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Integrated nitrogen management in rice (*Oryza sativa*) under system rice intensification

S SARAVANAKUMAR

ICAR – Krishi Vigyan Kendra, MYRADA, Erode, Tamil Nadu 638 453, India

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ABSTRACT

Rice (*Oryza sativa* L.) is the most important food crop cultivated in India with the average productivity of 2.9 t/ha. Rice has the largest yield potential crop which is to be tapped with sound management technologies like appropriate nutrient management techniques along with adoption of system rice intensification. To sustain present food sufficiency and to meet future food requirements, India has to realize an annual growth rate of at least 3% in productivity of rice. To maintain the nutritional standards, fertilizer nutrients should be applied in balanced and required proportion. Among the different nutritional elements, nitrogen (N) has received prime attention both by the farmers and researchers. Relationship among the growth, yield and nitrogen utilization in rice are becoming increasingly understood at the physiological and molecular level. Moreover, time and method of nitrogen application play a crucial role in increasing efficiency of fertilizers as well as the productivity of rice. This review paper attempts to document the different sources of nitrogen and its effect on growth and productivity of rice under system rice intensification

Key words: Nitrogen nutrition, Rice, Split application, System rice intensification

Rice (*Oryza sativa* L.) is one of the world's most important crops. The great challenge being faced today is to ensure that rice production keeps pace with the burgeoning population. In India, enhanced rice production is needed not only for food security but also for the livelihood of millions of small and marginal farmers and landless labourers' families. To sustain present food sufficiency and to meet future food requirements, India has to realize an annual growth rate of at least 3% in productivity of rice. Considering the future food requirements, new methods of rice cultivation must be identified and tested to increase water and crop productivity. The System of Rice Intensification (SRI) a method of rice cultivation developed at Madagascar in 1980's has been reported to increase grain yields of rice and save irrigation water based on the synergistic effects of adopting various cultivation practices simultaneously.

The effectiveness of nitrogen management practice can depend on season, soil type, climate, water management, rice variety and cropping pattern. There will probably be no universal best nitrogen management practice. Thus, more efforts are needed to identify improved nitrogen management strategy for a particular target environment. Improvement in nitrogen management could involve alternate N timing and rates and integration of organic and inorganic fertilizers (Yadav *et al.* 2006 and Pramanik *et al.* 1997).

The influence of 'Time of nitrogen application' on crop growth and grain yield is reported by many authors and attempts have been made to quantitatively describe the effect (Mendhe *et al*. 2006). Supplying N as and when the crop required is of paramount importance in increasing the use efficiency. The influence of different timing of N application on grain yield in relation to N uptake and utilization and related parameters are to be identified. Besides, seasonal influence on the rate and timing of N application need to be studied using the recently introduced N management approaches if leaf colour chart N application (Dobermann *et al.* 2004 and Gines *et al*. 2004).

Role of Azospirillum in rice nutrition

Azospirillum is being increasingly used in rice cultivation from the last decade. Their potential for fixation of atmospheric N enabled their use as a supplement or partial substitute for inorganic nitrogenous fertilizer in many countries.

Biofertilizers are of recent origin and are successfully applied to the crop plants to enhance the yield (Anandkumar *et al*. 1997). Atmosphere has 78% nitrogen and 88000 tonnes of N in every hectare of land the world over. Earth can support billions of bacteria that can trap the atmospheric nitrogen from the air and put into available form so that the plant can use it. Patel (2000) reported that use of biofertilizer, being an exploitation of renewable source of energy, is to be encouraged when the whole world is facing an energy crisis.

*Corresponding author e-mail: agrisarwan@gmail.com

Azospirillum forms an associative symbiosis with many plants particularly with those having the C_4 decarboxylic acid pathway of photosynthesis. They grow and fix nitrogen salts of organic acids such as malate, succinate, pyruvate and lactate. *Azospirillum* is applied as seed treatment and soil application in many crops (Anandkumar *et al*. 1997).

