# Note

# *Sesbania rostrata* as green manure for lowland rice in Casamance (Senegal)

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**The stem-nodulating tropical legume, *Sesbania rostrata*, was grown for seven consecutive years for 35–42 days in the pre-rice niche of traditional Casamance (south Senegal) rainfed lowland fields under the management of both researchers and farmers. The incorporation of about 25–35 Mg ha$^{-1}$ of fresh green manure (GM) biomass resulted in an average N accumulation of 90–150 kg N ha$^{-1}$. Lowland rice-grain yields increased from 2 Mg ha$^{-1}$ in weedy fallow control plots to about 4 Mg ha$^{-1}$ where seed-inoculated *S. rostrata* was incorporated. *Sesbania rostrata* GM technology may contribute to increase rice production in Casamance and warrants to be extended to regions with similar conditions.**

Keywords: Green manure; Nitrogen; *Sesbania rostrata*; Senegal

Rice is a major staple food in West Africa and Asia. In these countries the N requirements for rice-crop growth are rarely met from mineral fertilizer alone, and the use of legume green manure (GM) presents an attractive alternative. Asian rice farmers have traditionally used GM to improve soil fertility and increase rice yields (Singh *et al.*, 1991; Ladha *et al.*, 1992). African farmers, however, have little experience with GM use (Roy *et al.*, 1988), and lowland systems are usually not mechanized, making adoption of GM technology difficult in many instances.

Green manure use of West African lowland rice systems received renewed research attention with the identification of the root and stem-nodulating *Sesbania rostrata* (Dreyfus and Dommergues, 1981), a legume that grows naturally in many waterlogged soils of West Africa. High growth rates combined with an exceptionally high $N_2$-fixing potential and tolerance to soil flooding make *S. rostrata* a promising legume for short-duration GM use in the pre-rice niche of flooded lowlands (Dreyfus *et al.*, 1985). As a result of extension efforts based on several agronomic experiments on *S. rostrata* GM use in Asia and West Africa (Rinaudo *et al.*, 1988; Ladha *et al.*, 1992), farm-level adoption of GM technology has been increasing in some Asian countries (Mar *et al.*, 1992). Despite the fact that *S. rostrata* is indigenous to West Africa, it is currently not used in the traditional rice-based system of the region. Research on GM has been limited and has been concentrated mainly on demonstration trials.

Casamance (south of Senegal) is a significant rice-growing area in West Africa. Paddy fields are bunded and flooded by trapping rain, surface flow, and run-off water. Little or no mineral fertilizer is applied and, as a result, lowland rice yield rarely exceeds 1.5 Mg ha$^{-1}$. The soils are highly deficient in N and are often subject to dry-season salt-water intrusion. In addition, oxidation of sulfides make these soils prone to acidification (Pons, 1969; Sylla, 1994). The application of GM can add biologically fixed N to the system, help alleviate acidity and salt-related soil problems (Arunin *et al.*, 1988), and may improve the currently low yield level. The integration of *S. rostrata* into the existing cropping calendar of Casamance seems feasible since the rainy season starts in June, and rice is only transplanted in late August. The natural occurrence and the widespread distribution of the legume, the near total absence of mineral N fertilizer use, farmers' access to animal traction for GM incorporation, and a time span of 7–10 weeks for growth of a flood-tolerant GM in the pre-rice niche combine to provide potentially favourable socioeconomic and agronomic conditions for the farm-level adoption of *S. rostrata* GM technology in the Casamance.



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The objectives of the present study were to confirm the reported potential of *S. rostrata* for rice-yield increase at farm level, and to identify major constraints to its use in the traditional lowland rice-based systems of the Casamance.

## Materials and Methods

One researcher-managed trial and six farmer-managed trials were conducted in Casamance in the villages of Fanghote (one trial per year for four years) and Oussouye (one trial per year for two years). An average rainfall of 1000 mm in a monomodal distribution allows traditional farmers to grow a single crop of rainfed lowland rice, preceded and followed by weedy fallow. Temperatures during the rice-growing season range from 30 to 35°C. The experimental soil is Sulfaquent [clay, with a pH of 4; 5% organic C; 0.1–0.2% total N; 0.3% Olsen-P; and 0.2–0.3 meq $(100\text{-g})^{-1}$ exchangeable K].

