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SESBANIA ROSTRATA GREEN MANURE AND THE NITROGEN CONTENT OF RICE CROP AND SOIL

G. Rinaudo, B. Dreyfus and Y. Dommergues

Office de la Recherche Scientifique et Technique, Outre-Mer et Centre National de la Recherche Scientifique, B.P. 1386, Dakar, Senegal

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Summary—The effects of four treatments upon the N content of rice crop and soil in 1 m^2 irrigated microplots were compared: (1) PK fertilization + *Sesbania rostrata* (inoculated stems) ploughed in as green manure when it was 52 days old, (2) PK fertilization + *S. rostrata* (non-inoculated stems) ploughed in as green manure, (3) PK fertilization + ammonium sulphate (60 kg N ha^{-1}), (4) PK fertilization alone (control).

The application of chemical N fertilizer (treatment 3) increased the grain yield by 169 g m^{-2} (1.69 t ha^{-1}), whereas incorporating *S. rostrata* as green manure resulted in a grain yield increase of 372 g m^{-2} (3.72 t ha^{-1}). N_2 fixed by *S. rostrata* was estimated to be at least 26.7 g m^{-2} (267 kg N ha^{-1}), one third being transferred to the crop and two thirds to the soil.

INTRODUCTION

Cropping systems including legumes as green manure are probably the most efficient ones since the N input to the soil is directly related to the amount of N_2 fixed by the legume. Unfortunately such systems are generally not appealing because they do not yield food or cash directly. However, the introduction of legume green manure in cropping systems could be economically justified if the legume had high N_2-fixing potential, thus allowing a reduction in the immobilization time of the soil, a large increase in yield of the subsequent crop, and, possibly, a significant improvement of the soil N status.

Green manures for rice fields are either N_2-fixing legumes, namely *Astragalus sinicus*, *Sesbania aculeata*, *S. cannabina*, *Crotalaria juncea*, *Aeschynomene americana* (Watanabe and App, 1979; Patnaik and Rao, 1979; Dao The Tuan, personal communication) of *Azolla*, a widely used aquatic N_2-fixing fern. According to Chang (quoted by Patnaik and Rao, 1979), promising legume green manure crops gave 40–201 kg N ha^{-1} in about 2.5 months. Incorporation of *Azolla* green manure at the rate of 10 t ha^{-1} was reported by Talley *et al.* (1977) to increase the rice yield by 1.4 t ha^{-1}, which is equivalent to the effect of an application of 30 kg N fertilizer ha^{-1}.

Dreyfus and Dommergues (1981) have found that *Sesbania rostrata*, a tropical legume which colonizes waterlogged soils in the Sénégal Valley, forms N_2-fixing nodules with *Rhizobium* on both the roots and the stem. Due to its profuse stem nodulation, this plant has 5–10 times more nodules than most nodulated crop plants. Moreover, due to its stem nodulation, *Sesbania* can fix N_2 even when the N content of the nutrient medium was high (Dreyfus and Dommergues, 1980). Profuse stem nodulation and non-inhibition by soil N are two characteristics which probably contribute to the high N_2-fixing potential of *S. rostrata*. Our aim was to estimate the effect of the incorporation of 52 day-old *Sesbania rostrata* green manure on the yield of rice and the amount of N left in the soil after harvest.

MATERIAL AND METHODS

The experiments were conducted in 1980 during the rainy season at the ORSTOM Bel Air Station in Dakar on 24 microplots (1 m^2 each, 50 cm deep) containing 560 kg of soil (dry wt). The soil used was a typical sandy soil of Senegal (vernacular name: Dior) with C and N contents of 0.4 and 0.025% respectively (pH 7.0).

Treatments

Four treatments each with six replications were used as follows:

(1) S. rostrata *green manure, inoculated stems.* The plots were sown with *S. rostrata* and kept waterlogged for 45 days (40 seedlings in each microplot). The stems were inoculated by spraying them with a broth culture of the specific strain (ORS 551), 21 and 30 days after sowing. Irrigation was stopped for 7 days, then the stems of *S. rostrata* were cut just above the soil, chopped in 10 cm long pieces and incorporated in the 0–30 cm horizon. Nineteen days after incorporation, plots were fertilized with PK (17.4 g K_2HPO_4 m^{-2}), planted with 2 week-old rice seedlings cv. Moroberekan, and waterlogged again.

(2) S. rostrata *green manure, non-inoculated stems.* As treatment (1) but without stem inoculation.

(3) *Mineral N fertilization.* During the first 71 days, plots were kept in bare fallow with the same water management as in treatments (1) and (2). Then the plots were fertilized with PK and N (23.3 g $SO_4(NH_4)_2$, i.e. 60 kg N ha^{-1}), planted with rice and waterlogged.

(4) *Control.* As treatment (3), but plots received only PK, at the same rate as other plots.

For the four treatments, the rice was harvested when the plants were 135 days old.

Table 1. Influence of green manuring and application of N fertilizer on grain yield of rice and N content of rice crop and soil

Treatments	Grain yield ($g\,m^{-2}$)	N content of rice crop ($g\,m^{-2}$)	Soil N content ($g\,m^{-2}$) Fraction <2 mm	Fraction >2 mm	Total
(1) *S. rostrata* green manure (inoculated stems)	596 ± 125a	18.2 ± 4.5a	147 ± 11.8ac	27.1 ± 9.4a	174.4 ± 16.3a
(2) *S. rostrata* green manure (non inoculated stems	571 ± 116a	16.8 ± 3.0a	149.2 ± 11.6a	30.0 ± 7.3a	179.2 ± 12.5a
(3) Fertilization (60 kg N ha^{-1})	381 ± 29b	7.2 ± 0.6b	135.5 ± 6.6bc	3.1 ± 1.3b	138.6 ± 5.3b
(4) Control	212 ± 40c	4.0 ± 0.8c	128.8 ± 11.6b	3.6 ± 0.7b	132.4 ± 12.2b

Figures followed by the same letter do not differ significantly, $P = 0.05$.