Effect of Azospirillum on rice growth and productivity

Growth promotion by *Azospirillum* is due to its capability to produce plant growth promoting substances. It stimulates the density and length of root hairs, rate of appearance of lateral roots and root surface area. The chlorophyll content was also enhanced due to *Azospirillum* inoculation.

The combination of seed + root + soil treatment of *Azospirillum* significantly increased the plant height. According to Shanmugam and Veeraputhran (2000) combined application of green manure and *Azospirillum* produced significantly taller plants, more tillers/m^2, higher Leaf Area Index and dry matter production at harvest.

The application of *Azospirillum* alone recorded a grain yield of 5.03 t/ha, which was 19.2% higher than the uninoculated plots (Gopalswamy and Anthoni Raj 1997). *Azospirillum* application recorded significantly more panicles per hill, test weight, filled grains /panicle and grain yield (Manjappa 2001).

Green manuring in rice

Green manure is an age-old practice and refers to addition of green plant tissue to soil for increasing soil fertility. It is an inexpensive, eco-friendly alternative to mounting prices for fertilizer nitrogen and has become an effective technology in economizing the agricultural production system, ensuring productive capacity of soil without causing any environmental problem (Bana and Pant 2000). Among the organic manures, green manure (*Sesbania aculeata*) performed better in maintaining soil fertility status (Saravanapandian and Raniperumal 2000).

Sesbania aculeata and *Sesbania rostrata* are the most promising species. *Daincha* is the fast-growing crop and produces a green matter of 2.0 t/ha within 45 days. Among *Sesbania* species *Sesbania aculeata* recorded higher biomass on 40 DAS and *Sesbania rostrata* on 60 DAS (Kalidurai 1998). Among the green manure crops, *daincha* accumulated largest amount of biomass (26.3 t/ha) followed by *Sesbania rostrata* (24.9 t/ha), but in terms of N contribution both were comparable in yield 145 and 146 kg/ha N, respectively.

Saravanapandian and Raniperumal (2000) reported that, conjoint addition of green manure with fertilizer N improved the status of available N, organic carbon, NH_4-N, Olsen-P and NH_4OAc-K in soil. Enhanced level of organic carbon might be due to later stages of decomposition. Kalidurai (1998) observed that the green manure (*Sesbania aculeata*) undergoes slow decomposition and mineralization may help in the release of N to meet the requirement of rice crop at the critical stages as per the need of the crop.

S*esbania* green manure alone was capable of producing and sustaining more than 6 t/ha of rice yield, equal to more than 100 kg inorganic nitrogen was reported by Pandey *et al.* (1995). Green manure with about 60 kg fertilizer N boosted rice yield to 6.8 t/ha. A significant increase in plant height, number of effective panicles and grain weight per panicle, grain and straw yield was observed with the integrated application of green manure with fertilizer N over full dose of fertilizer N alone (Rajnirani and Srivastava 2001).

Nitrogen nutrition to rice

The response of rice genotypes to nitrogen application has been undoubtedly established. Supply of N is probably the most important factor for increased rice production.

It imparts dark green colour to plants,

It promotes rapid root growth, increase height and tillers, the latter being particularly important to increase grain yield.

It increases the size of the leaves and grains.

It increases the protein content in the grains.

The modern dwarf rice varieties are much more N responsive and lodging resistant than conventional varieties.

Split application of nitrogen

Basal application of N was not essential for transplanted rice on the mollisol if the crop is adequately fertilized at tillering and PI stage. Similarly, when N supply to rice crop was delayed up to 16 days after transplanting, higher grain yield was obtained due to increased tiller production and leaf N content (Thiyagarajan *et al*. 1994).

Many workers opined that application of N in two splits either on equal basis or vice versa (basal and tillering or basal and panicle initiation stages) resulted in comparable or better performance of growth and yield as compared to single or more number of splits in different parts of the country (Asif *et al*. 1999, Reddy and Kumar 1999).

Field experiment conducted at Madurai during the *kharif* season in hybrid rice CORH1 recorded higher plant height and number of tillers with three splits as basal, AT, PI at 150 kg N/ha, however, maximum number of spikelets and filled grains were observed in 200 kg N/ha applied at equal splits. This treatment also produced the higher grain yield but was comparable with three splits at lower dose of N (Thiyagarajan *et al*. 1994).

