ABSTRACT

Although fertilizer use is probably the easiest means of counteracting the pace of nutrient depletion, the spiraling cost, wide occurrence of multi-nutrient deficiencies and environmental degradation from inefficient use of fertilizers warrant the use of alternate sources at least as supplement though not as substitute. Green manures seem to be an attractive alternate source to meet a substantial portion of the rice N requirement and provide organic matter to wetland rice soils. N substitution of 60 -100 kg N ha⁻¹ has been obtained by green manuring to rice. Yield responses of high yielding rice cultivars to green manures in India ranged from 0.65 to 3.1 t ha⁻¹. An increase in soil nitrate ranging from 73 to 223 kg N ha⁻¹ within a period of 90 days of green gram cropping. The use of green manures for improving the soil productivity and as a source of N has been recognized from early times in rice growing areas. The research findings on the effect of green manuring on rice yield, N economy and soil fertility have been reviewed.

In Asia, where more than ninety per cent of the World's rice is produced, about sixty per cent of the N fertilizer consumed is on rice (Stangel and De Datta, 1985). However in the face of high costs of chemical fertilizers, and growing concern for maintaining long term soil productivity and ecological sustainability, interest in using leguminous green manures has increased (Khind et al., 1991). Green manuring with N fixing legume crops can provide a substantial quantity of rice N requirement with organic matter to wetland rice soils (Bouldin, 1988; Ladha et al., 1988). Various kinds of green manure crops are grown in rice-based cropping systems, among which, S. aculeata and S. rostrata are popular.

Green manures under cultivation

S. aculeata is one of the commonly grown green manures in India (Abrol and Palaniappan, 1988; Garrity and Finn, 1988). The N contribution of S. aculeata to wetland rice was studied by Ghai et al. (1988) and they reported that the grain yield and N uptake of rice were equivalent to that with 122 kg of fertilizer N application. Bhagat et al. (1988) reported that application of 50 per cent of the total N as S. aculeata and remaining N as urea gave higher rice yields and resulted in lower losses of ammoniacal and nitrate N. Beri et al. (1989) recorded N accumulation of 108 to 113 kg ha⁻¹ from 60 day old S. aculeata having a nitrogen fertilizer equivalence of 120 kg ha⁻¹.

S. rostrata was suggested as potential green manure, which has capacity to produce both root and stem nodules and can grow in flooded as well as dry conditions (Dreyfus et al., 1984). Studies conducted on nodulation of S. rostrata showed that due to profuse stem nodulation, besides root nodulation, it has five to ten times more nodules than most root nodulated green manure species (Dreyfus and Dommergues, 1981).

Several green manures were compared in terms of dry weight and N accumulation of which S. rostrata accumulated more N (165 kg ha⁻¹) than S. aculeata (137 kg N ha⁻¹) but S. aculeata recorded more dry weight (8.6 t ha⁻¹) as compared to S. rostrata (7.5 t ha⁻¹) with N content of 1.6 % and 2.2 % respectively (Porpavai et al., 1996).

Effect of green manures on rice yield

Yield responses of high yielding rice cultivars to green manures in India ranged from 0.65 to 3.1 t ha⁻¹ (Yadvinder Singh et al.,
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1991). Sethi et al. (1952) reviewed the early work and concluded that green manuring with *S. aculeata* increased rice yield by 21 to 114 per cent. Das and Datta (1992) reported that rice grain yields with *S. aculeata* and *S. rostrata* increased equally at both 50 and 100 kg N ha\(^{-1}\). Rinaudo et al. (1982) reported an increased grain (3.9 t ha\(^{-1}\)) and straw yields (4.9 t ha\(^{-1}\)) over no green manure when 45 days old *S. rostrata* was incorporated. Dreyfus et al. (1985) observed increased grain yield by 3.72 t ha\(^{-1}\) over control through the use of *S. rostrata*. The results of an experiment conducted to study the direct and residual effects of organic manures, FYM, *S. rostrata* and *S. aculeata* with and without inorganic fertilizers showed that highest grain yield of 6.0 t ha\(^{-1}\) could be obtained by combining inorganic fertilizer and *S. rostrata* (Palaniappan et al., 1991).

