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SOIL AMELIORATION WITH NITROGEN-FIXING ACACIA SPECIES

Final report of IAEA contract no.6375/R1/RB

by

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INTRODUCTION

Previous study showed that *Faidherbia albida* has a low nitrogen fixation potential (NFP). Therefore, it is necessary to **enhance** its N_2 fixation in order to increase the ability of this species to improve **soil fertility** and restore the N status. One approach to reaching this goal is to **select** *F. albida* provenances with the best NFP.

This study aims to compare the nitrogen fixing potential of different provenances of *F. albida* originated from Senegal and Burkina Faso.

MATERIALS AND METHODS

Greenhouse experiment was carried out at Dakar (Bel-Air experimental station) using local sandy soil (93% of soil). This soil has a pH of 7.0, 1.9% total C and 0.25% total N. The soil was sieved (< 1 mm), homogeneized and placed into pots (20 Kg/pot) 30 cm in diameter. To each pot 1 g K_2HPO_4 was added. Surface-sterilized seeds of *Parkia biglobosa* and *Faidherbia albida* were germinated in petri dishes containing soft agar 0.8% for 60 mn and 30 mn respectively. At 2 days old, they were transplanted into the pots (1 seedling/pot).

There were eight treatments with five replicates : one non fixing tree, i. e. *Parkia biglobosa* as reference crops and seven provenances of *Faidherbia albida* from Senegal (Merina, Dangalma, Ndiongolor, Pire and Kabrousse) and burkina Faso (Gomblora and Dem) inoculated with *Bradyrhizobium* ORS 136 applied as liquid inoculum (10 ml/pot) containing 10^9 cells/ml. To all pots, nitrogen fertilizer was then applied at the rate of 0.2 g N/pot as a solution of $(^{15}NH_4)_2SO_4$ with 10.01% atom excess. The pots were arranged randomly and watered so that the soil moisture was kept close to the field capacity.

At 6 months after transplantation into the pots, plants were harvested. Plant and nodule dry weights were recorded. Nitrogen content (%N) and % ^{15}N atom excess were determined by the IAEA laboratory at Seibersdorf. Nitrogen fixation was estimated using both isotope dilution and A-value methods.

RESULTS

*Plant growth and **nitrogen** yield*

There were significant **differences** between *F. albida* provenances in terms of %¹⁵N atom excess, dry matter (DM) and total **nitrogen** yield (Table 1). For each plant part, the %¹⁵N atom excess of provenances of Merina and Dangalma was higher than that of other trees including the **reference** tree whereas the provenance of Kabrousse had the lowest **one**. However, the provenance of Kabrousse seemed to yield more than other provenances in terms of dry weight and total **nitrogen** of the leaves and the stems even there was no significant **difference** between the provenances in the roots and the whole plant in term of dry weight and total nitrogen.

***Nitrogen** derived from fixation*

Whatever the method used, the proportion (%Ndfa) and amount (Ndfa) of **nitrogen** derived from fixation are more important in the provenance of Kabrousse than in the other provenances (Tables 2, 3, 4 and 5).

Referring to the isotope dilution technique (Tables 2 and 3), the coefficient of variation was **very** high due to the variability between the provenances : some of them (Merina and Dangalma) presented negative values means that they did not fix **nitrogen** whereas the other provenances showed a significant N₂ fixation even this fixation was quite low, which was demonstrated in the previous study : the pourcentage of **nitrogen** derived from fixation was -17.88%, -4.26%, 25.97%, 25.48%, 38.17%, 13.08 and 19.19% corresponding to an amount of -0.06, -0.03, 0.26, 0.24, 0.44, 0.10 and 0.16 g N plant⁻¹ for merina, Dangalma, Ndiongolor, Pire, Kabrousse, Gomblora and Dem respectively.

Referring to A-value method (Tables 4 and 5), no negative value was recorded. Nevertheless the provenances of Merina and Dangalma fixed less **nitrogen** than the other provenances. The proportion of **nitrogen** derived from fixation was 17.90%, 28.93%, 49.43%, 49.08%, 57.79%, 40.62% and 44.87% corresponding to an amount of 0.15, 0.21, 0.51, 0.44, 0.63, 0.31 and 0.36 g N plant⁻¹ for Merina, Dangalma, Ndiongolor, Pire, Kabrousse, Gomblora and Dem respectively. Similarly to the isotope dilution technique, the coefficient of variation was high due to the variability between the provenances.

Table 1. %¹⁵N atom excess, dry weight, nitrogen content and total nitrogen in different plants parts of *Parkia biglobosa* and seven *Faidherbia albida* provenances cultivated in pots containing 20 kg of non sterile soil.

