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A REVIEW

Sustainable nitrogen management in rice based cropping system

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Currently used management practices which are over dependent on mineral fertilizers do not provide a good balance between soil nutrient supply, crop requirements, deteriorating the sustainable soil fertility and health on long term basis. Continuous use of fertilizers, ignoring organic sources would lead to gradual decline of organic matter content and native fertility status in the soil, which in turn reflects on the productivity of rice crop. From the sustainability point of view, alternatives have to be found out to increase the nitrogen utilization efficiency without hindering the productive capacity of rice soils. In the face of the continuing global energy crisis and progressively prohibitive cost of fertilizer nitrogen, there is renewed interest towards sustainable low cost alternatives like organic manures. Farmyard manure was considered as nutrient rich renewable source to substitute partially the fertilizer nitrogen. Instead of using higher than recommended dose of nitrogen exclusively through fertilizer, a strategy of integrated use of recommended dose of nitrogen through fertilizer in combination with any amount of cheaper organic source, which is abundantly available locally should be tried to satisfy the higher nitrogen requirement of rice crop, to produce higher yield, without impairing soil health.

Organic manures, which can supply a portion of the P and K along with the secondary and micronutrients required by crops, can help offset the negative nutrient balances and slow down nutrient depletion processes. Hence, an integrated nutrient management approach seems appropriate for sustained crop production, which involves meeting a part of nutrient needs of crop through crop residues and other organic manurial sources along with mineral fertilizers for the crops under highly intensive cropping system.

The version of crop residue incorporation is beneficial depending upon the farming situation. Grain legumes, in contrast with green manures, provide grain to augment income and protein as well as reduce the use of mineral nitrogen in rice-based cropping systems. In areas, where clear cut fallow of a short duration is available preceding the transplanted low land rice crop, crops like greengram, cluster bean, fieldbean and cowpea can be raised as preceding crops to rice and after the harvest of the saleable yield, the left over crop residues

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of these crops can be incorporated prior to transplanting of succeeding rice. The practice of crop residue incorporation after pod harvest is feasible and economical, where a period of 45 to 60 days is available before planting of rice and this can contribute about 50 to 60 kg N ha^{-1} to the succeeding rice crop.

Organic manures and crop residues have been proved to be viable components of nitrogen management, which can supplement and successfully replace costly fertilizer nitrogen. Therefore, literature pertaining to the effect of incorporation of preceding crop residues, farmyard manure, inorganic nitrogen fertilizer, conjunctive use of organic and inorganic sources of nitrogen on growth, yield attributes, yield and nutrient uptake of rice is reviewed here under.

Effect of incorporation of preceding crop residues on growth parameters, yield attributes and yield of low land rice :

Cowpea green manure accumulated an average 68 kg N ha^{-1} and above ground residue after harvest of pods contained an average 46 kg N $ha^{-1}$and when incorporated, resulted in increased number of panicles m^{-2}, filled spikelets $panicle^{-1}$ and yield of rice by 7 q ha^{-1} over pre-rice fallow (John *et al.*, 1992). Yadavkumar *et al.* (1992) found that incorporation of greengram haulms after picking of pods resulted in about 6.5 q ha^{-1} higher grain yield of rice compared to pre-rice fallow. Incorporation of residues of preceding blackgram significantly improved the yield attributes and yield of rice such as number of panicles m^{-2}, panicle length, number of grains $panicle^{-1}$, 1000 grain weight and grain yield (Quayyum and Maniruzzaman, 1996). Significant increase in grain yield of rice was observed by Bal *et al.* (1997) with the application of 5 tonnes of glyricidia per hectare. Narayana Reddy and Surekha (2000) recorded increase in grain yield of rice over fallow due to incorporation of preceding greengram crop residues. Incorporation of preceding greengram crop residues after one picking produced higher grain yield of rice (Singh *et al.*, 2001). Addition of mungbean haulms after one picking of pods produced significantly higher plant height, number of leaves, LAI, number of tillers and drymatter accumulation of succeeding rice (Singh *et al.*, 2001). Mungbean residues incorporated into the soil significantly increased plant height and tiller number per hill but had no significant effect on succeeding rice crop. Application of different rates of cattle manure significantly affected plant height at PI and harvest. Grain yield of rice was not significantly affected by pre-rice management. However, incorporation of mungbean residues produced an increase in rice grain yield over fallow treatment. Incorporation of mungbean significantly increased panicle number per hill. Incorporation of mungbean residue and application of cattle manure produced the maximum panicle number per hill (Anan polthanee *et al.*, 2012).

