Biological Nitrogen Fixation and Sustainability of Tropical Agriculture
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A Wiley-Sayce Co-Publication

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Measuring nitrogen fixed by groundnut varieties in Senegalusing ^{15}N techniques

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SUMMARY

A field experiment was carried out at Nioro Agricultural Experiment Station in southern-central Senegal in order to measure groundnut productivity and nitrogen fixation. A comparative study of three groundnut varieties, inoculated or uninoculated with a *Bradyrhizobium* strain (TAL 1000), was made using two nitrogen fertilizer rates (20 and 100 kg N/ha) applied in the form of labelled ammonium sulphate with 5 and 1 atom % ^{15}N excess, respectively. The results showed that the high nitorgen application rate inhibited nitrogen fixation in all three varieties. At the low nitrogen rate, the uninoculated plants fixed more nitrogen and had a higher total nitrogen content than the inoculated ones, indicating the presence of efficient indigenous strains. There was no difference between the two fertilizer rates in terms of yield and yield components. The variety 73-33 produced the highest yield.

The use of fertilizers to increase crop productivity and maintain soil fertility has become necessary in Sencgal, where 61% of the population live in rural areas. However, the cost of fertilizers is prohibitive, and thus biological nitrogen fixation is an important option for improving agricultural productivity. Groundnut is widely grown in the country and is an important source of protein and animal feed.

The objective of this study was to quantify the amount of nitrogen fixed by different varieties of groundnut and investigate their response to inoculation under low and high application rates of N fertilizer.

MATERIALS AND METHODS

The study was conducted at Nioro Agricultural Experiment Station in southem-central Senegal (15°47'N, 13°43'E), which has an annual rainfall of 700 ± 200 mm. The soil is an Alfisol with a sandy texture; the pH is almost neutral (6.5) and the organic matter content very low (*see* Table 1 *overleaf*).

Table 1 **Some physicochemical properties of the soil at the experimental site, Senegal**

Soil parameter	Soil horizons (cm) 0-8	8.20
pH water	**6.12**	**6.23**
Ph KCl	**5.10**	**5.45**
Clay (%)	**8.00**	**9.00**
Silt (%)	**4.00**	**4.50**
Sand (20-50 μ) (%)	**17.10**	**17.20**
Sand (50-200 μ) (%)	**46.50**	**43.70**
Sand (200-2000 μ) (%)	**24.40**	**25.30**
Organic C (%)	**7.19**	**6.76**
Total **N** (%)	**0.69**	**0.66**
C/N	**10.40**	10.24
Total P_2O_5 (%)	0.31	**0.32**
Available P_2O_5 (ppm)	**26.20**	**24.32**
lixchangeabie cations (meq/lOO g)		
Ca	2.20	**2.19**
Mg	0.63	**0.40.**
Na	0.02	0.02
K	0.25	**0.15**

The groundnut varieties used were 55.437 (V_1), 73-30 (V_2) and 73-33 (V_3). V_2 is widely grown in the groundnut basin of Senegal, while V_3 is well adapted to the Nioro ecological zone. A non-nodulating groundnut variety from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) was used as the control crop. The inoculant used was *Bradyrhizobium* TAL 1000, obtained from the Nitrogen Fixation by Tropical Agricultural Legumes (NiFTAL) Project in Hawaii, USA; the inoculant was an aqueous suspension containing 10^8 cells. The seeds were soaked for 30 minutes in the liquid just before being sown. Two N fertilizer rates were applied (20 and 100 kg N/ha) in the fonn of ammonium sulphate with 5 and 1 atom % ^{15}N excess, respectively. A split-plot randomized block design was used, with inoculation as the main plot, the N fertilizer rate as a subplot and the groundnut varieties as a sub-subplot. There were five replications. Each ^{15}N subplot covered an area of 3 m^2, with an inter-row spacing of 50 cm and 15 cm within rows.

The above-ground portions of all plants were harvested 95 days after planting; below-ground parts were not cansidered in this study. The samples were oven-dried at 70°C. Percentage N was determined on a Kjeldahl digest and the N isotopes ratio analysis was perfomed on a VG-Isogas mass spectrometer in the Seibersdorf Laboratory of the International Atomic Energy Agency (IAEA).

