893[a]	4647	8540	477[a]
S_2 - Conventional Rice Cultivation	3039[b]	4027	7066	458[b]
SEd	162	234	-	3.5
CD (0.05)	515	NS	-	7.3
N Management				
N_0 - No Nitrogen	2606[e]	3375[c]	5980	382[e]
N_1 - 50 % Recommended N as Urea	3051[d]	4439[c]	7490	431[d]
N_2 - 100 % Recommended N as Urea	3484[c]	4331[b]	7815	464[c]
N_3 - 50 % Recommended N as CRN	3885[b]	4620[ab]	8505	511[b]
N_4 - 100 % Recommended N as CRN	4302[a]	4920[a]	9222	548[a]
SEd	117	157	-	15.3
CD (0.05)	241	324	-	33.6
Interaction effect				
S_1N_0	2867	3468	6336	395
S_1N_1	3476	4938	8414	441
S_1N_2	3972	4767	8739	475
S_1N_3	4299	4730	9029	520
S_1N_4	4848	5333	10181	554
S_2N_0	2345	3283	5628	371
S_2N_1	2626	3939	6565	423
S_2N_2	2997	3886	6883	452
S_2N_3	3470	4511	7981	501
S_2N_4	3755	4506	8261	542
SEd (S at N)	219	307	-	55.9
SEd (N at S)	165	222	-	68.3
CD (0.05) (S at N)	NS	834	-	NS
CD (0.05) (N at S)	NS	459	-	NS

In a column, means followed by a common letter are not significantly different at 5 percent level by LSD.

quantity of fertilizer applied and quantity of N uptake by the crop.

SRI recorded higher water productivity of 0.699 kg/m^3, three times higher than that the conventional rice cultivation (0.253 kg/m^3). The partial factor productivity of nitrogen was also more under SRI (50.8 kg/ kgN) than the conventional method (39.5 kg/kgN)

Yield

The method of transplanting and N management significantly influenced the grain yield (Table 1). Among the transplanting methods, the system of rice intensification (Square planting 20 x 20 cm with 14 days old seedlings) recorded a significantly higher grain yield of 3,892.7 kg/ha which was 28 percent more than that obtained by the conventional rice cultivation (3,038.6 kg/ha). The higher grain yield in the SRI method may be attributed to more number of fertile tillers produced because of increased water and N use efficiencies. The yield varied from 2,605.9 to 4,307.8 kg/ha because of various N management treatments. Application of 100 percent recommended N as CRN gave maximum grain yield of 4,301.8 kg/ ha which was 63 percent higher than the no N application (control), 23 percent more yield than the same dose of N as prilled urea, 11 percent more than half the dose of recommended N as CRN and 41 percent more than application of prilled urea at half dose of recommended N. Application of half dose of recommended N as CRN registered 49 percent higher yield than the control, 27 percent more yield than the application of same recommended dose (50 percent) of fertilizer as prilled urea and 12 percent higher yield than application of 100 percent N as prilled urea. The observed higher grain yield under CRN application may be because of the steady and slow release of N from CRN synchronized with crop demand.

Water Productivity

SRI recorded higher water productivity of 0.699 kg/m^3 (Figure1), three times higher than that the conventional rice cultivation (0.253 kg/m^3). With respect to N management practices, application of 100 percent recommended N as CRN registered higher water productivity of 0.575 kg/m^3 (Figure 2), which was 60 percent more than the control, 18 percent higher than 100 percent N as prilled urea and 7 percent more than half dose of CRN (0.536 kg/m^3). Among the combinations, SRI with 100 percent recommended N as CRN registered the maximum water productivity of 0.836 kg/m^3, which accounts 60 percent higher water productivity than the control under SRI followed by half the dose of CRN (0.782 kg/m^3), full dose of urea (0.723 kg/m3) and half the dose of urea (0.632 kg/m3). Among the interaction

