Integrated nutrient management for upland rice in eastern ghats of Orissa

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ABSTRACT

Field experiments were conducted from 2003-04 to 2004-05 at Malipungar watershed, Koraput, Orissa to evaluate integrated nutrient management (INM) options involving Gliricidia/ Farm yard manure (FYM) , chemical fertilizers and bio-fertilizers for their effect on performance of upland rice and soil properties. It was observed that growth, yield and net returns from Gliricidia amended plots were better than the FYM amended plots. Soil moisture, bulk density, soil pH, organic carbon and P in Glricidia and FYM amended plots were at par. However, residual N and K contents were significantly higher in plots amended with Gliricidia green leaf manure. Combined use of 50% recommended dose of fertilizers, Gliricidia @ 2.5 t ha^{-1} and biofertilizers (Azotobacter and phosphate solubilising bacteria) with highest grain yield (2.01 t ha^{-1}), net returns (Rs.4791 ha^{-1} and B:C ratio (1.6) was the best INM option. Moreover, soil moisture content, and available N, P and K status of soil recorded from plots having this treatment were also significantly higher than those with 100% Recommended dose of fertilizer.

Key words: *upland rice, integrated nutrient management, Gliricidia, farm yard manure*

Overall productivity of rice (2.93 t ha^{-1}) in India is low chiefly due to very low productivity of rainfed rice accounting for 55% of total rice area and rainfed upland rice (1 t ha^{-1}) having 6.0 m ha area (Chandrasekaran *et al*., 2008 and Anon., 2006) Upland rice is extensively grown in eastern ghats of Orissa under rainfed conditions. This region having sub-tropical climate receives abundant rainfall, but low soil fertility and imbalanced supply of nutrients result in very low yield of upland rice. Adequate and balanced supply of nutrients could be the solution for this problem. However, supply of nutrients to crops through chemical fertilizers alone can not be advocated as these are scarce and costly, and if used persistently, prove detrimental to environment and soil properties. On the strongly weathered and poorly buffered soils of tropics, continuous use of chemical fertilizers as main source of nutrients led to a significant decline in cereal crops yield after only few years of cropping because of soil acidification and compaction (Kang and Juo, 1986). This necessitates the devising of sustainable soil nutrient–enhancing strategies that involve the combined use and management of inorganic and organic nutrient sources in ecologically sound production systems (Janssen, 1993). While inorganic fertilizers supply their nutrients immediately to the plants, the organics, such as farmyard manure (FYM) and green manures, improve the physical properties of soil by lowering bulk density, increasing water holding capacity, and improving infiltration rates (Tester, 1990 and Werner, 1997).

FYM, the principal amendment used for fertilizing soil, is inadequate and very poor in quality. Low rate of mineralization and even immobilization of nitrogen, can take place after its use, particularly in years when low rainfall limits soil moisture and decomposition. Green leaf manures can be reliable alternate source of nutrients. One plant species that has received attention as green-leaf manure is the leguminous tree *Gliricidia sepium*. It produces large

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amount of easily decomposable and high quality prunings. In eastern ghats of Orissa, it grows vigorously and is locally known as *Khata gachho*. Its leaves are rich in plant nutrients (2.25% N, 0.28% P_2O_5 and 4.6% K_2O). In addition to green manure, use of micro-organisms that fix atmospheric nitrogen and secrete phytohormones to increase organic matter in soil also seems to increase availability of other nutrients (Pareek *et al*., 1996). However, use of manures or chemical fertilizers or bio-fertilizers in isolation may not sustain high level of crop productivity, but their integrated use may do. Hence, the present investigation was carried out with the objectives to compare the performance of *Gliricidia* green-leaf manure with FYM in improving crop yield and soil properties and also to find out the most rewarding, in terms of yield, income and soil health, INM option for rainfed upland rice.