Effect of incorporation of preceding crop residues on nutrient uptake :

Bhandari *et al.* (1992) reported that incorporation of mungbean haulms after picking the pods resulted in similar uptake of N, P and K by rice as recorded with 100 per cent fertilizer. Cowpea, as green manure and crop residue increased the total above ground N content of rice by 12 and 14 kg ha^{-1}, respectively (John *et al.*, 1992).

Effect of incorporation of preceding crop residues on post harvest soil fertility status :

Post harvest soil nutrient status after rice was found relatively lesser with the incorporation of preceding crop residues of cowpea and greengram than with dhaincha or sunhemp green manuring (Buresh and De Datta, 1991). Burying of fresh mungbean haulms after final picking of pods increased the organic carbon status of the soil over their initial values (Bhandari *et al.*, 1992).

Significance of organics in low land rice :

Application of organic materials influenced the growth of rice directly by providing nutrients (Palaniappan and Balasubramanian, 1991) and stimulating the microbial activity (Kukreja *et al.*, 1991). The significance of native soil N was apparent from the fact that 60 to 80 per cent of N (Manguiat *et al.*, 1994; Ponnamperuma and Detruck, 1993) absorbed by the low land rice crop would be derived from native soil N pool. Nitrogen in soils is mostly present in organic form in organic matter and in most of the soils it is 59-95 per cent (Srivastava and Singh, 1996).

Effect of farm yard manure (FYM) on growth parameters, yield attributes and yield of lowland rice :

Application of poultry manure resulted in higher filled grains $panicle^{-1}$ and test weight of rice grains over application FYM @ 5 t ha^{-1} (Budhar *et al.*, 1991). Rajput and Warsi (1991) concluded that application of FYM with and without inorganic N significantly increased tillers $hill^{-1}$. Being at par with the application of glyricidia leaf manure @ 5 t ha^{-1}, application of FYM @ 5 t ha^{-1} to rice significantly increased the plant height and drymatter production over control (Dalapathy *et al.*, 1993). Reddy (1996) noticed that the plant height, number of tillers m^{-2}, drymatter production, productive tillers m^{-2}, filled grains $panicle^{-1}$ and 1000-grain weight of rice were higher with FYM application compared to neem cake @ 120 kg N ha^{-1}. Singh *et al.* (1996) found that the panicle length and grains $panicle^{-1}$ were significantly increased with level of FYM from 0 to 20 t ha^{-1} but the increase was not significant beyond 10 t ha^{-1}. Significantly higher number of panicles $hill^{-1}$, panicle length, number of filled grains $panicle^{-1}$, 1000-grain weight, grain and straw yields were noticed with the application of FYM @ 5 t ha^{-1} than control, but was inferior to glyricidia leaf manure applied at the same rate (Bal *et al.*,1997). Dubey and Verma (1999) observed significantly higher grain and straw yields when entire N was supplied through FYM compared to control and was at par with entire N supplied through either poultry manure or glyricidia leaf manure. Application of FYM @ 10 t ha^{-1} and blue green algae (BGA) inoculation either alone or in combination, increased the grain yield of rice. The average increase in grain yield with the combined use of FYM and BGA was 6 q ha^{-1} (Dixit and Gupta, 2000). Incorporation of FYM along with fly ash at transplanting (3.6 t ha^{-1}) or 15 days before transplanting proved to be more effective in increasing grain yield than in the incorporation at 30 days before transplanting of rice (Karmakar *et al.*, 2006).