Figure 1. Water Productivity as Influenced by Transplanting Method

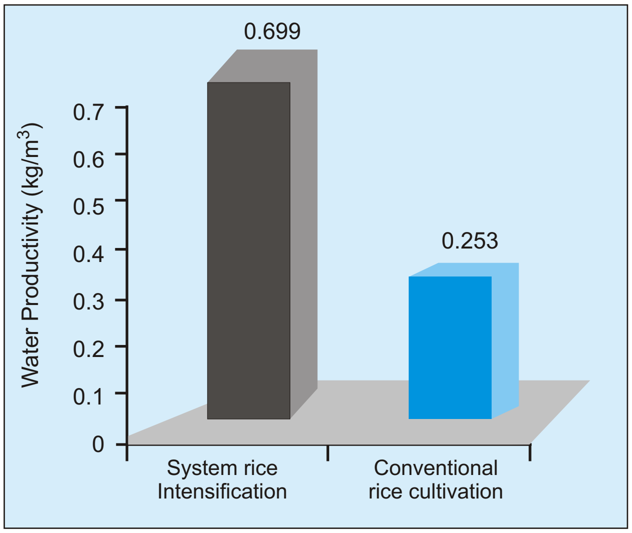
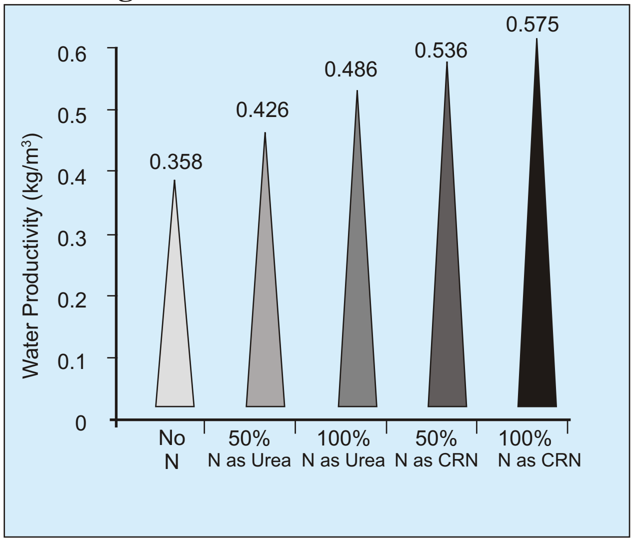


Figure 2. Water Productivity as Influenced by N Management



between conventional rice cultivation and N management, the levels (50 and 100 percent N) under each source of fertilizers were at par with each other.

Nitrogen Use Efficiencies

Among the different combinations, SRI with 100 percent recommended dose of nitrogen registered the maximum water productivity of 0.836kg per cubic metre.

Nitrogen use efficiency (NUE) of rice cropping systems must be improved along with yield potential of rice cultivars in order to improve profitability of rice production and prevent environmental degradation in irrigated areas. N use efficiency has been assessed through partial factor productivity, agronomic efficiency, physiological efficiency, and recovery efficiency.

Partial factor productivity (PFP)

PFP is a ratio of total grain yield to total amount of N applied per unit area. PFP for applied N is a useful measure of NUE because it provides an integrated index that quantifies total economic output relative to utilization of N in the system, including inherent soil N supply and applied N. PFP reflects both agronomic efficiency (AE) and the balance between indigenous soil N supply and applied N.

PFP of applied nitrogen was more under SRI (50.8 kg/kg N) than the conventional method of cultivation (39.5 kg/kg N). Among the two sources of fertilizers, CRN resulted an higher PFP than prilled urea application in both methods of cultivation. However, PFP decreased with increasing level of applied N as CRN and prilled urea application. Under SRI, application of 50 percent N as CRN led to higher PFP of 71.7 kg /kg N than the application of 50 percent N as prilled urea (57.9 kg/kg N and application of 100 percent N as CRN (40.4 kg/kg N) and prilled urea (33.1 kg/kg N). In the conventional method of cultivation the same trend noticed as in SRI. The least PFP value of 25.0 and 33.1 kg/kg N were recorded with application of 100 percent N as prilled urea in conventional and SRI method of cultivation respectively. Higher PFP of 50 percent N as CRN in both methods could be attributed to more nutrient uptake attributed by higher root growth leading to more number of panicles/m^2 and number of grains/panicle and grain yield. Increasing the level of N led to decline in PFP (Figure 3).