MATERIALS AND METHODS

An experiment was conducted for two consecutive years during 2003-04 to 2004-05 with upland rice cv Khandagiri in farmer's field under Malipungar watershed in the hilly belt of Orissa. The watershed area is located at an altitude range of 850-1120 m above mean sea level. Soil was a red lateritic sandy loam (sand 60.4%, silt 21.5% and clay 19.1%). Organic carbon, available N, available P and available K in the soil averaged over the entire area was 0.32%, 201.5 kg ha^{-1}, 17.4 kg ha^{-1} and 314.5 kg ha^{-1}, respectively, with pH 6.3. Permeability and electrical conductivity was 2.7 cm hr^{-1} and 64.4 µS cm^{-1}, respectively. The bulk density was 1.57 g cc^{-1}. During the crop season, rainfall of 794 mm (average of two years) occurred in 49 rainy days. August received the highest amount of rainfall followed by July. Mean maximum and mean minimum temperature were 26.6 and 19.2 ^{o}C, respectively. Average bright sunshine period was 3.43 hours day^{-1}.

The experiment, comprising of 7 treatments (Table 1), was set in a randomized complete block design with three replications. Each experimental unit had 100 sqm area (10m x 10m). A 1m strip on the borders of each plot was earmarked for randomly taking sample-plants for dry matter accumulation and dry root weight. Yield was taken from inner 8m x 8m area (net plot). Farm yard manure, *Gliricidia* biomass and the bacterial inoculants were incorporated into the soil 15 days before sowing. Crop was sown in the first week of July in both the years, at a spacing of 20cm (row to row). A seed rate of 100 kg ha^{-1} was used. Fertilizers were added as per the treatments. Remaining cultural operations, i.e., field preparation, weeding and hoeing were done as per farmers' practices.

Data on plant height, tillers $plant^{-1}$ and panicle length were recorded at maturity and leaf area index, dry-matter accumulation and dry root weight at flowering stage. Yield attributes like number of grains $plant^{-1}$ and 1000-grain weight were measured at harvest. For determining root dry matter, four consecutive plants $plot^{-1}$ were uprooted along with soil up to 30cm depth. Root portion was cleaned with water and separated from the plant. The roots were dried in an oven at $70^{0}C$ until constant weight was obtained. Economic parameters viz., net returns and benefit cost ratio for all the treatments were worked out on the basis of prevailing market prices of inputs and outputs. Soil moisture content was recorded at tillering, flowering and physiological maturity stages at 0-15cm and 15-30 cm depths using gravitation method.

After completion of two years of experimentation, composite soil samples were collected from the surface soil (0-15 cm) and analyzed. Bulk density was estimated by the core method, organic carbon by wet digestion method (Walkley and Black, 1934), available N by Alkaline $KMnO_4$ method (Subbiah and Asija, 1956) and available P by Bray and Kurtz - I method (Bray and Kurtz, 1945). Data were subjected to analysis of variance for a randomized complete block design as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth parameters like plant height, effective tillers, leaf area index (LAI), dry matter accumulation and root dry weight, were significantly affected by the treatments (Table 2). Application of 50% recommended dose of fertilizers (RDF) + *Gliricidia* @ 2.5 t ha^{-1} + *Azotobacter* and phosphate solubiliing bacteria (PSB) @ 2.5 kg ha^{-1} each, produced tallest plants (53.5cm) with the highest number of tillers $plant^{-1}$ (4.2), LAI (3.32), dry matter accumulation (8.91g $hill^{-1}$) and dry root weight (2.89 g $hill^{-1}$). This treatment was significantly better than farmers' practice involving FYM 2.0 t ha^{-1} + urea and DAP 25 kg ha^{-1} each and the use of *Azotobacter* and phosphate solubilising