Effect of farm yard manure (FYM) on post harvest soil fertility status :

Budhar *et al.* (1991) observed that there was higher amount of residual N in plots treated with FYM or poultry manure or biogas slurry @ 5 t ha^{-1}. Dubey and Verma (1999) recorded higher soil organic carbon and available N when entire nitrogen was applied through FYM and it was at par with poultry manure and glyricidia leaf manure. Radha Madhav *et al.* (1999) revealed that the available nitrogen and phosphorus status of soil after harvest of rice was significantly higher with incorporation of FYM @ 120 kg N ha^{-1} compared to other organic sources like glyricidia and Ipomea leaf manures. Substitution of FYM to the fertilizer nitrogen @ 25 kg ha^{-1} (5 t ha^{-1} of FYM) has significantly increased the organic carbon content of the soil from 0.19 to 0.21 per cent (Saran Ram *et al.*, 2000). Application of 15 t FYM ha^{-1}significantly increased soil organic matter and available water holding capacity but decreased the soil bulk density, creating a good soil condition for enhanced growth of the rice crop (Tadesse *et al*., 2013).

Influence of inorganic nitrogen fertilizer on the performance of low land rice :

Increase in the level of nitrogen increased straw yield upto 120 kg N ha^{-1}, which was, however, in parity with 80 kg N ha^{-1}. Straw yield was increased by 54.3 per cent with 80 kg N ha^{-1} over control (Marazi *et al.*, 1993). Increased level of N from 0 to 150 kg ha^{-1} progressively augmented the drymatter production of rice (Raju *et al.*, 1993). Thakur (1993) reported significant increase in 1000-grain weight upto 80 kg N ha^{-1}, beyond which the increase was negligible. Increase in panicle number with increasing levels of nitrogen has been reported by a number of research works (Thakur, 1993 and Pandey *et al.*, 2001). Shanmugasundaram and Selvakumar (1993) observed that the level of N has significant effect on grain yield. Application of N @ 120 kg ha^{-1} recorded the highest grain yield, which was however, at par with 160 kg N ha^{-1}. LAI, number of tillers, length of panicle was found consistently increased with each successive increment of N levels from 0 to 150 kg N ha^{-1} (Shukla *et al.*, 1993).Gopal (1994) observed increase in plant height and tillering upto 140 kg N ha^{-1}, while the drymatter production increased significantly only upto 100 kg N ha^{-1}. LAI, number of tillers, length of panicle was found significant variation with increasing levels of nitrogen upto 80 kg N ha^{-1} beyond which there was no response (Prasad *et al.*, 1994). Saravana Pandian and Rani Perumal (1994) reported that the panicle number increased upto 150 kg N ha^{-1} and further increase did not bring any significant change. Application of nitrogen had noticeable effect on the number of filled grains per panicle, which increased significantly with increasing levels of nitrogen (Syed Nazeer Peeran and Sree Ramulu, 1995; Chander and Pandey, 1996 and Gupta, 1996). Yield components *viz.*, number of panicles m^{-2}, total number of grains, filled grains $panicle^{-1}$ and 1000-grain weight increased significantly even upto 200 kg N ha^{-1} (Budhar and Palaniappan, 1997). Plant height, drymatter production and grain yield of rice has significantly increased with increase in nitrogen level from 0 to 150 kg ha^{-1}, beyond this the improvement in these parameters was not noticeable except straw yield which significantly increased even upto 200 kg N ha^{-1}. Growth attributes *viz.*, biomass accumulation, LAI and tillering increased significantly upto 120 kg N ha^{-1} (Raju and Reddy, 1997).

Influence of inorganic nitrogen fertilizer on harvest index :

De *et al.* (1992) reported that the harvest index was significantly increased with increased levels of nitrogen. According to Dwivedi (1997), highest harvest index was recorded with 60 kg N ha^{-1}, which was at par with 90 kg N ha^{-1}.

Influence of inorganic nitrogen fertilizer on nutrient uptake :

Both N content and uptake increased significantly with increased N levels. The percentage increase in N uptake at 80 kg N ha^{-1} over 40 kg N ha^{-1} in grain was 65 and in straw it was 60 (Singandhupe and Rajput, 1990). Sreedevi and Thangamuthu (1991) reported highest uptake of nitrogen, phosphorus and potassium with the application of 120 kg N ha^{-1} in paddy. Upadhyay and Patel (1992) noticed that enhanced supply of N had significantly increased the N uptake by grain and straw. Nitrogen uptake was higher with 120 kg N ha^{-1} applied through urea (Hari Prasad, 1993). A gradual increase in uptake of nitrogen, phosphorus and potassium with increased supply of nitrogen has been reported from several studies (Thakur, 1993; Shukla and Sharma, 1994 and Shashi Kumar *et al.,* 1995).