Agronomic efficiency (AE)

Agronomic efficiency is measured in terms of ratio between incremental grain yield owing to N applied plot compared to control plot and amount of N applied per unit area. AE represents the product of physiological efficiency (PE) with which the crop utilizes the acquired N to produce

Figure 3. Partial Factor Productivity as Influenced by N Management

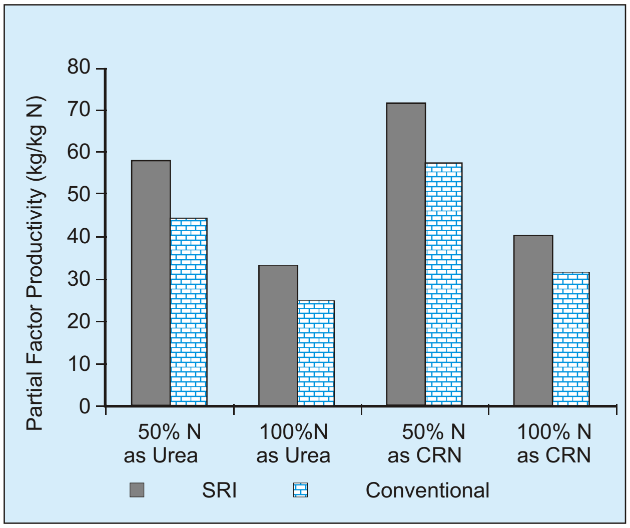
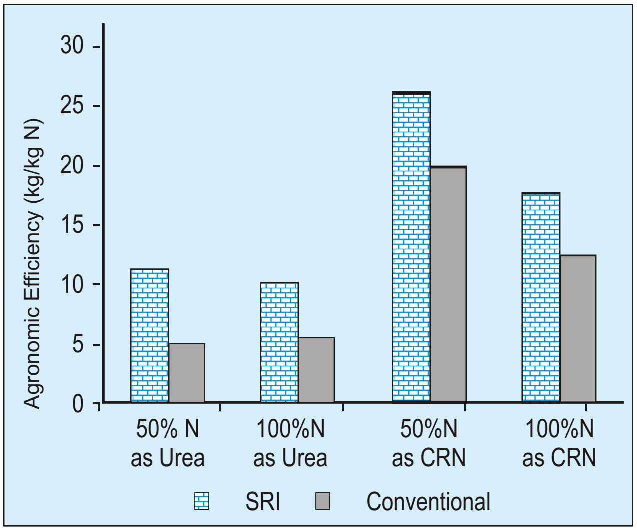


Fig. 4. Agronomic Efficiency as Influenced by N management



more grain and the recovery efficiency (RE) of applied N. The amount of N absorbed by the rice plant to produce more rice is physiological efficiency (PE), which is measured in terms of the ration between incremental gain yields for N applied plot compared to control plot and increase in crop N uptake that results from N application per unit area. The fraction of applied N that is absorbed by a crop is expressed as apparent N recovery efficiency (RE). It is measured in terms of the ratio between incremental crop N uptake for N applied plot to control plot and total amount of N applied per unit area.

Physiological Efficiency

Environmental stresses are important determinants of the apportioning of crop dry matter production between grain, straw, and roots and affect physiological efficiency (PE). They are also determined by plant genotype related characters. Physiological efficiency varied from 35.3 to 45.7 kg/kg N and 23.1 to 38.2 kg/kg N under SRI and conventional method of cultivation respectively and the mean value was higher for SRI (41.1 kg/kg N) than conventional rice cultivation [32.5 kg/kg N]. Application of CRN at 50 percent N and prilled urea at 100 percent N registered an almost equal PE in both methods of cultivation. PE increased with increase in the dose of prilled urea application and decreased with increase in level of CRN application under both methods of cultivation.

The increased PE under SRI (Figure 5) is attributed to the effect of changed management practices on the growth of the crop as well as nutrient dynamics in the soil leading to more grain yield. The observed increase in PE with increased in the dose of prilled urea application was mainly because of quick dissolution of fertilizer and the decrease with increase in CRN application was because of slow release of the fertilizer under irrigated rice.

Recovery Efficiency (RE)

The redistribution of N from roots to shoots will influence the recovery since only N uptake in the aerial portion of the crop is considered. Recovery efficiency (RE) was higher under SRI (37.6 percent) than the conventional method of cultivation (30.3 percent). RE decreased with increase in dosage of N either as prilled urea or CRN. This could be because of improved timing of reaction and formulation of applied N. However, CRN showed higher RE than prilled urea. Application of 50 percent N as CRN recorded more recovery efficiency (54.8 and 49.1 percent in SRI and conventional method respectively) than the application of 100 percent N as CRN (47.5 and 37.2 percent in SRI and