Plant and soil sampling

Rice crop. At harvest time, the rice tops were cut just above the crown. Grain and straw were separated by hand, dried at about 60°C and ground into powder.

Soil. In each plot we dug out a 20 (width) × 40 (length) × 50 (depth) cm soil sample from under two rice hills. Each soil sample (weighing about 44.8 kg) was sieved (<2 mm) to separate the mineral soil (fraction < 2 mm) from the plant debris (fraction >2 mm including undecomposed debris of *S. rostrata* stems and leaves which had been incorporated and the root litter of *S. rostrata* and rice). The mineral soil was air dried and carefully homogenized. Plant debris was washed in running water, dried at about 60°C and ground into powder. Samples of soil and plant debris were carefully partitioned into subsamples of 1 g (soil) or 100 mg (plant debris) for N analysis.

Nitrogen analyses

Nitrogen was analyzed according to a microkjeldahl procedure involving H_2O_2 (G. Rinaudo, unpublished Thesis Dr Eng., Montpellier University, 1970). For each individual sample of soil or plant material there were three replications. Statistical analyses were carried out using the mean of the three individual analyses related to each plot.

RESULTS

Both the inoculated and non-inoculated stems of *S. rostrata* exhibited profuse nodulation, probably because the non-inoculated plants were contaminated, the specific *Rhizobium* strain being carried by the air or insects. Thus the results of treatments (1) and (2) did not differ significantly (Table 1) and in the following discussion the data from treatments (1) and (2) were pooled.

Comparison of green manuring (treatments 1 and 2) to the control (treatment 4)

Green manuring increased the grain yield by 372 $g\,m^{-2}$ (3.72 t ha^{-1}) and the N content of the crop by 13.5 ± 4.6 $g\,m^{-2}$ (135 ± 46 kg N ha^{-1}). Green manuring increased the soil N content by 44.4 ± 26.6 $g\,m^{-2}$ (444 ± 266 kg N ha^{-1}), slightly affecting the N content of the mineral soil (fraction <2 mm), but markedly augmented the amount of N in the plant debris (fraction >2 mm). Such debris appeared to be the soil N reserve that might be exploited by a subsequent crop, an hypothesis that is currently being investigated.

Comparison of chemical N fertilizer application (treatment 3) to the control (treatment 4)

The application of 60 kg N ha^{-1} increased the grain yield by 169 $g\,m^{-2}$ (1.69 t ha^{-1}), but did not significantly increase the soil N content.

Tentative estimate of N_2 fixed by S. rostrata

If we take into account the lower estimate for the exportation of N by the whole crop (135 − 46 = 89 kg N ha^{-1}) and for the N added to the soil (444 − 266 = 178 kg N ha^{-1}), the amount of N_2 fixed by *S. rostrata* during its 52 days growth was at least 89 + 178 = 267 kg N ha^{-1}. Thus, one third of N_2 fixed was transferred to the crop and two thirds remained in the soil.

DISCUSSION

It is well known that rice soils have an exceptional ability to benefit from the input of N resulting from the activities of phototrophic and heterotrophic N_2-fixing microorganisms. However, this input is at most *ca.* 40 kg N ha^{-1} $crop^{-1}$, an average of 25–30 kg N ha^{-1} $crop^{-1}$ originating from the activity of blue-green algae (Venkataraman, 1979; Roger and Kulasooriya, 1980), 0–30 kg N ha^{-1} $crop^{-1}$ being fixed by heterotrophic bacteria (Dommergues and Rinaudo, 1979). Another rough estimate of N_2 that is spontaneously fixed in rice fields can be deduced from the average rice yield in countries that use very low levels or no N fertilizers (namely Bangladesh, India, Burma, Thaïland, Philippines). According to Stangel (1979), this yield is *ca.* 2 t ha^{-1} $crop^{-1}$, which means that N_2 fixation in the related rice field is *ca.* 40 kg N ha^{-1} $crop^{-1}$, if we assume that to produce 100 kg of grain, the rice plant, regardless of soil type or time of transplanting, requires *ca.* 2.0 kg of N (Patnaik and Rao, 1979). This last estimate is similar to that observed from the above mentioned evaluation of heterotrophic and blue-green algal N_2 fixation. Thus to meet the requirements of crops yielding more than 2 t grain ha^{-1}, it is necessary to add exogenous N to the rice field either as chemical fertilizer or as organic or green manures.

The application of chemical N fertilizer (treatment 3) resulted in an increase of 169 g m^{-2} (1.69 t ha^{-1}) in the grain yield. If we assume that the production of 100 kg of grain requires 2 kg of N, the reported increase of 1.69 t ha^{-1} would necessitate 34 kg N ha^{-1}. Since 60 kg of N chemical fertilizer ha^{-1} was applied, the efficiency of the fertilizer was *ca.* 57%, a figure which could be expected since the fertilizer was surface applied. On that basis, the application of *S. rostrata* green manure resulted in a grain yield increase of 372 g m^{-2} which would be equivalent to that obtained by the use of *ca.* 130 kg N fertilizer. Thus *S. rostrata* as green manure appears to be a satisfactory substitute for chemical N fertilization. Moreover, it should be emphasized that after the rice harvest the soil N status was significantly improved, which could benefit a subsequent rice crop.

Trials on a larger scale are under way to confirm the high N_2-fixing potential of stem nodulating *S. rostrata* and its effect on the rice grain yield and soil N content in the field.

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