Fractional application increased the grain yield mainly due to continuous availability of N during the entire growth period. Application of N at three equal splits at basal, AT, PI helped in better production and sustenance of rice (Mendhe *et al*. 2006). Application of N in four splits at basal, AT, PI and panicle development stage was reported by IRRI.

Application of *daincha* at 6.25 t/ha plus 100 kg N/ha in four equal splits at basal, 21 DAT, panicle initiation, and first flowering to rice gave higher grain yield (7210 kg/ha) and straw yield (8.1 t/ha). It also influences growth and yield attributes such as plant height, total dry matter production, productive tillers, number of filled grains and 1000 grain weight (Parasuraman 2005).

Critical growth stages of rice crop and N supply

Fertilizer N should be applied at times that are compatible with the stage of development of the crops that permits higher recovery which will ensure adequate sink (panicles and spikelets) and source (leaves and stems). Inadequate N supply at any critical or physiological stages may retard the growth and yield of rice under system rice intensification techniques. N should be applied in suitable fractions to synchronize with the stages of vigorous absorption and efficient N assimilation by the plant for grain production. Split application needed to be phased at transplanting, maximum tillering and panicle initiation to correspond to the need of rice (Parasuraman 2005). The similar findings were also noticed by Anandhakrishnaveni *et al*. (2001) in the system rice intensification.

N supply during vegetative period

The postponing of first dose of N application until PI had no significant effect on grain yield (Thiyagarajan *et al*. 1994). This was also indicated by the capacity of the soil to maintain the time course of sufficient leaf N concentration. They showed that the first N application could be delayed to the time up to which native soil N supply could maintain the leaf N concentration. Studies in Japan indicated that a controlled amount of basal N followed by a large amount of top-dressed N gave better results than traditional method and N application focused on the latter half of growing period had resulted in an average yield of more than 4.5 t/ha.

N supply at panicle initiation

Application of 100 kg N/ha at PI increased the grain yield of variety CR 1009 which received different amount at 10 DAT and the crop N uptake was very low at PI (Thiyagarajan *et al*. 1994). Application of 80 kg N/ha in five splits, i.e. 20 percent each at basal, 15 DAT, tillering initiation, maximum tillering, and panicle initiation stages proved the best in terms of productivity and net returns of scented rice (Shekhar *et al*. 2004). The dry matter produced and the grain yield were found to be strongly correlated with the average crop N status from PI to flowering and the number of spikelets per unit area was strongly related to the increase in total crop weight during this period which indicated the importance of N application at PI stage.

N supply after PI

Controlling the supply of N during initial growth stages and following with the application of large amount of N as top dressing in the reproductive phases bring higher yield than the recommended split application in the system rice instensification techniques, the crop produces more number of tillers which requires N sources during the ripening stages for improving productivity (Pandey *et al*. 1997). N application during ripening period was more beneficial for yield and the effects fluctuated from variety to variety.

Effect of split application of N on growth characters

Split application of N maintained higher leaf area and leaf duration thus contributing to the growth and development of the plants improved by increased photosynthetic activity. Vaiyapuri *et al*. (1998) reported that addition of 100 kg N/ha in three splits resulted an increased in dry matter accumulation with 200 kg N/ha in hybrid rice. Kavitha (2001) observed that the plant height, number of tillers, Leaf Area Index, Dry matter production were higher in three equal splits at AT stage, but during later stages the four equal split application of N and K at AT, PI, post panicle initiation and flowering recorded higher growth attributes under system rice intensification techniques.

Effect of split application on yield components and yield

The application of 200 kg N/ha in hybrid rice in three equal splits produce more productive tillers, filled grain percentage and 1000 grain weight (Venkitaswamy *et al*. 1997). Yield increase was higher when N was applied as four splits. Similar yield differences were reported in hybrid rice. Application of 200 kg N/ha in four splits at basal, AT, PI and panicle emergence recorded higher grain yield in CORH-1 which was comparable with the application of 150 kg N in three splits at basal, AT and PI. Dheebakaran and Ramasamy (1999) reported that for medium duration rice variety, N may be applied into five split doses at 40 kg basal, 20 kg AT, 20 kg seven days after AT, 20 kg PI and 20 kg heading stages significantly increase the productive tillers, panicle efficiency, 1000 grain weight, Harvest Index and grain yield (6486 kg/ha) in clay.