Figure 5. Physiological Efficiency as Influenced by N management

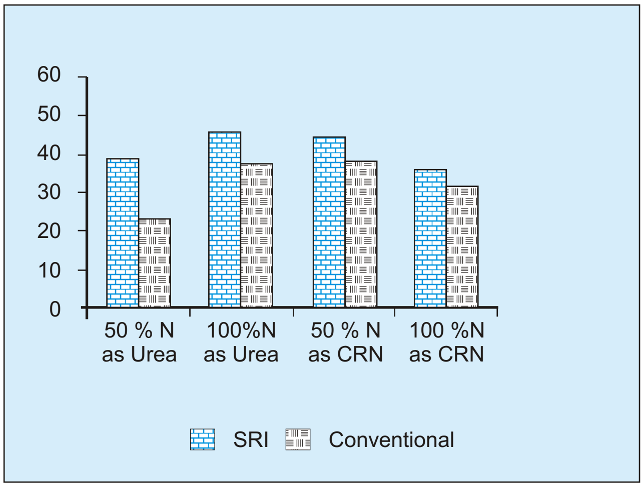
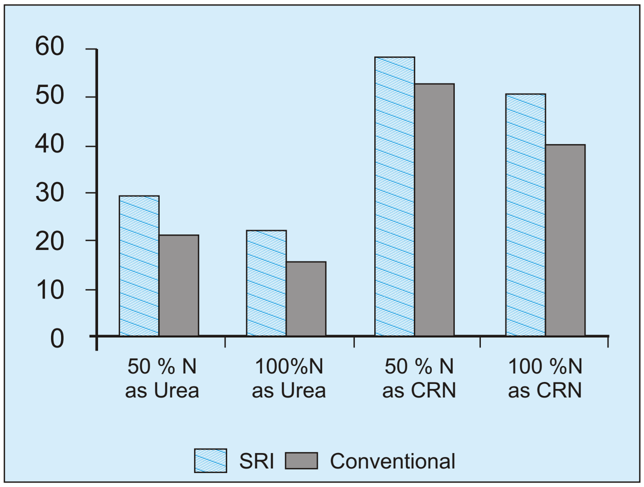


Figure 6. Recovery Efficiency (percent) as Influenced by N management



conventional method respectively). RE was higher under SRI than the conventional method of cultivation (Figure 6). This could be attributed to more N uptake evidenced from higher SPAD reading and chlorophyll content facilitated by the specific changes in management.

Agronomic efficiency ranged from 9.5 to 24.4 kg/kg N and from 4.7 to 18.8 kg/kg N under SRI and conventional method of cultivation respectively. Irrespective of N applied, the AE was more under SRI [15.3 kg/kg N] than the conventional method of cultivation [10.2 kg/kg N]. Higher dose of fertilizer application either as CRN or prilled urea resulted in lower AE in both methods of rice cultivation. However, application of 50 percent N as CRN led to higher AE under both SRI [24.4 kg/kg N] and conventional methods of cultivation [18.8 kg/kg N] The AE decreased with increase in N application as CRN and prilled urea and in both methods of cultivation (Figure 4).

Application of same quantity of N leads to higher grain yield in SRI

Conclusion

SRI significantly recorded higher grain yield and higher water productivity over the conventional method rice cultivation. In fact, water productivity was three times higher than conventional rice cultivation. Application of same quantity of N leads to higher grain yield in SRI. Nitrogen use efficiency is higher in SRI. Application of 100 percent recommended N as CRN application increased grain yield, water productivity and N use efficiency besides reducing groundwater pollution. By using lesser amount of nitrogen and water, SRI has potential to produce more output. Reduced application of precious inputs such as water and nitrogen will have great economic impact on farmers.

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IWMI-Tata Water Policy Program

The IWMI-Tata Water Policy Program was launched in 2000 with the support of Sir Ratan Tata Trust, Mumbai. The program presents new perspectives and practical solutions derived from the wealth of research done in India on water resource management. Its objective is to help policy makers at the central, state and local levels address their water challenges – in areas such as sustainable groundwater management, water scarcity, and rural poverty – by translating research findings into practical policy recommendations.

Through this program, IWMI collaborates with a range of partners across India to identify, analyse and document relevant water-management approaches and current practices. These practices are assessed and synthesised for maximum policy impact in the series on Water Policy Research Highlights and IWMI-Tata Comments.

The policy program's website promotes the exchange of knowledge on water-resources management, within the research community and between researchers and policy makers in India.

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