RESULTS AND DISCUSSION

Many nodules were observed on the uninoculated plants, and most of them were pinkish in colour, suggesting that they were fixing nitrogen efficiently. There were significant differences between uninoculated and

Table 2 Effects of inoculation with *Brady hizobium* strain TAL 1000 and two nitrogen application rates on yield components (t/ha) of three groundnut varieties

Factor effect	Pods	Straw
Inoculation effect:		
without TAC 1000	3.06 b[a]	4.36 b
with TAL 1000	2.49 a	4.15
c v (%)	13	17
Ferti irer effect:		
with 20 kg N/ha	2.74 a	4.07 a
with 100 kg N/ha	2.80 a	4.38 b
c v (%)	8	10
Varietal effect:		
Variety 55-437 (V_1)	2.65 a	4.08 a
Variety 73-30 (V_2)	2.55 a	4.05 a
Variety 73-33 (V_3)	3.11 b	5.64 b
c v (%)	8	11

Note: a Values in the same column followed by the same letter do not differ significantly at p = 0.05 (Duncan).

inoculated plants. The pod and straw yields from the uninoculated plots were higher than those from the inoculated plots (*see* Table 2). Thus, inoculation did not improve the performance of the three groundnut varieties; in the case of V_1, it even resulted in a reduction in grain yield (*see* Figure 1 *overleaf*). The inefficiency of the inoculation may have been caused by the presence of indigenous bradyrhizobia that were more efficient than the TAL 1000 strain used in this experiment.

As shown in Table 2, the higher N application rate also failed to increase pod yield. The response of straw to inoculation and N fertilizer, in terms of total N, was the same as for dry matter (*see* Table 3 *overleaf*). No varietal difference was observed in terms of the amount of N derivad from the soil at the higher N application rate, but there was a significant difference between the varieties at the lower rate. Compared to the other two varieties, V_3 showed a significant difference in the amount of N derived from the atmosphere and the fertilizer. The differences in the amount of N derived from the soil, fertilizer and atmosphere in the inoculated and uninoculated varieties at the two N fertilizer rates is shown in Figure 2 (*overleaf*).

The high N application rate reduced nitrogen fixation by 35%, except forthe inoculated V_3 variety (*see* Table 4 *overleaf*). Inhibition of nitrogen fixation by fertilizer has been reported by a number of workers, including Fried and Broeshart (1975) and Dansa, (1986). The total amount of nitrogen fixed by all three varieties ranged between 20 and 70 kg N/ha.

The finding that nitrogen fixation by indigenous rhizobia was higher than with the introduced strain justifies screening more rhizobia, both indigeous and exotic strains, to identify those that are more efficient in the experimental conditions described here. The differences between the groundnut varieties also warrant screening of more varieties to identify the best groundnut/*Bradyrhizobium* association.

Figure 1 Grain yield of three varieties of groundnut as influenced by inoculation with *Bradyrhizobium* strain TAL 1000 and two rates of fertilizer N

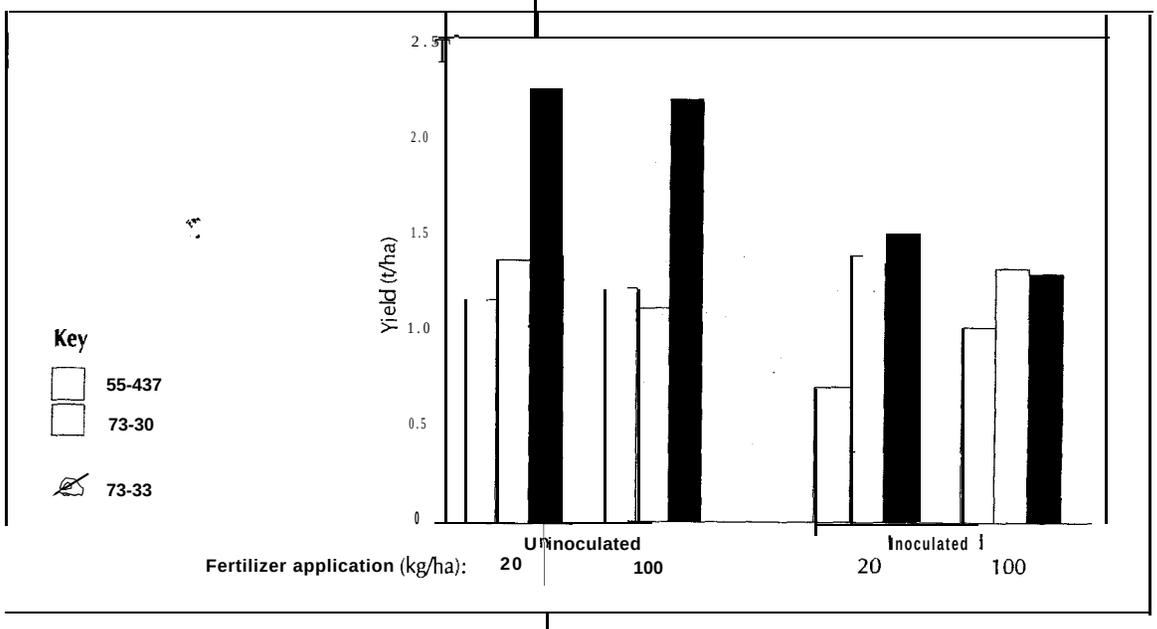

Figure 2 Amount of N derived from soil, fertilizer and the atmosphere by three varieties of groundnut as influenced by inoculation with *Bradyrhizobium* strain TAL 1000 and two rates of fertilizer N