Table 1. Treatment details and amount of nutrient added

Treatments	Nutrient content (kg ha^{-1})			
	N	P	K	Total
Farmers' practice (FP: FYM 2.0 t ha^{-1} + Urea 25Kg ha^{-1} + DAP 25 kg ha^{-1})	26.8	16.9	12.5	56.2
Farmer's pratice+ Phosphate solubilizing bacteria @ 2.5 kg ha^{-1} +Azotobactor @2.5 kg ha^{-1}	41.8	30.9	12.5	85.2
Farmer's pratice +*Gliricidia* @ 5 t ha^{-1}	153.5	44.5	235	433.0
Farmer's pratice+Farm yard manure @ 5 t ha^{-1}	53.8	44.4	30.0	128.2
Recomended dose fertilizer (40-20-20 N:P:K)	40.0	20.0	20.0	80.0
50 % RDF+ FYM @2.5 t ha^{-1} +PSB @2.5 kg ha^{-1} + Azotobactor @2.5 kg ha^{-1}	48.5	30.8	25.5	104.8
50 % RDF+ *Gliricidia* @2.5 t ha^{-1} +PSB@2.5 kg ha^{-1} + Azotobactor.@2.5 kg ha^{-1}	91.25	31.0	125.0	247.3

Note: N fixed by Azotobactor is 15 kg ha^{-1} (Sharma, 2002), Amount of P solubilized by PSB is 14 kg ha^{-1} (Balasuberananiyan and Palaniappan, 2001). Nutrient content of Gliricidia sepium is N 2.25%, P_2O_5 0.28% and K_2O 4.60% . Whereas, FYM contains 0.54%, N, 0.27% P_2O_5 and 0.62% K_2O

Table 2. Effect of integrated nutrient management on growth parameters of upland rice (average of 2 years)

Treatments	Plant height (cm)	Effective tillers plant^{-1}	Leaf area index	Dry matter accumulation/ plant (g hill^{-1})	Root dry matter (g hill^{-1})
Farmers' practice (FP: FYM 2.0 t ha^{-1} + Urea 25Kg ha^{-1} + DAP 25 kg ha^{-1})	44.47	2.2	2.51	3.87	1.42
FP+ PSB @ 2.5 kg ha^{-1} +Azotobactor @2.5 kg ha^{-1}	46.67	2.5	2.71	5.62	1.93
FP +*Gliricidia* @ 5 t ha^{-1}	50.13	3.8	2.94	6.46	2.58
FP+FYM @ 5 t ha^{-1}	49.07	3.6	2.92	6.44	2.49
RDF (40-20-20 N:P:K)	52.60	3.5	3.11	7.71	2.46
50 % RDF+ FYM @2.5 t ha^{-1} +PSB @2.5 kg ha^{-1} + Azotobactor @2.5 kg ha^{-1}	49.13	4.1	3.23	7.74	2.76
50 % RDF+ *Gliricidia* @2.5 t ha^{-1} +PSB@2.5 kg ha^{-1} + Azotobactor.@2.5 kg ha^{-1}	53.50	4.2	3.33	8.91	2.89
CD (P=0.05)	3.39	1.15	0.20	0.64	0.23

bacteria (PSB) 2.5 kg ha^{-1} each alongwith farmer's practice for all the growth parameters; application of 5 t ha^{-1} *Gliricidia or* FYM alongwith farmers' practice, for plant height, LAI and dry matter accumulation; and recommended dose of fertilizers (RDF: 40-20-20 N:P:K) for LAI, dry matter accumulation and dry root weight. Most of the growth parameters resulted from supply of 2.5 t ha^{-1} *Gliricidia* or FYM in addition to 50 % RDF and bio-fertilizers were similar. Use of RDF produced healthier plants than farmers' practice and the treatments wherein farmers practice was supplemented with bio-fertilizers or higher amount of *Gliricidia* or FYM. Overall, the use of *Gliricidia* alongwith either farmers' practice or with chemical fertilizers and bio-fertilizers resulted in remarkable improvement in growth parameters of upland rice over FYM. (Table 2). This could be due to very high amount of nutrients (Table 1) and fast decomposition of *Gliricidia* leaves resulting in early release of nutrients into the soil. *Gliricidia* leaves decompose twice as fast as cattle FYM and N release is more synchronized with plant demand (Mundus *et al*., 2008); 86% of its N is released before day 42 of its incorporation into soil (Lehmann *et al*., 1995).

