Africa Rice Center (WARDA)
pp. 117 - 122, 2006

ISSN 2070-3678

Green manuring for soil fertility management for rice: A review

P.A. Ibrahim[1], A.O. Osunde[2], A. Bala[2] and F.D. Ibrahim[2]
[1]National Cereals Research Institute Badeggi, P.M.B. 8 Bida, Niger State, Nigeria
[2]School of Agric and Agricultural Technology, Federal University of Technology Minna, PMB 65, Minna, Niger State, Nigeria

Abstract

Organic manures are now regaining popularity due to increase in mineral fertiliser costs and greater concern for sustainability of productivity. Scientists at the National Cereals Research Institute Badeggi in Nigeria have developed and introduced to farmers a pre-rice green manure technology using *Sesbania* and *Aeschynomene* spp. as organic (N) nutrient source along side recommended mineral fertiliser and farmers' practice. Results obtained from various trials conducted on farmers' fields at various locations in Niger state of Nigeria showed increase in rice grain yield of between 2 – 4.2 t ha^{-1} resulting from the organic fertiliser sources. These yields are comparable to those from recommended inorganic (NPK) fertiliser and farmers practices. This, therefore, shows that the pre-rice green manure legumes have potential to serve as supplements or even alternatives to inorganic fertiliser where the latter is not readily available. The green manuring technology is also found to be economically viable leading to adoption by the resource-poor farmers.

Keywords: Green manure legumes, economics, technology adoption, inorganic fertiliser

Introduction

Rice *(Oryza sativa L.)* is a major staple food crop, globally cultivated on 150 million ha, with a production of 563 million tons (FAO, 1998). It is grown under different intensive cropping systems and in varied soil types both as irrigated and rainfed crop. Nutrient defiencies constitute a major constraint to increasing rice productivity. Therefore, rice production cannot be increased unless the declining trend in soil fertility is reversed adequately. Application of inorganic fertilisers to rice fields to correct nutrient deficiencies is limited by scarcity and high cost of the materials which is often out of reach of an average resource-poor farmer.

In traditional rice systems, soil fertility was generally maintained by keeping the fields under fallow and applying organic fertilisers. Several promising new technologies such as recycling of crop residue (Westcott and Mikkelson, 1988) and green manuring (Beri and Meelu, 1981) have been studied as alternatives for a better management of agricultural resources in lowland rice based cropping system. Green manure, especially nitrogen fixing legumes (Giller, 2001) provide a more feasible option and form a viable component of integrated nutrient management in rice-based cropping systems (Palaniappam and Siddeswaran, 1993).

Nitrogen fixing green manure technology involves incorporating easily decomposable green and fresh plant materials into the soil to supply nutrients especially nitrogen (N), to the subsequent crops. Green manuring techniques differ in different rice-growing regions. In the lowland ecosystems of Badeggi, Central Nigeria, rice seedlings are transplanted into puddle fields in which the green manure legumes, *Sesbania* and *Aeschynomene spp* are incorporated.

The green manure legumes are usually seeded on ridges or mounds, which are usually constructed at the on-set of rains to conserve moisture and harvested at 50 – 60 days after planting, chopped to pieces and manually incorporated into the soil.

Growing green manure species such as sunn hemp or dhaincha (*Sesbania aculeate* pers.) during pre-rice summer season and *in-situ* incorporation into soil is the normal practice in the lowland irrigation rice systems (Abrol and Palaniappan, 1988).

A wide range of legumes have traditionally been used as green manures in Asia, including some grain legumes, such as cowpea or mungbean (Giller, 2001). However, it is the stem-nodulating species *Sesbania rostrata* and *Aeschynomene spp*. that have attracted much research interest because of their adoption to waterlogged condition. Stem-nodulating species, such as *A. afraspera* and *S. rostrata* have the advantage of being fast growing (Alazard and Becker, 1987) and capable of fixing N_2 under water logged condition (Becker and George, 1995).

In Senegal, *A. afraspera* and *A. nilotica* were reported to have accumulated 420 – 530 kg N ha^{-1} in 7 weeks of growth (Alazard and Becker, 1987).