Influence of conjunctive use of organic and inorganic sources of nitrogen on growth parameters :

Application of FYM along with inorganic nitrogen significantly increased tillers $hill^{-1}$ (Rajput and Warsi, 1991). Jose Mathew *et al.* (1994) found that application of FYM and green manure in combination with inorganic nitrogen at different proportions favoured vegetative growth in terms of plant height and tiller density. Reduction of mineral nitrogen to even 25 per cent did not adversely affect crop growth when combined with the application of 10 t ha^{-1} green manure. Sujathamma *et al.* (1996a) reported significantly taller plants, more number of tillers m^{-2}, larger LAI and higher dry matter production at different stages of rice with 100 per cent recommended dose of nitrogen through fertilizer being at par with the application of 25 per cent of recommended nitrogen through bio-agrorich compost and 75 per cent through inorganic fertilizer. Jadhav *et al.* (1997) reported significantly higher dry matter production of rice at harvest with 75 per cent of nitrogen through urea and 25 per cent of nitrogen through vermicompost.

Influence of conjunctive use of organic and inorganic sources of nitrogen on yield components :

Raju and Anand Reddy (1991) reported the highest panicle weight with application of 50 kg N ha^{-1} coupled with *Sesbania* @ 5 t ha^{-1}. Saravana Pandian and Rani Perumal (1994) recorded the highest number of productive tillers, filled grains $panicle^{-1}$ and 1000 grain weight with the application of mineral nitrogen in combination with green manure when compared to FYM or *Azospirillum* alone. Sharma and Sharma (1994) noticed that application of 30 kg N ha^{-1} through FYM along with 90 kg N ha^{-1} as urea resulted in more number of panicles m^{-2}, number of spikelets $panicle^{-1}$ and higher grain yield over other treatments. Syed Nazeer Peeran and Sreeramulu (1995) reported that combined application of fertilizer nitrogen and FYM or green manure and *Azospirillum* has significantly increased panicle production, panicle length, number of filled grains $panicle^{-1}$ and thousand grain weight. Application of 75 per cent of the recommended dose of N, P and K in conjunction with 10 t FYM ha^{-1} produced significantly higher number of panicles m^{-2}, total number of grains $panicle^{-1}$, filled grains $panicle^{-1}$ and more test weight in transplanted rice (Puste *et al.,* 1996). The effect of FYM, green leaf manure and BGA alone and in combination with given level of inorganic fertilizers was statistically at par on yield components of rice (Dutta and Bandyopadhyaya, 2003). The yield components of rice recorded with 25 per cent N either through green leaf manure (GLM) or farm yard manure + 100 per cent fertilizer nitrogen through urea were comparable and significantly superior to 100 per cent FN, 25 per cent N through FYM or GLM + 75 per cent N through urea (Malla Reddy *et al.*, 2003). Hossaen *et al.* (2011) reported that higher plant height, number of total tiller per hill, number of effective tillers per hill, panicle length, maximum number of total grain per plant, test weight, grain yield and straw yield were recorded with application of 70 per cent NPKS + 2.4 t poultry manure ha^{-1}. Mohanty *et al.* (2013) reported that application of 1/3rd recommended dose of N each through chemical fertilizer, FYM and *Azolla* registered the highest plant height and leaf area index in rice as compared to other treatment combinations. Higher yield components, grain and straw yield of rice were also achieved from the same treatment as compared to 100 per cent recommended dose of fertilizer and control. Tilahun Tadesse *et al*.