Plant parts	Tree species	Provenances*	% ¹⁵ N _{at}	Dry weight (g plant ⁻¹)	%N	Total N (g plant ⁻¹)
Leaves	<i>P. biglobosa</i>		0.691^{ab}	13.35^a	2.71^b	0.36^{ab}
	<i>F. albida</i>	Merina (S)	0.776 ⁱ	7.36 ⁱ	2.87 ^b	0.23 ^b
		Dangalma (S)	0.745^a	8.40^{bc}	3.06^b	0.26^{ab}
		Ndiongolor (S)	0.509^{cd}	12.18^{ab}	2.75^b	0.33^{ab}
		Pire (S)	0.523^{cd}	9.95^{abc}	3.08^b	0.31^{ab}
		Kabrousse (S)	0.415^d	12.36^{ab}	3.11^b	0.38^a
		Gomblora (BF)	0.596^{bc}	6.66^c	3.59^a	0.23^b
		Dem (BF)	0.528^{cd}	7.80 ⁱ	3.58^a	0.28^{ab}
		c v (%)	14.60	24.10	8.70	24.50
Stems	<i>P. biglobosa</i>		0.649^{bc}	11.95^{bc}	1.02^c	0.12^b
	<i>F. albida</i>	Merina (S)	0.854 ⁱ	7.77 ⁱⁱ	1.12 ^{bc}	0.09 ^b
		Dangalma (S)	0.726 ⁱⁱ	9.10^{bc}	1.18^{abc}	0.11^b
		Ndiongolor (S)	0.499^{cd}	13.12^{abc}	1.06^{bc}	0.14^{ab}
		Pire (S)	0.496^{cd}	14.50^{ab}	1.13^{bc}	0.16^{ab}
		Kabrousse (S)	0.393^d	18.43 ⁱ	1.07^{bc}	0.20^a
		Gomblora (BF)	0.581^{bcd}	7.54^c	1.37 ⁱⁱ	0.10^b
		Dem (BF)	0.544^{bcd}	9.80^{bc}	1.28^{ab}	0.13^b
		c v (%)	18.00	30.00	11.20	31.10
Roots	<i>P. biglobosa</i>		0.624^{ab}	27.35 ⁱⁱ	1.28 ⁱ	0.35^a
	<i>F. albida</i>	Merina (S)	0.729 ⁱⁱ	20.47 ⁱⁱ	1.73^b	0.36^a
		Dangalma (S)	0.611^{ab}	20.95^a	1.76^{ab}	0.37^a
		Ndiongolor (S)	0.447^{bc}	27.60^a	1.87^{ab}	0.52 ⁱⁱ
		Pire (S)	0.446^{bc}	24.65 ⁱⁱ	1.66^b	0.40^a
		Kabrousse (S)	0.404^c	27.91^a	1.84^{ab}	0.50^a
		Gomblora (BF)	0.530^{bc}	20.35^a	2.06 ⁱ	0.40^a
		Dem (BF)	0.511^{bc}	19.51^a	1.90^{ab}	0.36 ⁱⁱ
		c v (%)	19.70	34.10	9.60	34.80
Total	<i>P. biglobosa</i>		0.650^{abc}	52.65^a	1.67 ⁱⁱ	0.83^a
	<i>F. albida</i>	Merina (S)	0.780 ⁱ	35.60^a	1.91^b	0.67^a
		Dangalma (S)	0.700^a	38.45^a	2.00^b	0.73^a
		Ndiongolor (S)	0.490^{de}	52.90^a	1.90^b	0.99^a
		Pire (S)	0.490^{de}	49.94 ⁱⁱ	1.96^b	0.87^a
		Kabrousse (S)	0.410^e	58.70 ⁱⁱ	2.01^b	1.08^a
		Gomblora (BF)	0.570^{bcd}	34.54^a	2.34 ⁱⁱ	0.74 ⁱⁱ
		Dem (BF)	0.530^{cde}	37.11^a	2.26 ⁱ	0.77^a
		CV (%)	15.20	28.70	6.60	28.40

* : (BF) : Burkina Faso ; (S) : Senegal

For each plant part, values in the same column followed by the same letter do not differ significantly at p = 0.05.

Table 2. Proportion of **nitrogen** derived from atmosphere (%Nd_{fa}), fertilizer (%Nd_{ff}) and **soil** (%Nd_{fs}) in different plants parts of *Parkia biglobosa* and seven *Faidherbia albida* provenances cultivated in pots containing 20 kg of non sterile soil using isotope dilution.