Seeds of *S. rostrata* were collected from wild-growing plants in the region. To break dormancy, cleaned seeds were immersed in hot water (95°C) and left soaking in the cooling water for 10 h. With the onset of the first rains, *S. rostrata* seeds were broadcast at 7 kg $ha^{-1}$ (corresponding to approximately 50 seeds $m^{-2}$) on a soil that was previously cleared and ploughed as per traditional practice. In the researcher-managed trial, legume seeds were inoculated (2 days, continuous shaking at 30°C) with a liquid yeast–lactate culture of the specific *Azorhizobium caulinodans* strain ORS 571 (Dreyfus *et al.*, 1988). Twenty kilograms P $ha^{-1}$ (TSP) and 40 kg K $ha^{-1}$ (KCl) were basally applied, and the stems of 20-day-old *S. rostrata* plants were additionally inoculated by spray application of a diluted rhizobial broth suspension. No fertilizer or stem-inoculation was applied in the farmer-managed trials. Twenty-five-day-old seedlings of the improved lowland rice variety IR 1529 (120 days) were transplanted in the flooded or saturated soil at a 10 cm × 20 cm spacing one week after weed or GM incorporation.

In 1988 a researcher-managed trial was laid out in a randomised complete block (RCB) with eight replications and 40 $m^{-2}$ plot size, comparing an unfertilized control (weedy fallow), mineral fertilizer N (60 kg urea-N in three equal applications), and incorporation of 42-day-old, *in situ* grown, *S. rostrata* GM. During the subsequent six years, farmer-managed trials compared rice-grain yield after incorporation of the traditional weedy fallow with that of 35- to 42-day-old *S. rostrata* GM in parts of the communal village rice fields. Average yearly plot size varied between 3 000 and 10 000 $m^2$. The residual effects from one GM application on the grain yields of a subsequent unfertilized rice crop was evaluated in 1993 in the village of Oussouye.

Fresh legume biomass was determined before incorporation (35–42 days after seeding) in composite samples from ten 1-$m^2$ sampling areas per replication. *Sesbania rostrata* plants were chopped by hand and incorporated into the water-saturated soil using a shovel-like traditional tool (*Kajendou*). Rice yield was determined at maturity on a whole-plot basis. The N content of *S. rostrata* was determined by the micro-Kjeldahl procedure. Treatment means from eight replications in the researcher-managed trial and from two and four years in farmer-managed plots were subjected to mean comparison at the 5% level using Fisher's test (LSD).

## Results

### Researcher-managed trial

*Sesbania rostrata* established rapidly and after three weeks grew at rates of up to 10 cm per day. Spray-inoculation resulted in profuse nodulation of the stems. The fresh biomass accumulation of six-week-old plants was 35 Mg $ha^{-1}$ (equivalent to 7 Mg $ha^{-1}$ of dry matter), corresponding to about 150 kg N $ha^{-1}$. Lowland rice yield after incorporation of 35 Mg $ha^{-1}$ of *S. rostrata* biomass was 4.9 Mg $ha^{-1}$ compared to only 2.0 Mg $ha^{-1}$ without incorporation and to 2.9 Mg $ha^{-1}$ for the treatment which received 60 kg of urea-N. Nitrogen use efficiency (NUE) of organically applied N was significantly higher than that of mineral fertilizer N (20 vs 15 kg grain yield increase per kilogram of N applied). Data are summarized in Table 1.

### Farmer-managed trials

In farmer-managed trials in both villages, fresh GM biomass of 35- to 42-day-old *S. rostrata* was about 25 Mg $ha^{-1}$ corresponding to an average N accumulation of 100 kg $ha^{-1}$. Rice-grain yield in GM-treated plots was 3.9 Mg $ha^{-1}$ at the Fanghote site (average of four years) and 4.2 Mg $ha^{-1}$ at the Oussouye site (average of

**Table 1** Nitrogen input, rice-grain yield, and agronomic nitrogen use efficiency (NUE) on researchers' trials

| | Researchers' trials[1] | | |
|---|---|---|---|
| Treatment | N input (kg $ha^{-1}$) | Yield (Mg $ha^{-1}$) | NUE (kg $ha^{-1}$) |
| Control | 0 | 2.1 b | — |
| Urea | 60 | 2.9 b | 15 b |
| *Sesbania* | 150 | 4.9 a | 20 a |

[1]Mean of eight replications
Values followed by the same letter within a column do no differ significantly by Fisher's test: LSD (<0.05)