(2013) reported that LAI, CGR, NAR, the number of filled spikelets per panicle, N and P uptake, biomass yield and grain protein content as well as agrophysiological efficiency of N and P were significantly enhanced in response to increasing the rates of FYM and inorganic N and P fertilizers. Organic and inorganic manures in combination increased the plant height, fertile tillers per hill, number of grains per panicle, panicle length, number of panicles per hill, 1000-grain weight. Maximum number of fertile tillers per plant, number of panicles per hill, 1000- grain weight were recorded from the plots receiving poultry manure @ 10 t/ha in combination with 50 per cent of RDF (Muhammad Arif *et al*., 2014). Application of 50 per cent N through RDF + 50 per cent N through vermicompost recorded higher growth attributes like plant height, no. of tillers per plant, panicle length, grains per panicle, 1000-grain weight, grain yield and straw yield of rice (Dekhane *et al.*, 2014).

Influence of conjunctive use of organic and inorganic sources of nitrogen on yield :

Rao *et al.* (1996) reported that in integrated nitrogen management system including a combination of organic (azolla compost, water hyacinth, compost, *Sesbania aculeate, Sesbania rostrata* or FYM each supplied @ 37.5 kg N ha^{-1}) and inorganic nitrogen sources produced comparable rice yields to that of application of 1 00 per cent fertilizer nitrogen alone. Application of 60 kg N as urea + 60 kg N as FYM gave the highest rice grain yield (Roy *et al.,* 1997). Hegde (1998) noticed that substitution of 25 to 50 per cent nitrogen for rice through different organic sources (FYM or green manure) had similar effect on grain yield of rice. Selvam (2000) revealed that conjunctive use of 50 per cent fertilizer + 25 per cent each through FYM N and green manure N has resulted in higher grain yield. Dutta and Bandhopadhyaya (2003) reported that the effect of FYM, green leaf manure and BGA alone and in combination with given level of inorganic fertilizers was statistically at par on grain yield of rice. The grain and straw yield of rice recorded with application of 25 per cent N either through green leaf manure (GLM) or farm yard manure + 100 per cent fertilizer nitrogen through urea were comparable and significantly superior to 100 per cent FN, 25 per cent N through FYM or GLM + 75 per cent through urea (Malla Reddy *et al.*, 2003). Nitrogen applied @ 50 per cent N through inorganic (urea) and 50 per cent N through organic sources (FYM + green manures) resulted in the highest grain yield of rice compared to 100 per cent N supply through fertilizer (Priyadarshini and Prasad, 2003). The highest grain yield of rice (2.83 t ha^{-1}) registered under integrated use of 75 per cent RDF + pelleted form of organic manure than sole chemical fertilizer addition which produced 1.6 t ha^{-1} of rice (Bhuvaneswari *et al.*, 2007). Application of 60 kg N ha^{-1} as urea with 60 kg N ha^{1} as mustard oil cake produced maximum grain and straw yield which was statistically similar to the yield of 50 kg N ha^{-1} as urea with 50 kg N ha^{-1} as mustard oil cake*(*Alim, 2012). Applying FYM at 15 t ha^{-1} combined with 120 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1} increased grain yield by 123 per cent and 38 per cent compared to the negative (0- 0-0 kg ha^{-1} FYM-N-P_2O_5) and positive (0-120-100 kg ha^{-1} FYM-N-P_2O_5) controls, respectively (Tilahun Tadesse *et al*., 2013). Application of organic and inorganic sources of nutrient in combination remarkably increased yield, yield attributes and nutrient uptake of rice than alone. 125 per cent RDF+5 t/ha vermicompost recorded significantly higher yield, yield attributes and nutrient uptake (Kumar *et al*., 2014) and Haque *et al*. (2015) observed that different FYM and gypsum combinations along with different N levels have significant effect on growth and yield of rice. Mean effect of FYM and gypsum combinations found the highest for grain yield where plot received FYM @ 5 tha^{-1} +gypsum 210 kg ha^{-1}. Maximum grain yield of rice was found with application of FYM @ 5 tha^{-1} and gypsum 210 kg ha^{-1} along with 125 kg N ha^{-1}.