Longest panicles (14.33cm) with the highest number of grains (47.3) and panicle weight (1.23 g) were produced by the combined application of 50% RDF, 2.5 t ha^{-1} *Gliricidia* and bio-fertilizers (Table 3). However, panicle length did not vary significantly with the use of higher amount of *Gliricidia* or FYM over and above framers' practice, RDF and integrated use of lower amount of *Gliricidia* or FYM and the half dose of chemical fertilizers and bio-fertilizers. Number of grains and grain weight per panicle resulted from

Table 3. Effect of INM on yield attributes, yield and economics of upland rice cv. Khandagiri 2003-2005

Treatments	Panicle length (cm)	No. of filled grains panicle^{-1}	Panicle weight (g)	Yield (t ha^{-1})		Harvest index (%)	Net returns (Rs.ha^{-1})	B:C ratio
				Grain	Straw			
Farmers' practice (FYM 2.0 t ha^{-1}) + Urea 25Kg ha^{-1}+ DAP 25 kg ha^{-1})	11.33	36.7	0.86	1.19	1.55	43	591	1.08
FP+ PSB @ 2.5 kg ha^{-1} +Azotobactor @2.5 kg ha^{-1}	13.20	40.3	1.03	1.36	1.76	43	866	1.11
FP +*Gliricidia* @ 5 t ha^{-1}	13.80	41.5	1.10	1.78	23.0	44	3595	1.44
FP+FYM @ 5 t ha^{-1}	13.47	40.5	1.06	1.73	2.27	43	944	1.09
RDF (40-20-20 N:P:K)	13.67	46.8	1.22	1.99	2.66	43	4782	1.57
50 % RDF+ FYM @2.5 t ha^{-1} +PSB @2.5 kg ha^{-1}+ Azotobactor @2.5 kg ha^{-1}	14.07	44.6	1.20	1.88	2.74	41	3986	1.46
50 % RDF+ *Gliricidia* @2.5 t ha^{-1} +PSB@2.5 kg ha^{-1}+ Azotobactor.@2.5 kg ha^{-1}	14.33	47.3	1.23	2.01	2.88	51	4791	1.55
CD(P=0.05)	1.10	4.86	0.08	0.138	0.203	NS	1056	0.15

Note: Sale price of grains: Rs. 530/q Straw: Rs100/q

RDF, 50% RDF + FYM @ 2.5 t ha^{-1} + biofertilizers and 50% RDF + *Gliricidia* @ 2.5 t ha^{-1} + biofertilizers were statistically at par. Plants receiving farmers' practice and farmers' practice supplemented with bio-fertilizers had significantly lower number of grains and grain weight panicle^{-1} than RDF and integration of lower dose of *Gliricidia/* FYM with half dose of fertilizers, and bio-fertilizers. Overall higher values of yield attributes of plants supplied with 50% RDF +2.5 t ha^{-1} *Gliricidia* + bio-fertilizers (2.5 kg ha^{-1}) could be inferred from higher availability of nutrients from chemical fertilizers, early decomposition of *Gliricidia*, mobilization of N and solubilization of P by PSB, in addition to other benefits like aggregation of soil, thereby, facilitating higher infiltration and retention of rainwater in the soil profile. Plots amended with *Gliricidia* depicted slightly higher values of yield attributes over those amended with FYM. This is ascribed to the higher nutrient contents and their early release from *Gliricidia* as compared to FYM.