Green Manuring In Lowland Rice-based systems In Nigeria. The International Institute of Tropical Agriculture (IITA) pioneered green manuring work in Nigeria in collaboration with WARDA, Cote d voire. In one of such trials at Ibadan, the performance of *Sesbania* *rostrata* as *N* source to lowland rice was reported as "encouraging" (Mulongoy, 1986). In another trial, the use of *S. rostrata* mulch resulted in a rice yield of 3.6 t ha^{-1} compared with 2.7 t ha^{-1} in the control plots. Ibrahim *et al.* (2000) reported similar results at Badeggi, Central Nigeria where *Sesbania rostrata, S. emerus* and *A. afraspera* gave rice grain yields of 2.7, 3.05 and 2.2 t ha^{-1}, respectively, against 2.1 t ha^{-1} from the control plot (Table 1). Earlier on, (NCRI, 1996) in long term soil fertility trial in irrigated lowland rice, combinations of *Sesbania rostrata* and inorganic fertilisers resulted in rice grain yields ranging between 1.49 to 3.05 t ha^{-1}. The summary of four years data (1992 - 96) confirmed the response of rice to organic fertilisation (Table 2).

Following the identification of *Aeschynomene indica* through a survey by Scientists from NCRI and IITA in 1990 and the acknowledgement by farmers of the ability of this stem and root nodulating legumes to improve rice yields (Carsky and Ajayi, 1990) conscious efforts have been made through on-station and on-farm studies at Kuta, Chanchaga, Musa, Majin-Gari to evaluate the potentials of these legumes. Results so far obtained showed grain yields of 1.42 to 4.8 t ha^{-1}, which was encouraging (Table 3).

Economics of green manuring. In spite of the positive influence of green manures on increased yield of crops and improved soil fertility, farmers are reluctant to devote land and resources for growing legumes solely for green manures, because it provides no immediate income or food (Buresh and De Datta, 1991). The economic viability of including green manure in rice system has been brought out by many researchers. Ibrahim (1997) reported that green manuring in lowland rice production in Badeggi, Central Nigeria, using *Sesbania rostrata, S. emerus* and *Aeschynomene afraspera* is economically viable since the cost / benefit ratio is greater than 1 for all the green manure treatments and the net income analysis showed that the application of *S. emerus* was the most profitable as N

Table 1: Effects of green manuring and inorganic fertilisers on lowland rice in Badeggi, Nigeria.

Treatment	Paniicle number	Panicle Length (cm)	1000 grain weight (g)	Rice grain yield (kg /ha)
Sesbania rostrata	17	22	12.3	2772
Sesbania emerus	16	21.4	10.6	3050
Aeschynomene afraspera	15	22.4	10.7	2219
40 kg N/ha as Urea	12	21.9	7.4	2572
80 kg N/ha as urea	12	21.4	10.1	2900
control	13	22.2	7.9	2130
LSD (0.05)	6.55	2.6	3.67	1447.6
CV%	18.2	7.2	24.79	35.7

Source: Modified from Ibrahim *et al.* (2000).

Table 2: Effect of continous application of macro and micro nutrients and organic manure on grain yield of lowland rice (1992 - 1996 cropping season).

Tréatment	Grain yield (t/ha)				
	1992	1993	1995	1996	Mean
Control	2.22^{c}	1.41^{bc}	1.67^{g}	1.33	1.66
N	2.24^{c}	1.66^{bc}	1.93^{fg}	2.10^{bc}	1.98
NP	2.24^{c}	1.83^{bc}	2.20^{e-g}	1.87	2.04
NK	1.90^{c}	1.67^{bc}	2.60^{ce}	1.83	2
PK	2.14^{c}	1.30^{c}	2.40^{df}	1.69	1.88
NPK	2.35^{ab}	1.71^{bc}	2.53^{de}	2.11^{bc}	2.18
NPKZn	2.35^{ab}	1.71^{bc}	2.87^{b-d}	2.42^{ab}	2.34
NPKS	2.44^{ab}	1.71^{bc}	2.78^{b-e}	2.11^{bc}	2.26
NPKZnS	3.13^{a}	1.94^{bc}	2.79^{a-d}	2.33^{ab}	2.55
NPK & SesbanIa	3.05^{ab}	1.89^{bc}	3.16^{a-c}	2.00^{bc}	2.53
NPK & Rice straw	1.94^{c}	1.49^{bc}	2.84^{b-d}	1.95	2.06
NPK + Sesbania	2.48^{ab}	1.96^{b}	3.31^{ab}	2.25^{bc}	2.5
NPKS + Sesbania	2.53^{ab}	4.59^{a}	3.51^{a}	2.95^{a}	3.4

Means followed by the same letters along columns are not significantly different from each other ($P = 0.05$). Source: Modified from NCRI, 1996.

source for the area (Tables 4 and 5). Combined application of green manure and mineral fertilizer N to rice produced high net returns (Padmavathy, 1992).