Influence of conjunctive use of organic and inorganic sources of nitrogen on nutrient uptake :

A field study conducted on organic manures, fertilizers and their integrated use revealed superior N, P and K uptake by rice with FYM or green manuring (Alok Kumar and Yadav, 1995). Syed NazeerPeeran and SreeRamulu (1995) noticed that combining fertilizer nitrogen with FYM or green manure resulted in higher N, P and K uptake than the corresponding fertilizer nitrogen treatments. Jana and Ghosh (1996) stated that the uptake of N, P and K was more when 75 per cent requirement was applied through inorganic fertilizer and 25 per cent as organic sources to rice than with 100 per cent N, P and K supplied through inorganic source. Jadhav *et al.* (1997) observed higher N, P and K uptake by rice with treatment receiving 75 kg N ha^{-1} through urea along with 25 kg N ha^{-1} through organics. Dutta and Bandhopadhyaya (2003) reported that the effect of farm yard manure, green leaf manure and BGA alone and in combination with given level of inorganic fertilizers was statistically at par in uptake of nutrients by rice. Priyadarsini and Prasad (2003) revealed that application of 50 per cent N through inorganic (urea) and 50 per cent N through organic sources (FYM or green manure) resulted in the highest nutrient uptake (N, P and K) by rice than 100 per cent N supply through fertilizer. Among the different organic sources of N for rice, FYM in conjunction with inorganic fertilizers proved significant in enhancing the nutrient uptake of rice (Sairam and Sambasiva Reddy, 2004). Tadesse *et al*. (2013) observed that application of 15 t FYM ha^{-1} increased the level of soil total nitrogen from 0.203 per cent to 0.349 per cent. Combined application of 15 t ha^{-1} FYM and 100 kg P_2O_5 ha^{-1} increased the available phosphorus from 11.9 ppm to 38.1 ppm. Positive balances of soil N and P resulted from combined application of FYM and inorganic N and P sources. Application of 15 t ha^{-1} FYM and 120 kg N ha^{-1} resulted in 214.8 kg ha^{-1} N positive balance while application of 15 t ha^{-1} FYM and 100 kg P_2O_5 ha^{-1} resulted in a positive balance of 69.3 kg P_2O_5 ha^{-1} available P.

Influence of conjunctive use of organic and inorganic sources of nitrogen on post harvest soil fertility status:

Under integrated nutrient management considerable buildup of soil fertility status (N, P and K) was observed. This furnished possibility of replacing 25 per cent RDF through pellated form of organic manure or FYM for sustainable production, improving quality and fertility buildup of soil (Mithunsaha Mantal *et al.*, 2007). Application of 7 t ha^{-1} farmyard manure+110 kg N ha^{-1} was comparable to application of 5 t ha^{-1} rice straw compost + 110 kg N ha^{-1} with regard to the potential to increase soil organic matter content and soil nutrient availability, and both were better in this respect than the sole application of chemical nitrogen fertilizer (Zayed *et al*., 2013).

Economics of the rice based cropping systems :

Hegde (1992) conducted economic analysis of various rice based cropping systems and concluded that there was a scope for curtailment in fertilizer dose in some crop sequences at selected locations without any adverse effect on the monetary returns. Dubey and Verma (1999) concluded that integrated use of 50 per cent N, P and K + 50 per cent FYM was advantageous in sustaining the crop and soil productivity and obtaining higher net returns compared to 100 per cent N P K supplied through either inorganic fertilizers or FYM alone. Selvam (2000) revealed that conjunctive use of 50 per cent fertilizer + 25 per cent each through FYM N and green manure N has resulted in higher economic returns without impairing the soil fertility. Tilahun-Tadesse *et al*. (2013) observed that 15 t ha^{-1} FYM combined with 120 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1} resulted in the maximum grain yield, grain protein content, and terminal moisture stress escape. Though grain yield continued increasing significantly upto the highest combinations, results of the economic analysis showed that the maximum net benefit was obtained in response to the application of 7.5 t ha^{-1} FYM combined with 120 kg N ha^{-1} and 100 kg P_2O_5 ha^{-1}. Zayed *et al*. (2013) reported that recommended chemical nitrogen fertilizer application could be reduced by one-third with application of 5 t ha^{-1} rice straw compost or 7 t ha^{-1} of farmyard manure. The treatment with inorganic nitrogen fertilizer alone gave the highest net return followed by the treatment of 5 t ha^{-1} rice straw compost straw + 110 kg N ha^{-1}. Organic manure application gave acceptable yield levels of economic significance, particularly with continued application.

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