Better growth and yield attributes accrued from the use of 50 % RDF + *Gliricidia* @ 2.5 t ha^{-1}) + *Azotobactor* @ 2.5 kg ha^{-1} + PSB @ 2.5 kg ha^{-1} resulted in the highest grain (2.01 t ha^{-1}) and straw (2.88 t ha^{-1}) yield of upland rice (Table 3) which was, however, statistically at par with 100% RDF, but significantly higher than all other treatments. This could be due to the combined effect of nutrient supply, synergism and improvement in physical and biological properties of soil (Sarwad *et al*., 2005). Net returns and B: C ratio obtained from these two treatments was almost equal. Application of FYM @ 2.5 t ha^{-1} along with 50% RDF and bio-fertilizers was the third best treatment. Application of *Gliricidia* leaves and twigs (rich in nutrients and easy to decompose) as organic amendment was superior to FYM in terms of grain and straw yield of upland rice. Higher rice yield with green manuring over FYM has also been reported by Singh *et al*., 2008. Similarly, Turkhede *et al*. (1996) reported that incorporation of *Gliricidia* leaves at 5 t ha^{-1} significantly increased grain yield of rice over no green leaf manure. Net returns and B:C ratio recorded from *Gliricida* biomass treated plots was far higher than that of FYM treated plots due to relatively higher procurement cost of the latter.

Gravimetric soil moisture content recorded at three different stages of rice crop and at two depths of surface soil was significantly affected by treatments (Table 4). Plots receiving FYM/ *Gliricidia* @ 5 t ha^{-1} over and above soil farmers' practice exhibited almost similar results, but significantly higher soil moisture content at all the stages and at both the depths, than the plots receiving either only recommended dose of chemical fertilizers or lower amount of these amendments. Use of 2.5 t ha^{-1} FYM/ *Gliricidia* in conjunction with 50% RDF and bio-fertilizers had resulted in slightly lower soil moisture than with the use of higher rates of FYM and *Gliricidia*. Higher moisture content in plots treated with higher amount of FYM and *Gliricidia* amendments alone or with their

Table 4. Effect of integrated nutrient management on soil moisture content at different stages of crop growth

Treatment	Moisture content (%)					
	At tillering		At panicle emergence		At maturity	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Farmers' practice (FP: FYM 2.0 t ha^{-1} + Urea 25Kg ha^{-1}+ DAP 25 kg ha^{-1})	18.36	19.85	13.45	15.12	12.21	14.58
FP+ PSB @ 2.5 kg ha^{-1} +Azotobacter @2.5 kg ha^{-1}	18.42	19.92	13.92	15.61	12.56	14.85
FP +*Gliricidia* @ 5 t ha^{-1}	21.45	23.48	16.53	18.65	15.68	17.90
FP+FYM @ 5 t ha^{-1}	22.05	23.81	16.51	18.57	15.62	17.82
RDF (40-20-20 N:P:K)	17.88	19.34	13.25	15.05	12.0	14.52
50 % RDF+ FYM @2.5 t ha^{-1} +PSB @2.5 kg ha^{-1}+ Azotobacter @2.5 kg ha^{-1}	20.35	22.00	15.45	17.43	14.36	16.75
50 % RDF+ *Gliricidia* @2.5 t ha^{-1} +PSB@2.5 kg ha^{-1}+ Azotobactor.@2.5 kg ha^{-1}	20.22	21.96	15.28	17.36	14.25	16.65
CD (P=0.05)	3.1	3.45	2.3	2.58	2.24	2.41

lower amount in combination with chemical and bio-fertilizers could be due to improvement in soil aggregation, infiltration rates and water holding capacity (Tester, 1990 and Werner, 1997). In general, moisture content was higher in lower layer (15-30 cm) than in the surface layer (0-15 cm) due to fine texture of the lower layer, and greater extraction of moisture by crop from the upper soil layer. Moisture content recorded at maturity was considerably lower than at tillering and panicle emergence stages. This could be due to higher antecedent moisture contents, cloudy weathers, and low temperatures during early and mid monsoon months (tillering and panicle emergence) and clear weather, high temperatures, and low antecedent moisture contents during maturity stage.

Estimation of soil properties after completion of 2 years experimentation showed that effect of treatments on physical as well as chemical properties of soil was significant for all the treatments with respect to control (Table 5). Application of *Gliricidia*/FYM in addition to farmers' practice, significantly reduced bulk density of surface soil as compared to those treatments which included either in low amount or no amount of these amendments. Similar results have been reported by Tester (1990) and Werner (1997). Other treatments did not differ significantly for bulk density. pH of the surface soil was not affected significantly by the treatments; it remained in slightly acidic range in almost all the treatments. Similar effects of organics have been reported by Gopinath *et al*. (2008).