Economics of adoption of green manuring. Although most organic nutrients are not purchased, they require land, labor, and other inputs for their production and application. Low nutrient content and high bulkiness associated with organic sources mean that the effective price of nutrients from these sources tends to be higher than that for chemical fertilisers. The high cost of organic nutrients was the major reason for a rapid decline in their

Table 3: Response of rice yield parameters to fertiliser sources in Badeggi (2005).

Treatment	Tiller number	Panicle number	Panicle length	Rice plant height (cm)	Straw/ grain weight (g)	1000 grain weight (g)	Grain yield (t/ha)
Aeschynomene only	24.3bc	23	21.3	102.3	850	29.3	4.2
Aeschynomene + 15F	26.0b	25.3	21.5	102.5	925	29.3	4.6
Aeschynomene + 45P	22.8bc	24	21.5	98.5	775	28	4
Sesbania only	24.5bc	23.8	21.8	98.5	962.5	29.9	4.8
Sesbania + 15P	23.8bc	22.3	21.5	98.8	890	28.5	4.4
Sesbania + 45P	21.5c	22	22	101	962	28	4.8
Recommended NPK	32.3a	27.3	21.8	100	1062.5	29.7	5.3
Control	22.3bc	23	21.3	99.3	1087.5	27.7	4.7
LSD (0.05)	4.17	NS	NS	NS	NS	NS	NS
CV%	11.5	17.8	2.79	3.82	33.38	6.16	36.41

Source: NCRI, 2003.

Table 4: Input and output levels for production of an hectare of lowland rice under integrated fertilizer management in Nigeria.

	Treatments					
Economic elements Land	T1	T2	T3	T4	T5	T6
1. Labour inputs (Man-days/ha) Land preparation						
Planting of green manure legumes	43	43	43	43	43	43
Weeding of green manure plots	5	5	5	-	-	-
Nursery bed preparation	5	5	5	-	-	-
Seedling in the nursery	3	3	3	3	3	3
Weeding (2x)	2	2	2	2	2	2
Incorporation of green manure	21	21	21	21	21	21
Transplanting of rice	25	25	25	-	-	-
Fertilizer application (2x)	17	17	17	17	17	17
Opening of drainage channels	-	-	-	5	10	-
Harvesting	4	4	4	4	4	4
Threshing	15	15	15	15	15	15
Transportation	13	13	13	13	13	13
2. Non-labour input (kg/ha)	2	2	2	2	2	2
Rice seeds						
Green manure seeds	50	50	50	50	50	50
Fertilizer (Urea)	10	10	10	-	-	-
3. Output (kg/ha)	-	-	-	87	174	-
Rice grain yield	2772	3050	2219	2572	2900	2130

T1 = *Sesbania rostrata*; T4 = 40kg N/ha; T2 = *Sesbania emerus*; T5 = 80kg N/ha; T3 = *Aeschynomene;* T6 = control.
Source: Ibrahim, 1997.

Table 5: Cost and benefit analysis of different sources of fertilizer on lowland rice production in Badeggi, Nigeria.

Items	Treatments					
	T1	T2	T3	T4	T5	T6
A. Variable cost/ ha						
Labour at ₦80 / man-day	12400	12,400	12400	10,080	10,400	9,600
Rice seed at ₦70/kg	3500	3500	3500	3500	3500	3500
Green manure seed at ₦10/kg	100	100	100	-	-	-
Fertiliser at ₦12 /kg	-	-	-	1044	2,088	-
Total variable cost	16,000	16,000	16,000	14,624	15,988	13,100
B. Gross benefit (₦/Ha)						
Value of rice grain at ₦ 40/kg	110,880	122,000	88,760	102,880	166,000	85200
C. Net income						
Net Income (profit) (B – A)	94,880	106,000	72,760	88,256	100,012	72,100
D. Benefit / Cost ratio B/A	6.93	7.63	5.55	7.04	7.23	6.5

T1 = *Sesbania rostrata*; T2 = *Sesbania emerus*; T3 = *Aeschynomene afraspera*; T4 = 40kg N/ha; T5 = 80kg N/ha; T6 = control; ₦ = Naira (Nigeria currency)

Source: Ibrahim, 1997.

use in Japan, where farmers used commercial organic fertilisers extensively during the Meiji Era (Kanazawa, 1984).

