In West Africa, the stem-nodulating legumes *Sesbania rostrata* and *Aeschynomene afraspera* generally behave as wild annual plants in periodically flooded soils. They are particularly sensitive to photoperiod and temperature; at the latitude of Senegal (15 °N), they grow well during the rainy season (Jun-Sep). *S. rostrata* and *A. afraspera* are fast-growing and fix \( N_2 \) more actively than most root-nodulating legumes. Stem nodules are less affected than root nodules by the inhibitive action of flooding and combined \( N \). Stem nodules result from the infection of predetermined sites with specific strains of *Rhizobium*. In nature, when soils already harbor native stem strains, nodules appear on the lower parts of the stems; however, their distribution is often irregular. Stem inoculation is generally recommended to optimize \( N_2 \) fixation. When used as green manure at the beginning of the rainy season, *S. rostrata* and *A. afraspera* can provide more than 100 kg N/ha to a rice crop, resulting in significant yield increases. *S. rostrata* also acts as a plant trap for the pathogenic nematodes *Hirschmanniella oryzae* and *H. spinicaudata*, the prevalent species in flooded ricefields in West Africa.

Nitrogen is one of the most important factors governing plant productivity; to produce 100 kg of grain, rice requires 1.8-2.0 kg N (Patnaik and Rao 1979). The plant absorbs N from three major sources: soil N, fertilizers, and biological \( N_2 \) fixation. In West Africa, soil N reserves are limited, and N fertilizers are often too expensive for African farmers. Biological \( N_2 \) fixation presents an appealing alternative to fertilizers that has often been underutilized. Roger and Watanabe (1984) reviewed the potential for practical utilization of biological \( N_2 \) fixation technologies in rice.

It is well known that long-term productivity may decline unless efforts are taken to maintain soil fertility. The utility of green manure for increasing soil productivity has been recognized from early times in some rice-growing areas, particularly China, India, and Northeast Asia (Jiao Bin 1983, Singh 1984, Watanabe 1984, Wen Qi-Xiao 1984). The potential benefits are many. Green manure can increase soil N content, concentrate P and significantly increase the available phosphate content in the soil, maintain and renew soil organic matter, and improve soil structure and physical characteristics (Jiao Bin 1983). \( N_2 \)-fixing plants that have been used as green...
1. Flowering behavior of Sesbania rostrata in response to daylength and mean weekly temperatures. Plants were sown in 30-liter PVC pots with a diameter of 30 cm and filled with 20 kg of Bel-Air soil (4 plants/pot). After 3 wk growth, the soil was kept waterlogged. Plants were inoculated by spraying the stems with a culture of Rhizobium ORS 571 3 wk after seeding, then at 2-wk intervals. Growth cycle = 13 wk. Arrows indicate beginning of flowering.

Potential N\textsubscript{2} fixation

We estimated N\textsubscript{2} fixation by S. rostrata during the 1985 rainy season using the \textsuperscript{15}N isotope dilution method and the difference method. There was good agreement between the methods. The results are as follows:

1. About 30 g N/m\textsuperscript{2} could be fixed in 53 d by S. rostrata, which confirms its high N\textsubscript{2}-fixing potential (Table 2).

<table>
<thead>
<tr>
<th>Planting date</th>
<th>Plant height (m)</th>
<th>N content (g/plant)</th>
<th>Stem ARA (\textsuperscript{15}C\textsubscript{2}H\textsubscript{4}/plant per h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>22 Feb</td>
<td>0.19</td>
<td>0.38</td>
<td>0.85</td>
</tr>
<tr>
<td>22 Mar</td>
<td>0.18</td>
<td>0.39</td>
<td>0.84</td>
</tr>
<tr>
<td>17 May</td>
<td>0.31</td>
<td>0.72</td>
<td>1.34</td>
</tr>
<tr>
<td>12 Jul</td>
<td>0.76</td>
<td>1.54</td>
<td>2.13</td>
</tr>
<tr>
<td>6 Sep</td>
<td>0.72</td>
<td>1.49</td>
<td>1.80</td>
</tr>
<tr>
<td>4 Oct</td>
<td>0.28</td>
<td>0.82</td>
<td>0.77</td>
</tr>
<tr>
<td>1 Nov</td>
<td>0.23</td>
<td>0.29</td>
<td>0.35</td>
</tr>
</tbody>
</table>

*Mean of 4 replications, WAS = weeks after seeding.

2. Because of stem modulation, S. rostrata can actively fix N\textsubscript{2} even in waterlogged conditions (Dallquiries et al. 1985). In a comparative study with S. rostrata in waterlogged soil, root modulation was poor. N\textsubscript{2}-fixing activity was due mainly to stem nodules (about 96% of total ARA) (Fig. 2).