Plant parts	Tree species	Provenances*	%Nd _{fa}	%Nd _{ff}	%Nd _{fs}
Leaves	<i>P. biglobosa</i>		0.00	7.17 ^{ab}	92.83 ^{ab}
	<i>F. albida</i>	Merina (S)	-12.33"	8.05 ^a	104.28 ^a
		Dangalma (S)	7.87"	7.73"	100.14"
		Ndiongolor (S)	26.34 ^{ab}	5.28 ^{cd}	68.38 ^{cd}
		Pire (S)	24.31 ^{ab}	5.43 ^{cd}	70.26 ^{cd}
		Kabrousse (S)	39.86 ^a	4.31 ^d	55.83 ^d
		Gomblora (BF)	13.75 ^b	6.18 ^{bc}	80.07 ^{bc}
		Dem (BF)	23.33 ^{ab}	5.50 ^{cd}	71.18 ^{cd}
		c v (%)	84.50	14.60	14.00
Stems	<i>P. biglobosa</i>		0.00	6.73 ^{bc}	97.27 ^{bc}
	<i>F. albida</i>	Merina (S)	-31.65"	8.86 ^a	122.79"
		Dangalma (S)	-11.86 ^{bc}	7.53 ^{ab}	104.33 ^{ab}
		Ndiongolor (S)	23.17 ^a	5.17 ^{cd}	71.65 ^{cd}
		Pire (S)	23.64 ^a	5.14 ^{cd}	71.22 ^{cd}
		Kabrousse (S)	39.54 ^a	4.07 ^d	56.39 ^d
		Gomblora (BF)	10.45 ^{ab}	6.03 ^{bcd}	83.52 ^{bcd}
		Dem (BF)	16.15 ^a	5.65 ^{bcd}	78.21 ^{cd}
		c v (%)	174.70	14.00	17.70
Roots	<i>P. biglobosa</i>		0.00	6.47 ^{ab}	95.53 ^{ab}
	<i>F. albida</i>	Merina (S)	-16.86 ^b	7.56 ^a	109.29 ^a
		Dangalma (S)	2.05 ^{ab}	6.34 ^{ab}	91.61 ^{ab}
		Ndiongolor (S)	28.40 ^a	4.63 ^{bc}	66.97 ^{bc}
		Pire (S)	28.49 ^a	4.63 ^{bc}	66.88 ^{bc}
		Kabrousse (S)	35.13 ^a	4.20 ^c	60.67 ^c
		Gomblora (BF)	15.00 ^a	5.50 ^{bc}	79.50 ^{bc}
		Dem (BF)	18.11 ^a	5.30 ^{bc}	76.59 ^{bc}
		c v (%)	111.30	19.70	19.00
Total	<i>P. biglobosa</i>		0.00	6.79 ^{abc}	93.21 ^{ab}
	<i>F. albida</i>	Merina (S)	-17.88 ^c	8.16 ^a	112.12 ^a
		Dangalma (S)	-4.26 ^{bc}	7.20 ^{ab}	98.68 ^{ab}
		Ndiongolor (S)	25.97 ^a	5.03 ^d	69.00 ^{cd}
		Pire (S)	25.48 ^a	5.06 ^d	69.45 ^{cd}
		Kabrousse (S)	38.17 ^a	4.69 ^d	57.63 ^d
		Gomblora (BF)	13.07 ^{ab}	5.90 ^{bcd}	81.03 ^{bc}
		Dem (BF)	19.19 ^a	5.48 ^{cd}	69.81 ^{cd}
		c v (%)	100.60	15.10	15.50

* : (BF) : Burkina Faso ; (S) : Senegal

For **each** plant part, values in the **same** column followed by the **same** letter do not differ significantly at p = 0.05.

Table 3. Proportion of **nitrogen** derived from atmosphere (Nd_{fa}), fertilizer (Nd_{ff}) and **soil** (Nd_{fs}) in different plants parts of *Parkia biglobosa* and seven *Faidherbia albida* provenances cultivated in pots containing 20 kg of non **sterile soil** using isotope dilution.