The weak extension mechanism and low input supply to farmers in the developing countries is responsible for low adoption rate of new agricultural technologies available at the research stations which renders such innovations useless.

In a recent study, however, the adoption of green manuring technology in the rice growing areas of Central Nigeria using the regression model, reported adoption rate of 44% which was considered fairly high (NCRI, 2003).

A close analysis of the adoption of green manure as a source of nutrient or as an alternative to inorganic fertiliser reveals a relatively low cost of production. Costs of transportation, loading and off loading, as well as other costs associated with movement of inorganic fertiliser from point of purchase to the farmers field are eliminated, thus leading to an appreciable increase in farmer's income benefit. Farmers in the area were, therefore, encouraged to make use of green manure (Table 6) in addition to credit.

Constraints to green manuring practice in rice-based cropping systems in Nigeria. The practice of green manuring is restricted to the inland valley (IV) ecosystems and irrigated lowlands, where water requirements of both the legumes and rice crop are met. However, the land tenure systems and inadequate infrastructural facilities are high constraints that hinder the effective development of the IVs for crop production in the Nigeria Savannas. The Chiefs and Emirs hold the IVs in trust for the community and accessibility is restricted (Bala *et al.*, 1995).

The challenges of green manuring technology in the IVs and the irrigated lowlands are enormous. The IV ecosystems are associated with many debilitating diseases such as guinea-worm, malaria and river blindness, which very often, ravaged the farming population around these ecosystems, thus further decreasing the labour force available for the cultivation of the IVs.

Another major constraint of this technology is the insect pest problems associated with some of the legumes used. Plant defoliators such as *Phaedonia areata* and *Lagria villosa* are common pests of the *Sesbania spp* in central Nigeria. These can cause total defoliation of planted field within days because of the succulent and Luxuriant growth nature of the legumes. The continued use of these legumes must be programmed to escape the period of attack from these pests.

Conclusion

Integrated organic and inorganic fertiliser management in rice-based systems in Nigeria is inevitable for the fact that, no single source of nutrients can be said to be appropriate for soil fertility maintenance in the farming

Table 6: Cost and benefit analysis of different sources of fertilizer on lowland rice production in Badeggi, Nigeria.

Variables	Co efficient	T- Value
Age	-0.101	-0.564
Household	0.0241	1.2038
Literacy level	0.0003	0.2415
Farming experience	0.0075	0.6272
Land ownership	0.3343	1.9429
Extension contact	0.128	0.9626
Membership cooperatives	0.141	0.6004
Farm size	0.0207	0.587
Credit	0.3781	2.58817*

*Significant at 5% level.
Source: NCRI, 2003

Ordinary least square regression.

$$Y = B_o + b_1x_1 + b_2x_2 + b_3x_3 \text{ ———————— } B_9X_9 + U$$

Where

X_1 = Age of farmer
X_2 = Household size
X_3 = Literacy level (in number of years)
X_4 = Farming experience (in years)
X_5 = Land Ownership (1 for Ownership, 0 for otherwise)
X_6 = Extension Contact (number of times / month)
X_7 = Membership of cooperatives (1 for membership, 0 for otherwise)
X_8 = farm size (Ha)
X_9 = Access to credit (1 for user, 0 for otherwise)
B = Coefficient
U = Error term
Y = Adoption of green manure.

systems. The soils are poor and deficient in nutrients and therefore require external supply of nutrients through fertilisation. However, inadequate supply and high mineral fertiliser prices have placed the resource-poor farmers at disadvantage hence the need to encourage the use of organic fertiliser amendments to complement the mineral fertilisers where the latter is available.

Acknowledgement

The authors are grateful to the National Cereals Research Institute (NCRI) Badeggi, Nigeria for providing an enabling environment and funds for these projects. Similarly, the active collaboration by the International Institute of Tropical Agriculture (IITA) Ibadan, ROCARIZ / WARDA, Benin and the Federal University of Technology, Minna Nigeria is highly appreciated.