3. Because acetylene reduction is an indirect method of estimating N\textsubscript{2}-fixing activity, integrating it into the curve that represents stem nodule activity provides a cumulative curve that allows a qualitative estimate of N\textsubscript{2} fixed at different plant ages (Fig. 2). We found that a) N\textsubscript{2} fixation in S. rostrata became significant 35 d after seeding (DAS), 14 d after inoculation; b) the N\textsubscript{2} fixed accumulated linearly

**Table 2.** N\textsubscript{2} fixation by 53-d-old S. rostrata as estimated by 2 different methods (Rinaudo and Moudiongui 1987).

<table>
<thead>
<tr>
<th>Method</th>
<th>N\textsubscript{2} fixation expressed as</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N (%) derived from N\textsubscript{2} fixation</td>
</tr>
<tr>
<td>Direct isotope dilution</td>
<td>38.6</td>
</tr>
<tr>
<td>Difference</td>
<td>43.5</td>
</tr>
</tbody>
</table>

*Mean value ± confidence interval (P=0.05). Containers were 30-liter PVC pots filled with Bel-Air soil, each with 4 plants inoculated with Rhizobium ORS 571 at 21 and 31 d after seeding.

**Figure 2.** Acetylene reduction activity (\textsuperscript{15}C\textsubscript{2}H\textsubscript{4}/plant per h) and Acetylene reduction (mmol \textsuperscript{15}C\textsubscript{2}H\textsubscript{4}/plant).

2. N\textsubscript{2}-fixing activity (acetylene reduction) of S. rostrata as a function of plant age. a) acetylene reduction activity, b) cumulated values.
Satisfactory stem nodulation is obtained by spraying the shoots with a suspension containing about $10^8$ bacteria/ml, using the following bacterial suspensions: liquid culture of *Rhizobium*, colloidal suspension obtained by mixing *Rhizobium* with a chitosan polymer (Jung et al. 1982). Seed inoculation with the same chitosan polymer is needed.

Inoculation is generally recommended to optimize *N₂* fixation by stem-nodulating legumes. The problem is choosing a suitable inoculation date.

Figure 3 shows the *N₂*-fixing activity (acetylene reduction) of *S. rostrata* as a function of plant age and planting date. Plants were inoculated at 3, 5, and 7 WAS. The *N₂*-fixing activity of 9-wk-old plants was the sum of activities of stem portions inoculated successively at 3, 5, and 7 wk.

The activity of each stem portion has been integrated to calculate the contribution of stem nodules—initiated at different inoculation dates—to total activity during growth.

Results show that the activity was mainly due to nodules initiated 3 and 5 WAS. If we attribute the nodules initiated by 3-wk-old plants to spontaneous nodulation (which affects the lower parts of the stems), then the most suitable date for inoculation is 5 wk. The corresponding stem nodules contributed about half the total *N₂*-fixing activity.

### Using stem-nodulating legumes as green manure

#### Microplot experiments

In microplot experiments during several rainy seasons, use of stem-nodulating legumes *S. rostrata*, *A. afraspera*, and *A. nilotica* as green manure significantly increased rice grain and straw yields and the *N* content of both grain and straw (Alazard and Becker 1987; Rinaudo et al. 1982, 1983; Rinaudo and Moudiongui 1987).

Experiments with *S. rostrata* were performed with two soils: Bel-Air soil, a typical sandy soil of Senegal (common name: Dior), and Tilene soil, an alluvial soil of the Senegal valley. In both cases, rice grain yields, *N* uptake by the plant, and number of productive tillers were markedly influenced by green manure (grain yields more than doubled). Significant responses to residual *N* were obtained with the second rice crop (Table 6, 7). Similar results were obtained with *A. afraspera* and *A. nilotica* (both species form the second cross-inoculation group of the genus *Aeschynomene* and develop profuse stem nodulation) (Table 8). Furthermore, it could be expected that the *N* remaining in the soil after a rice crop would benefit a second crop, as was observed with a *S. rostrata* crop. Only 25-35% of the total *N* accumulated by *Aeschynomene* was transferred to the rice crop (Alazard and Becker 1987).

Experiments on 25-m² plots

We collaborated with the Senegalese Institute of Agricultural Research (ISRA) and the West Africa Rice Development Association (WARDA) to perform larger scale irrigated experiments.

At the ISRA station at Djibelor (Casamance, south of Senegal), *S. rostrata* green manure had a more marked effect on rice yields than did organic matter (Table 9). It doubled grain yield (Diack 1986).
and A. affinis as green manure for rice at the beginning of the rainy season. Total dry matter yields of about 10 t/ha have been obtained from both species at 8-9 wk growth. That represents an accumulation of more than 200 kg N/ha.

Assuming that about 50% of the N accumulated in legumes originates from biological N₂ fixation, it appears that green manuring with stem-nodulating legumes could provide about 100 kg N/ha to a rice crop. Results obtained at IRR1 (1985, 1986) are consistent: S. rostrata was more effective than other Sesbania species as a premonsoon green manure for lowland rice.

References cited


Notes

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