Treatments involving either FYM or *Gliricidia* @ 5 t ha^{-1} each, over and above farmers' practice, and supply of 2.5 t ha^{-1} of FYM or *Gliricidia* alongwith 50% RDF and biofertilizer (PSB and *Azotobactor,* 2.5 kg ha^{-1} each) resulted in similar soil organic carbon content. However, all these treatments recorded significantly higher organic carbon content over farmers' practice and farmers' practice + bio-fertilizers. Higher organic carbon content in plots amended with higher rates of FYM and *Gliricidia* or with lower rates of these manures alongwith mineral fertilizers and bio-fertilizers could be due to direct addition of organic matter and increased root biomass and its recycling. Available N, P and K status of soil was also significantly affected by treatments. Plots supplied with 5 t ha^{-1} *Gliricidia* over and above farmers' practice had the highest amount of available N (295.7 kg ha^{-1}) which was significantly higher than all other treatments. Again, application of 2.5 t ha^{-1} *Gliricidia* along with 50% RDF and bio-fertilizers, being next best treatment, significantly enhanced soils available N-status. This could be ascribed to higher N content of *Gliricidia* and its role in stimulating microbial activity, contribution of *Azotobactor* by fixing atmospheric N (Rao, 2007), and increased mineralization of organically bound soil N (Bharadwaj and Omanwar, 1994). Whereas, the highest available P content was recorded in the treatment having 50% RDF + 2.5 t ha^{-1} FYM + 2.5 kg ha^{-1} each of PSB and *Azotobactor* (31.4 kg ha^{-1}) which was similar to the treatment having 50% RDF + 2.5 t ha^{-1} *Gliricidia* + 2.5 kg ha^{-1} each of PSB and *Azotobactor* but significantly higher than all other treatments. Available K status was also significantly

Table 5. Soil status after 2 years of experimentation

Treatment	Bulk density (g cc^{-1})	pH	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available-K (kg ha^{-1})
Farmers' practice (FYM 2.0 t ha^{-1} + Urea 25Kg ha^{-1} + DAP 25 kg ha^{-1})	1.51	6.32	0.27	192.6	12.3	327.5
FP+ PSB @ 2.5 kg ha^{-1} +Azotobacter @2.5 kg ha^{-1}	1.50	6.30	0.29	200.4	15.7	458.3
FP +*Gliricidia* @ 5 t ha^{-1}	1.44	6.34	0.36	295.7	15.7	371.1
FP+FYM @ 5 t ha^{-1}	1.42	6.34	0.38	242.5	16.8	251.3
RDF (40-20-20 N:P:K)	1.50	6.31	0.36	229.5	20.2	283.9
50 % RDF+ FYM @2.5 t ha^{-1} +PSB @2.5 kg ha^{-1} + Azotobacter @2.5 kg ha^{-1}	1.46	6.33	0.37	238.2	31.4	349.3
50 % RDF+ *Gliricidia* @2.5 t ha^{-1} +PSB@2.5 kg ha^{-1} + Azotobacter.@2.5 kg ha^{-1}	1.47	6.34	0.37	265.8	29.6	338.4
CD (P=0.05)	0.05	NS	0.08	20.5	2.2	22.4

higher in the *Gliricidia* containing treatments as compared to others which could be due to very high K content of *Gliricidia* biomass and quick release into the soil.

Looking into the significant improvement in growth, yield, net returns, soil moisture retention, organic carbon and nutrient status of soil, and reduction in bulk density of plough layer, it could be concluded that *Gliricidia* biomass (leaves and twigs) is a potential source of nutrients for upland rice, and even can be a better option than FYM. The combination of *Gliricidia* 2.5 t ha^{-1} + bio-fertilizers + 50% RDF is the most productive and remunerative integrated nutrient management practice for eastern ghats of Orissa.

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