References

Abrol, I. P and Palaniappan, S. P. 1988. Green Manure Crops In Irrigated and Rainfed Lowland Rice-based Cropping System. *In*: Sustainable Agriculture: Green Manure in Rice Farming. pp. 71 – 82. The International Rice Research Institute, Los Banos, Philippines.

Alazard, D. and Becker, M. 1987. *Aeschynomene* as green manure for rice. Plant soil 101:141 – 143.

Bala, A., Osunde, A. O. Oladiaran, j. A., Gana, F. S., Odofin, J. A., Salako, E. A. and Ezenwa, M. I. S. 1995. Potentials, problems and management of inland Valleys of West Africa for sustainable crop production with special delivery emphasis on Niger State of Nigeria. Paper presented at the 1st Inland valley consortium workshop. NCRI, Badeggi Nigeria, 17 – 19 March, 1995.

Becker, M. and George, T. 1995. Nitrogen fixation response of stem and root-nodulating. *Sesbania* Species to flooding and mineral nitrogen. Plant soil 175:189 - 196.

Beri, V. and Meelu, O.P. 1981. Substitution of nitrogen through green manure in rice. India Farming 31 (2): 3 – 4.

Buresh, R. J, and De Datta, S. K. 1991. Nitrogen dynamics and management in rice legume cropping systems. Advances in Agronomy 45: 1 –59.

Carsky, R. J. and Ajayi, E. O. 1990. Fitting Soil improving legumes into Inland Valley rice-based cropping systems in West Africa. In: Mulongoy, K., Gueye, M and Spencer,

D. S. C (eds). Biological nitrogen fixation and sustainability of tropical agriculture. John Wiley and Sons Ltd. UK. pp. 395 – 404.

FAO (Food and Agriculture Organization of the United Nations). 1998. FAO production year book 1997. Rome, Italy: FAO.

Giller, K. E. 2001. Nitrogen fixation in tropical cropping system. 2nd Edition CABI publishing, Walling ford, UK. pp. 423.

Ibrahim, P.A. 1997. Effects of green manuring on Lowland rice in Badeggi, Central Nigeria. M.Sc (ag) Thesis (unpul), University of Ibadan, Nigeria. 48 pp.

Ibrahim, P. A., Carsky, R. J., Aiyelari, E.A . and Misari, S.M 2000. Stem – nodulating legumes as pre-rice green manure in Badeggi, Nigeria. Nigeria Journal of Soil Science 12: 100 – 106.

Ibrahim, P.A., Tiamiya S. A., Osunde, A. O Ibrahim F.D and Alabi, M.O. 2006. On-farm evaluation of green manure legumes on lowland rice in Central Nigeria. Paper presented at the Africa Rice Congress of ROCARIZ / WARD held at M-plaza hotel, between 27th September to 1st October 2004 at Accra, Ghana.

Kanazawa, N. 1984. Trends and economic factors affecting organic manure in Japan. *In:* Organic matter and rice. Manila (Philippines). International Rice Research Institute. pp. 557 – 568.

NCRI, 1996. Nationally Coordinated Pesearch programme on rice. Annual Report. National Cereals Research Institute, Badeggi, Nigeria.

NCRI, 2003. Farming Systems Research Programme. Annual Report. National Cereals Research Institute, Badeggi Nigeria.

Padmavathy, V. K. 1992. Effect of green manures and green gram on the economy of nitrogen management in rice-based cropping system. M.Sc (Ag) Thesis, Tamil Nadu Agricultural University, Coimbatore, India. 133 Pp.

Palaniappan, S. P. and Siddeswaran, K. 1993. Nitrogen uptake of rice as influenced by green manure, grain legumes and fertiliser N. Paper presented at the SARP Workshop on crop and soil management 1 – 10 November 1993, Suweon South Korea.

Sakala, W. D., Kumwenda, J. D.T. and Saka, A. R. 2004. Potential of green manures to increase soil fertilizer and maize yields in Malawi. In: managing nutrient cycles to sustain soil fertility in sub-saharan Africa. (Andre' Bationo Ed) Academy Science Publishers (ASP) Nairobi, Kenya. pp. 374 – 383.

Westcott, M.P. and Mikkelson, D. S. 1988. Effect of green manure on soil fertility in the United State. In: Green manure in rice farming. pp. 257 – 274. International Rice Research Institute (IRRI) Manila, Philippines.