Studies conducted on the age of incorporation of *S. rostrata* on rice grain yield (Sudjadi et al., 1989) showed that incorporation of *S. rostrata* after 45 days growth gave higher grain yields of rice than incorporation after 35 days growth. With the use of *S. rostrata*, rice yields increased by 1.4 t ha\(^{-1}\) over unweeded fallow, and results indicated that an input of 80 kg N ha\(^{-1}\) could be saved without any reduction in rice yield (IRRI, 1988). Incorporation of *S. rostrata* at 12.5 t ha\(^{-1}\), seven days before transplanting and at the time of transplanting of rice increased grain yield by 16 and 13 per cent, respectively over no green manure (Somusundaram, 1991).

*S. rostrata* when applied to rice gave the same rice yield equivalent to 46 kg N ha\(^{-1}\) as urea (Nazemi et al., 1995). Pandey et al. (1995) found that sesbania alone produced more than 6 t ha\(^{-1}\) of rice grain yield (about 2.5 t more than control), which was statistically equal to 120 kg N ha\(^{-1}\) as prilled urea. *S. rostrata* alone (16 t ha\(^{-1}\) green biomass equal to 56 kg N) was significantly superior to prilled urea. They also opined that response to green manure increased with time probably due to build up of organic matter. Singh et al. (1999) found that the application of green manure (*S. rostrata*) increased the grain yield (4.9 t ha\(^{-1}\)) over the unfertilized control (3.2 t ha\(^{-1}\)). Higher nutrient availability under the treatment might have contributed to higher yields of rice.

Integrated nutrient management with green manures

To save on fertilizers costs, green manure is used in conjunction with fertilizer N. Raju and Reddy (1991) studied the integrated use of green manure and fertilizer N and reported that addition of 50 kg N ha\(^{-1}\) coupled with *S. aculeata* gave the highest yield of 65.4 q ha\(^{-1}\) and the increase was to an extent of 33 per cent over the application of *S. aculeata* alone. *S. aculeata* applied alone or in combination with urea gave yields similar to that from a full dose of urea N (Haroon et al., 1992). Effects of *S. aculeata* along with inorganic N was studied by Sharma and Kuhad (1993) who found that *S. aculeata* applied at 12.5 t ha\(^{-1}\) along with fertilizer N at 120 kg ha\(^{-1}\) yielded significantly more than 125 kg N ha\(^{-1}\) and about the same as 180 kg N ha\(^{-1}\). Integrated effect of urea (50 kg N ha\(^{-1}\)) and glyricidia green manure (10 t ha\(^{-1}\)) on grain yield of transplanted rice was studied by Dhane et al. (1995), who concluded that the maximum yield of 5.2 t ha\(^{-1}\) which was significantly higher than the control.

The effect of integrating green manure *Glyricidia maculata* and *S. aculeata* with different levels of N (urea) on grain yield of transplanted rice was evaluated. Fertiliser application at the recommended dose and integration of fertilizer N with green manure proved superior to the control. Basal application of 7.5 t glyricidia with 25 kg urea N ha\(^{-1}\) was on par with 100 kg urea N ha\(^{-1}\) in terms of yield. With this treatment, a saving of 75 kg urea N ha\(^{-1}\) was achieved (Chavan et al., 1996). Devi et al. (1997) studied the integrated
nutrient management in rice based cropping system with various organic manures and found that application of 50% fertilizer NPK with 50% NPK through green manure resulted in the highest yield. They opined that using an equal proportion of each source of nutrient would be optimum for producing higher and sustained yield over time.

Sahoo and Datta (1997) studied the effect of *Azolla caroliniana* and *S. rostrata* on rice yield and concluded that the addition of *S. rostrata* as green manure (providing 60 kg N ha\(^{-1}\)) in the presence of *Azolla* almost negated the requirement of the addition of chemical N, whereas the addition of 30 kg N as urea to the above combination resulted in a significant 100 per cent increase in the grain and straw yield over control. Nagarajan et al. (2000) studied the effect of continuous application of NPK at 125:50:50 kg ha\(^{-1}\) in *kharif* and 150:60:60 kg ha\(^{-1}\) in *rabi* season along with green manure, *S. rostrata* at 6.25 t ha\(^{-1}\) in *kharif* and FYM at 12.5 t ha\(^{-1}\) in *rabi* registered significantly higher grain yield in both seasons consecutively for five years. Rice yield obtained with 75 per cent of recommended NPK alone (39.3 q ha\(^{-1}\)) was statistically at par with that obtained with green manure with 50 per cent of recommended NPK (35.17 q ha\(^{-1}\)). Thus the contribution was 25 per cent of the recommended NPK under green manure (Singh et al., 2000).