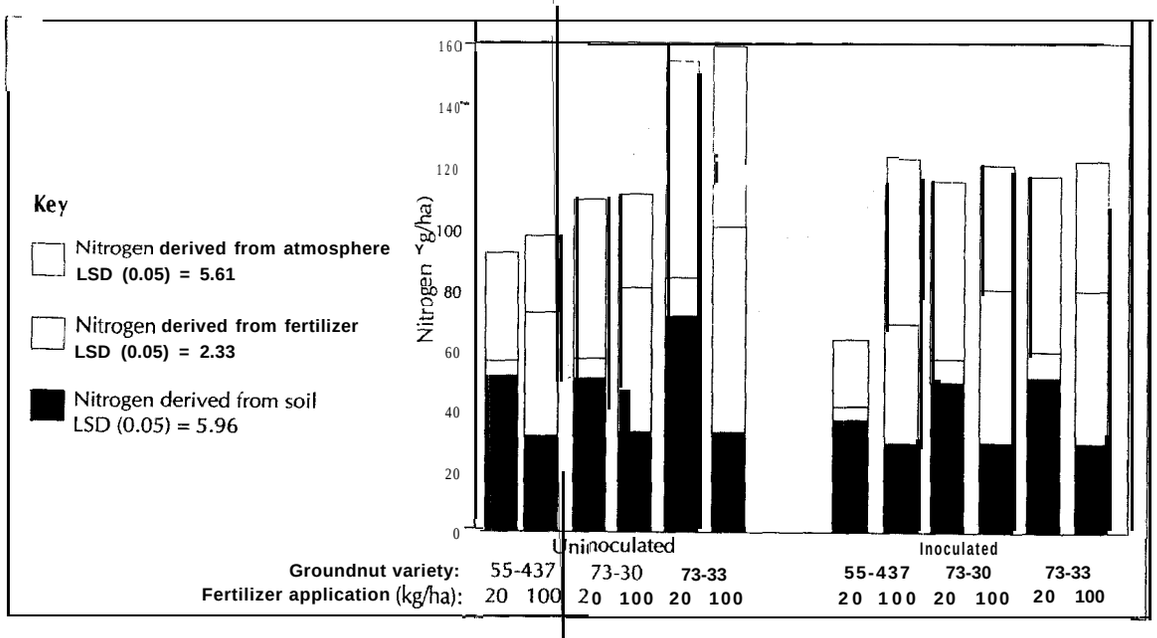

Table 3 Shoot N (kg/ha) of three groundnut varieties as influenced by inoculation with *Bradyrhizobium* strain TAL 1000 and two rates of trogen fertilizer application

Variety accession no.	Inoculation	Fertilizer rates (kg N/ha) 20	100
55-437 (V_1)	With TAL 1000	67.5 a[a]	93.7 c
73-30 (V_2)		117.3 b	120.8 b
73-33 (V_3)		117.2 b	121.3 b
55-437 (V_1)	Without TAL 1000	91.7 c	97.7 c
73-30 (V_2)		108.9 bc	112.1 b
73-33 (V_3)		153.9 a	159.4 a
CV (%)		9	9

Note: a Values in the same column followed by e same letter do not differ significantly at p = 0.05 (Duncan).

Table 4 Percentage of nitrogen fixed by t ee groundnut varieties as influenced by inoculation with *Bradyrhizobium* strain TAL 1000 id two rates of nitrogen fertilizer application

Variety accession no.	Inoculation	-- Fertilizer rates (kg N/ha) --- 20	100
55-437 (V_1)	With TAL 1000	38 a[a]	28 a
73-30 (V_2)		52 b	33 b
73-33 (V_3)		50 b	33 b
55-437 (V_1)	Without TAL 1000	38 a	26 a
73-30 (V_2)		47 b	30 a
73-33 (V_3)		46 b	36 b

Note: a Values in the same column followed by e same letter do not differ significantly at p = 0.05 (Duncan).

Acknowledgements

This study was funded by the Food and Agricult Organization (FAO)/International Atomic Energy Agency (IAEA) African Regional project. 1 wish to thank Dr M iueye for providing the inoculum, H. Axmann (IAEA Seibersdorf lahoratory) for conducting the isotopic analysis a Y. Ndaiye, S. Cissé and S. Faye for managing the field trial.

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