**Table 2** Nitrogen inputs, rice-grain yield, and agronomic nitrogen use efficiency (NUE) on six years farmers' trials

| | Farmers' trials | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Fanghote | | | | | | Oussouye | | | |
| Treatment | N input (kg ha$^{-1}$) | Yield (Mg ha$^{-1}$) 1 yr | 2 yr | 3 yr | 7 yr | NUE (kg kg$^{-1}$) | N input (kg ha$^{-1}$) | Yield (Mg ha$^{-1}$) 5 yr | 6 yr | NUE (kg kg$^{-1}$) |
| *Sesbania* | 0 | 3.3 a | 4.3 a | 4.0 a | 4.0 a | — | 0 | 4.1 a | 4.3 a | — |
| Control | 92 | 1.7 b | 2.2 b | 2.1 b | 1.9 b | 19 | 105 | 2.0 b | 2.1 b | 22 |

Values followed by the same letter within a column do no differ significantly by Fisher's test: LSD (<0.05)

two years), compared to 2.0 Mg ha$^{-1}$ in weedy fallow controls at both sites. The agronomic use efficiency of applied organic N was about 20 kg rice-grain increase per kilogram of N applied. Data are summarized in Table 2. Results from the 1993 trial at the Oussouye site indicate a significant 35% residual effect from *S. rostrata* GM application on the yield of a subsequent unfertilized crop of rice. Yields were 2.4 and 1.8 in *S. rostrata*-treated and traditional weedy fallow plots, respectively (data not shown).

## Discussion and Conclusions

Six years of farmers' experimentation on GM use in rice lowlands indicate that *S. rostrata* is a suitable biofertilizer for the temporarily flooded rice lowland ecosystems of the Casamance. Nitrogen inputs of approximately 100 kg ha$^{-1}$ in 35- to 42-day-old legume biomass doubled rice-grain yields. This supports previous reports from India and the Philippines (Ladha *et al.*, 1992). High yield increases and an NUE above that of split-applied mineral N indicate beneficial effects other than N nutrition from GM application. For example, the addition of large quantities of organic C and N is expected to contribute to the improvement of soil physical properties. Farmers' results are in agreement with findings reported earlier from Africa and Asia (Becker *et al.*, 1988; Dreyfus *et al.*, 1988; Rinaudo *et al.*, 1988; Mulongoy and Nguu, 1989; Ladha *et al.*, 1992). However, in comparison to Asia where reported residual effects range from 0 to 15% (Becker *et al.*, 1995), much higher residual effects were observed in Casamance. Alleviation of acidity and Fe toxicity as well as improved chemical and physical parameters of the soil due to GM application (Becker *et al.*, 1995) may be partly responsible for the dramatic increase in rice-grain yield (both direct and residual) under GM management at the study site. Continued application of GM may have beneficial long-term effects on system productivity (Ladha *et al.*, 1992).

Given the potential benefits from GM use, the adoption of *S. rostrata* technology by farmers and its large-scale use in Senegal's rice-farming systems need investigations. Survey data (Becker *et al.*, 1995) indicate the following key factors which might be responsible for limited farm-level adoption of GM technology in most Asian countries: (1) non-availability of legumes adopted for a specific condition, (2) problematic seed supply, (3) short time span available for GM growth in pre-rice niche, (4) relatively low cost and ready availability of mineral N fertilizer, and (5) high cost of labour for GM incorporation. The situation is different in Africa, where most small farmers cannot buy chemical fertilizers and therefore could widely benefit from the use of stem-nodulating legumes. *Sesbania rostrata* is indigenous and therefore well adapted to the Casamance environment. The time available for growing *S. rostrata* is sufficient to allow the integration of *S. rostrata* into the traditional rice-cropping systems. Furthermore, mineral N fertilizers are usually not available to rice farmers. These factors combined with the exceptional performance of *S. rostrata* create a favourable environment for potential adoption of this technology in Casamance.

African farmers have little experience with GM use (Roy *et al.*, 1988), and lowland systems are usually not mechanized, making adoption of *S. rostrata* GM technology difficult in many cases. Farmers can collect legume seeds from wild-growing plants around the paddy fields, but production is insufficient and plants are often severely attacked by insects which seriously inhibit *S. rostrata* growth. Consequently, farmers depend on seeds from abroad which are usually supplied to them for experimentations. These sometimes reach them late, which can cause delays in the cultural calendar. Farmers are now encouraged to assure their own farm-seed availability.