**Effect of green manures on N economy**

Inclusion of legumes in the cropping system improved the soil N status, thus reducing N application to succeeding crop (Palaniappan et al., 1976). Sanyasi Raju (1952) reported that green manure crops such as *S. aculeata*, *Crotalaria juncea* and cowpea, when incorporated after 60 days growth, contributed N ranging from 74 to 134 kg ha\(^{-1}\). Meelu and Morris (1986) obtained N substitution of 60 kg N ha\(^{-1}\) by green manuring to rice. Abrol and Palaniappan (1988) reported a substitution of 60 to 100 kg N ha\(^{-1}\) by green manure crops, under rice-based cropping systems. Sharma and Mithra (1988) from their findings reported that mineral N to the extent of 45 to 60 kg ha\(^{-1}\) could be replaced by growing green manures.

Gupta and Gupta (1997) studied the effect of inorganic fertilizers with green manures on rice yield, nutrient uptake and soil fertility. Application of 50% fertilizer N with 50% as green manure gave highest response over control, indicating that a 50% NPK saving could be achieved by continuous application of green manure. The total productivity over the years was comparable with that of 100% fertilizer N. These results suggest that combined use of organic and inorganic fertilizer can sustain soil fertility and grain yield.

**Effect of green manures on soil fertility**

Several benefits in the improvement of soil fertility are credited to green manure application. Legumes are potentially important to diversify cereal-based monocropping into cereal-legume sequences, which have nutrient cycling advantages (Torres et al., 1988). Singh (1984) opined that legumes grown in rotation with lowland rice could increase the availability of mineral N.

Green manures, when buried just before transplanting rice, create reducing conditions, which help in mobilizing several other nutrient elements (Singh, 1984). By growing green manures in the off-season, leaching loss of N and other nutrients could be reduced and the green manure crop could use forms of P and Zn less available to rice and increase their availability. Soil recovery of green manure N ranged from 15 to 35 per cent of the added amount, which is found to be higher than the recovery of fertilizer N (Westcott and Mikkelson, 1987).

Singh and Rai (1973) studied the effect of green manure on availability of organic P and concluded that maximum increase in
organic P in the soil occurred on the 30th day of decomposition of a 60 day-old crop. Ranjan and Kothandaraman (1986) reported increased availability of P from rock phosphate applied to rice with green manure. Enhanced availability of some micronutrients (e.g. Fe) due to green manure incorporation, was reported by Takkar and Nayyar (1986). In addition to supplying nutrients like N, P and K, green manure is an important source of organic matter and can improve soil physical properties such as porosity and strength (Wen Qixiao and Yu Tiarren, 1988). Use of green manures increases the nutrient retention capacity, improves soil structure and microbial activity (Arunin et al., 1988). Application of green manure resulted in better aggregation, which may be the possible reason for decreased bulk density due to the application of green manure (Mishra and Sharma, 1997). The application of S.rostrata resulted in higher soil organic content (0.73%) over unfertilized control (0.55%) and available N was 261 kg ha\(^{-1}\) over 231 kg ha\(^{-1}\) under control (Singh et al., 1999).

The organic matter added to the soil in the form of green manure is highly labile and would influence the soil reactions and availability of nutrients including N (Azam, 1990). Singh et al. (1990) reported that the percentage of organic carbon in the green manure plots was 0.91 as compared to 0.69 in the fallow plots. Kumar et al. (1992) studied the effect of continuous application of green manure and concluded that soil physical properties like bulk density, infiltration and size of water stable aggregates were favourably influenced.