The recommended N + K in four splits, i.e. 16.7% at 7 DAT, 33.3% at 21 DAT, 33.3% at 55 DAT, 16.7% at 65 DAT registered the higher grain yield of 4.5% over the existing practice of three splits (Anandhakrishnaveni *et al*. 2001). Applying 16.7% of recommended N levels as basal followed by 33.3% N at 10 DAT, 25% N at 20 DAT and 25% N at 40 DAT was found to be significantly superior than all the other treatments tried and recorded higher grain yields and N use efficiency (Angayarkanni and Ravichandran 2001).

Economics

Integrating organic sources with inorganic nitrogen minimized the fertilizer N cost by 50% with green manure and 42% with FYM. Dobermann *et al.* (2004) and Gines *et al*. (2004) pointed out that basal application of 7.5 t/ha of green manure with 25 kg urea N/ha was at par with 100 kg N/ha in terms of yield under system rice instensification. Cost of cultivation, gross return, net return, benefit: cost ratio of the integrated nutrient management treatment was comparable with those of the recommended dose and there was a saving of 75 kg urea N/ha. Considering the maximum grain and straw yields and the highest benefit: cost ratio, 50% N through organic and 50% N through inorganic means is the best treatment (Balasubramanian and Veerabadran 1997).

Strategies for promoting INM in system rice intensification

Rice is the second most important food crop cultivated in India. The productivity of rice crop in India is only 2.9 t/ha, but there is a huge potential for improving the productivity of rice by adopting system rice intensification techniques with appropriate N management practices. Emphasis should be given on application of organic and inorganic sources of nutrients and split doses for improving the rice productivity.

The knowledge level of extension officials working in the line departments should be improved through adequate training and frontline demonstration programmes. This would ensure the wider dissemination among the farming community. Progressive farmers at panchayat level should be trained on various aspects of nutrient management techniques and its effect on rice productivity under system rice intensification method.

REFERENCES

Anandhakrishnaveni S, Balasubramanian R and Badmaja P. 2001. Efficient nutrient management for late *rabi* rice. *Madras Agricultural Journal* **88**(7-9): 469–72.

Anandkumar S, Nandini N and M D Yassin. 1997. Ecofriendly alternative and organic approach. *KISAN WORLD*: 54–6.

Angayarkanni A and M Ravichandran. 2001. Judicious fertilizer N split for higher use efficiency in transplanted rice. *Indian Journal of Agricultural Research* **35**(4): 278–80.

Asif M, Chaudhary F M and Saeed M. 1999. Influence of NPK levels and split N application on grain filling and yield of fine rice. *International Rice Research Notes* **24**(1): 30–1.

Balasubramanian R and Veerabadran V. 1997. Substitution of inorganic nitrogen through local green leaf manure and azospirillum in rice. *Indian Journal of Agronomy* **42**(2): 285–7.

Bana O P S and Pant A K. 2000. Green manure for ecologically sound crop production. *Indian Farmers Digest*. 19–20.

Dheebakaran G and Ramasamy S. 1999. Source and time of splits of nitrogen on N uptake and its efficiency on irrigated lowland rice. *Madras Agricultural Journal* **86**(7-9): 429–31.

Dobermann A S, Abdulrahman H C, Gines Nagarajan R, Satawathananont S, Wang G H Simbahan G C, Adviento M A A and Witt C. 2004. *Agronomic performance of site-specific nutrient management in intensive rice-cropping systems of Asia*, pp. 307–36. Science Publishers, Enfield, NH, and IRRI, Los Banos, Philippines.