A drawback to using *S. rostrata* is the need for inoculation the first year of the GM establishment (Ndoye and Dreyfus, 1988). Fortunately, once introduced, the micro-organisms survive in the acid soils like those of Fanghote and Oussouye making a second inoculation unnecessary (Ndoye, pers. commun.). This property was previously observed in the Philippines and in India (Ladha *et al.*, 1992). A potential environment stress constraint is the annual moisture deficiency. The distribution of the rain during the wet season is usually uneven resulting in the surface layers of the soil becoming desiccated during GM growth. Nevertheless, the main limiting factor for large-scale adoption of GM technology in the rather specific case of Casamance is seen to be the incorporation of a large GM biomass. A range of technical options, including trampling and use of animal traction, need to be evaluated and tested in farmers' fields.

As a result of extensive efforts recently made by a large number of small-farmer organizations in West Africa, the use of *S. rostrata* could rapidly develop on a large scale in the traditional rice-based systems of the region (Boivin *et al.*, 1996). The trial site represents an environment that covers large areas including the Gambia, Guinea Bissau, and Guinea, and despite different socioeconomic conditions, the Casamance farmers' experiments are actually being tested by national programmes.

## References


Arunin, S., Dissatapom, C., Anuluxtipan, Y. and Nana, D. (1988) Potential of *Sesbania rostrata* as green manure in saline rice soil in Thailand, in: *Green Manure in Rice Farming* (ed. IRRI), Rice Res. Inst., Manila, Philippines, pp. 83–95

Becker, M., Ladha, J.K. and Ali, M. (1995) Green manure technology, potential, usage, limitation, A case study for lowland rice, *Plant and Soil* **174** 181–194

Becker, M., Ladha, J.K. and Ottow, J.C.G. (1988) Stem-nodulating legumes as green manure for lowland rice, *Philipp. J. Crop Sci.* **13** 121–127

Boivin, C., Ndoye, I., Molouba, F., de Lajudie, P., Dupuy, N. and Dreyfus, B. (1996) Stem nodulation in legumes: diversity, mechanisms, and unusual characteristics, *Crit. Rev. in Plant Sci.*(in press)

Dreyfus, B.L. and Dommergues, Y.R. (1981) Nitrogen-fixing nodules induced by *Rhizobium* on the stem of the tropical legume *Sesbania rostrata*, *FEMS Microbiol. Lett.* **10** 313–317

Dreyfus, B.L., Garcia, J.L. and Gillis, M. (1988) Characterization of ***Azorhizobium caulinodans*** gen. nov., a stem-nodulating nitrogen-fixing bacterium isolated from *Sesbania rostrata, Int. J. Syst. Bacteriol.* **38** 89–98

Dreyfus, B.L., Rinaudo, G. and Dommergues, Y.R. (1985) Observation on the use of *Sesbania rostrata* as green manure in paddy fields, *Mircen J.* **1** 111–121

Ladha, J.K., Pareek, R.P. and Becker, M. (1992) Stem-nodulating legume–*Rhizobium* symbiosis and its agronomic use in lowland rice, *Adv. Soil Sci.* **20** 147–192

Mar, M., Saing, T., Thein, T. and Palis, R.K. (1992) Sesbania green manure program for rice farming in Myanmar, in: *Proc.* Int. Rice Res. Conf., 21–25 April 1992, Int. Rice Res. Inst., Manila, Philippines

Mulongoy, K. and Nguu, N.V. (1989) Use of *Sesbania rostrata* in alley cropping system, in: Sesbania rostrata *International Congress*, Dakar, Senegal, pp. 121–125

Ndoye, I. and Dreyfus, B. (1988) $N_2$ fixation by *Sesbania rostrata* and *Sesbania sesban* estimated using N-15 and total N difference methods, *Soil Biol. Biochem.* **20** 209–213

Pons, L.J. (1969) *Acid Sulfate Soils of Thailand*, Dep. Land Dev. Ministry of Natl. Dev. Rep. SSR-81, Bangkok

Rinaudo, G., Alazard, D. and Moudiongui, A. (1988) Stem nodulating legumes as green manure for rice in West Africa, in: *Sustainable Agriculture. Green Manure in Rice Farming*, Int. Rice Res., Manila, Philippines, pp. 97–109

Roy, A.C., Wanki, S.B.C and Takow, J.A. (1988) Use of green manure in rice farming systems in West and Northwest Cameroon, in: *Sustainable Agriculture. Green Manure in Rice Farming*, Int. Rice Res., Manila, Philippines, pp. 333–342

Singh, Y., Khind, C.S. and Singh, B. (1991) Efficient management of leguminous green manures in wetland rice, *Adv. Agron.* **45** 135–189

Sylla, M. (1994) Soil salinity and acidity: spatial variability and effects on rice production in West Africa's Mangrove Zone, *Ph.D. thesis*, Wageningen University, The Netherlands, 175 pp.