Bhattacharyya and Mandal (1997) studied the contribution of green manure in controlling the loss of applied fertilizer N from rainfed soil and concluded that green manures significantly reduced both leaching and gaseous losses of fertilizer \(^{15}\text{N}\) and remained most efficient under drought prevailing at the vegetative stage. Maximum reduction in gaseous losses of fertilizer \(^{15}\text{N}\) through green manure was 66.13 per cent in sandy soil under drought at the reproductive stages. Thus green manures significantly increased the grain yields of rice registering maximum increments of 57.59 per cent over control. The organic carbon of the soil improved in general with green manure, whereas control plot recorded lower value than initial and it declined to 0.4 per cent (Thakur et al., 1999). Saravana Pandian and Rani Perumal (2000) studied the effect of integrated nitrogen management on fertility status of rice soil and found that there was a depletion of all the major nutrients with the application of fertilizer N alone. Conjoint addition of green manure (S. aculeata) with fertilizer N improved the status of available N, organic carbon, NH\(_4\)-N, Olsen-P and NH\(_4\)OAc-K.

Decomposition and transformation of grain legumes and green manures

Green manures, unlike inorganic N fertilizers, must undergo decomposition and mineralisation, before its N becomes available to the rice crop (Nagarajah, 1988). Models of organic matter decomposition in flooded soils have characterized organic amendments, as containing two distinct components: one decomposing within a few months but have little residual effects and the other decomposing slowly over several years (Bouldin, 1988). Diekmann and De Datta (1992) reported that due to green manure decomposition, high concentration of organic acids, phenolic substances and other organic compounds were released which could influence the growth and establishment of rice seedlings.

The NH\(_4\)^+-N released from green manure is rapidly adsorbed onto the cation exchange complex of the soil leaving the balance of NH\(_4\)^+-N in the soil solution (Ponnamperuma, 1965). Following incorporation of S. aculeata (Khind et al.,
1985; Nagarajah, 1988; Beri et al., 1989) and *S. rostrata* (Nagarajah, 1988; Diekmann, 1990) the accumulation of soil ammonium peaked at 7 to 20 days after rice transplanting and then gradually declined.

Nagarajah (1988) determined the net N release for green manures (*S. rostrata* and sunnhemp) and grain legumes (greengram, cowpea, redgram, groundnut and soybean) and concluded that plant N content ranged from 11 g kg⁻¹ for soybean to 27 g kg⁻¹ for *S. rostrata* with higher content ranging from 57 g kg⁻¹ for greengram to 134 g kg⁻¹ for redgram. Net recovery of plant N at 50 days ranged from 1.6 per cent for soybean to 43 per cent for *S. rostrata*. Release of N from green manure is initially rapid, but slows down markedly within a fairly short time (Bharadwaj and Dev, 1985).

Rajeswari (1990) reported a rapid decrease in flood water NO₃-N until transplanting, and slight increase two days after planting. Bharadwaj and Dev (1985) reported that through tying up of mineralized N by green manures, loss by denitrification, volatilisation and leaching could be minimized. The per cent loss of applied N varied from 1.05 to 2.69 kg N ha⁻¹ in the case of fertilizer N, whereas it ranged from 0.64 kg to 2.49 kg N ha⁻¹ when fertilizer N was applied in conjunction with green manure (Chakravorthi et al., 1989). Das et al. (1995) studied the transformation of N as affected by different sources and methods of N application and found that application of prilled urea with green manure to be the most efficient fertilization forms which resulted in generally higher yields with relatively low N losses to volatalisation and leaching.

Economics of green manuring in rice-based cropping systems

Among the green manures, Rabindra et al. (1989) obtained an increase in net profit by US $ 125 ha⁻¹ with the use of *S. rostrata*. Thakur (1991) reported that *S. rostrata* incorporation at the time of transplanting rice, with recommended N fertilizer, produced more net returns as compared to *S. aculeata* incorporation with recommended dose of fertilizers for rice. Pandey et al. (1995) conducted an economic analysis, which revealed that using green manure increased the cultivation cost by US $ 27.20 but this was compensated by their yield increases. Integrating inorganic sources with green manure economized fertilizer N by 50 per cent. Green manure with urea gave an extra benefit of US $ 36 over the recommended dose of 120 kg N. Green manure alone gave an extra benefit of US $ 260 ha⁻¹ over no N and US $ 30 ha⁻¹ over 90 kg of urea N. Bhattacharya and Mandal (1997) reported that green manure recovers fertilizer N losses from rainfed rice soil to a great extent and stimulates yield to benefit the economy of rainfed rice farming by a margin of US $ 19.28 to US $ 186.76 ha⁻¹ yr⁻¹ under various rainfall conditions.

REFERENCES