Gines H C Redondo G O Estogoy A P and Dobermann. 2004. Site-specific nutrient management for irrigated rice systems of central Luzon, Philippines. *Increasing productivity of intensive rice systems through site-specific nutrient management*, pp. 145-170. Dobermann A (Eds). Science publishers, Enfield, NH, and IRRI, Los Banos, Philippines.

Gopalswamy G and Anthoni Raj S. 1997. Partial substitution of nitrogen through combined application of biofertilizers in rice. *Madras Agricultural Journal* **84**(2): 68–70.

Kalidurai M. 1998. Nitrogen fixation and mineralization of *Sesbania rostrata* in rice soil ecosystem. *Annals of Agricultural Research* **19**(4): 365–9.

Kavitha M. 2001. 'Studies on nitrogen and potassium management in maximizing the productivity'. M Sc. Thesis. Tamil Nadu Agricultural University, Coimbatore.

Manjappa K. 2001. Effect of *Azospirillum* at different levels of nitrogen on yield of rainfed transplanted rice (*Oryza sativa*). *Indian Journal of Agronomy* **46**(4): 643–7.

Mendhe J T Mankar P S Khawale V S Jarande and Kanase A A. 2006. Effect of briquette, inorganic fertilizers and organic manure fertilization on the growth and yield of paddy. *Journal for Soil and Crops* **16**(1): 232–5.

Pandey P C Bisht P S and Lal P. 1995. Green manure: a suitable for inorganic fertilizer nitrogen in lowland rice. *International Rice Research Notes* **20**(1): 22–3.

Parasuraman P. 2005. Integrated nitrogen management in rice (*Oryza sativa* L.) through split application of fertilizers at different levels with green manure. *Mysore Journal of Agricultural Sciences* **39**(1): 90–4.

Patel J R. 2000. Effect of water regime, variety and blue green algae on rice (*Oryza sativa*). *Indian Journal of Agronomy* **45**(1): 103–6.

Pramanik S C and Mahapatra B S. 1997. Effect of integrated use of inorganic and organic nitrogen sources on mineralization, uptake and grain yield of rice. *Oryza* **34**: 181–4.

Rajnirani and Srivastava O P. 2001. Effect of integration of organics with fertilizer N on rice yield and N uptake. *Fertilizer News* **46**(9): 63–5.

Reddy and Kumar M D K A. 1999. Effect of levels and timing of N application on performance of late puddle seeded rice (*Oryza sativa* L.). *Indian Journal of Agronomy* **44**(2): 297–300.

Saravanapandian P and Raniperumal. 2000. Effect of integrated nitrogen management on soil fertility status of rice soil. *Madras Agricultural Journal* **87**(4-6): 217–22.

Shanmugam P M. and Veeraputhran R. 2000. Effect of organic manure, biofertilizers, inorganic nitrogen and zinc on growth and yield of rabi rice (*Oryza sativa* L.). *Madras Agricultural Journal* **87**(1-3): 90–2.

Shekhar C, Khajanji S N and Shrivastava G K. 2004. Effect of seedling age and split application of nitrogen on production of scented rice (*Oryza sativa* L). *Journal of Agricultural Issues* **9**(1&2): 105-107.

Thiyagarajan T M Sivasamy R and Ten Berge H F M. 1994. Time course of leaf N concentration required to attain target yields in transplanted rice. (*In*) *N Economy in Irrigated rice: Field and Simulation Studies*. TenBerge H F M, Woperies M C S and Shin J C (Eds). *SARP Res. Proc*. A.B/ DLO, Wageningen, The Netherlands.

Vaiyapuri V Ravichandran M and Srirama Chandra Sekharan M V. 1998. Effect of graded levels of *Sesbania speciosa* with time of N application on growth and yield in rice-rice sequence. *Annals of Agricultural Research* **19**(1): 1–3.

Venkitaswamy R C Sridaran S Madhiyazhagan R and Prabahakaran N K. 1997. Split application of N and K to MGR hybrid rice of CORH-1. *Madras Agricultural Journal* **84**(1): 44–5.

Yadav B K and Christopher Lourduraj A. 2006. Effect of organic manures and panchagavya spray on rice (*Oryza sativa* L.) quality. *Crop Research* **31**(1): 6–10.