Plant parts	Tree species	Provenances*	Nd _{fa} (g pl. ⁻¹)	Nd _{ff} (g pl. ⁻¹)	Nd _{fs} (g pl. ⁻¹)
Leaves	<i>P. biglobosa</i> <i>F. albida</i>		0.00	0.030 ^a	0.33*
		Merina (S)	-0.03 ^c	0.020 ^a	0.23 ^a
		Dangalma (S)	-0.02 ^c	0.020 ^a	0.26 ^a
		Ndiongolor (S)	0.09 ^b	0.020 ^a	0.23 ^a
		Pire (S)	0.07 ^b	0.020 ^a	0.22 ^a
		Kabrousse (S)	0.16 [']	0.020 ^a	0.21 ^a
		Gomblora (BF)	0.03 ^{bc}	0.01 0 ^a	0.19 ^a
		Dem (BF)	0.06 ^b	0.020 ^a	0.15 ^a
		c v (%)	86.30	28.20	28.80
Stems	<i>P. biglobosa</i> <i>F. albida</i>		0.00	0.008 ^a	0.1 1 ^a
		Merina (S)	-0.02 ^d	0.008 ^a	0.10 ^a
		Dangalma (S)	-0.01 ^{cd}	0.008 ^a	0.1 1 ^a
		Ndiongolor (S)	0.03 ^{bc}	0.007 ^a	0.10 ^a
		Pire (S)	0.04 ^b	0.008 ^a	0.1 1 ^a
		Kabrousse (S)	0.08 [']	0.008 ["]	0.10 ^a
		Gomblora (BF)	0.01 ^{cd}	0.006 [']	0.09 ^a
		Dem (BF)	0.02 ^{bcd}	0.007 ^a	0.09 ^a
		c v (%)	130.60	32.40	31.30
Fioots	<i>P. biglobosa</i> <i>F. albida</i>		0.00	0.020 ^a	0.32 ^a
		Merina (S)	-0.05 ^c	0.030 ^a	0.38 ^a
		Dangalma (S)	0.01 ^{bc}	0.020 ^a	0.34 ^a
		Ndiongolor (S)	0.16 ^{ab}	0.020 ^a	0.34 ^a
		Pire (S)	0.12 ^{abc}	0.020 ^a	0.26 [']
		Kabrousse (S)	0.20 ^a	0.020 ^a	0.29 ^a
		Gomblora (BF)	0.06 ^{abc}	0.020 ^a	0.32 ^a
		Dem (BF)	0.08 ^{abc}	0.020 ^a	0.27 ^a
		c v (%)	110.70	34.60	34.80
Total	<i>P. biglobosa</i> <i>F. albida</i>		0.00	0.05 ^a	0.77 ^a
		Merina (S)	-0.06 [']	0.05 ^a	0.72 ^a
		Dangalma (S)	-0.03 ^c	0.05 ^a	0.71 ^a
		Ndiongolor (S)	0.26 ^{ab}	0.05 ["]	0.67 ["]
		Pire (S)	0.24 ^{ab}	0.04 ^a	0.59 ^a
		Kabrousse (S)	0.44 ^a	0.05 ^a	0.66 ^a
		Gomblora (BF)	0.10 ^{bc}	0.04 ^a	0.59 ^a
		Dem (BF)	0.16 ^{bc}	0.04 ^a	0.52 ^a
		c v (%)	95.40	34.10	29.40

* : (BF) : Burkina Faso ; (S) : Senegal

For **each** plant part, values in the **same** column followed by the **same** letter do not differ significantly at p = 0.05.

Table 4. Proportion of **nitrogen** derived from atmosphere (%Nd_{fa}), fertilizer (%Nd_{ff}) and **soil** (%Nd_{fs}) in different plants parts of *Parkia biglobosa* and seven *Faidherbia albida* provenances cultivated in pots containing 20 kg of non sterile soil using A value method.

Plant parts	Tree species	Provenances*	%Nd _{fa}	%Nd _{ff}	%Nd _{fs}
Leaves	<i>P. biglobosa</i> <i>F. albida</i>			7.17^{ab}	92.83 ["]
		Merina (S)	20.38 ["]	8.05 [']	71.57 ^b
		Dangalma (S)	23.54 ["]	7.73 ["]	68.73 ^b
		Ndiongolor (S)	47.79 ^{ab}	5.28 ^{cd}	46.93 ^{cd}
		Pire (S)	46.35 ^{ab}	5.43 ^{cd}	48.22 ^{cd}
		Kabrousse (S)	57.37 ^a	4.31 ^d	38.32 ^d
		Gomblora (BF)	38.86 ^b	6.18 ^{bc}	54.96 [']
		Dem (BF)	45.65 ^{ab}	5.50 ^{cd}	48.85 ^{cd}
		c v (%)	23.00	14.60	13.10
Stems	<i>P. biglobosa</i> <i>F. albida</i>			6.73^{bc}	93.27 ^a
		Merina (S)	9.91 ^c	8.86 ["]	81.22 ^{ab}
		Dangalma (S)	23.45 ^{bc}	7.53 ^{ab}	69.02 ^b
		Ndiongolor (S)	47.43 ^a	5.17 ^{cd}	47.40 ^c
		Pire (S)	47.74 ^a	5.14 ^{cd}	47.11 ^c
		Kabrousse (S)	58.53 ^a	4.07 ^d	37.40 ["]
		Gomblora (BF)	38.72 ^{ab}	6.03 ^{bcd}	55.25 [']
		Dem (BF)	42.62 ["]	5.65 ^{bcd}	51.73 ^c
		c v (%)	31.00	18.00	16.06
Roots	<i>P. biglobosa</i> <i>F. albida</i>			6.47^{ab}	93.53 ["]
		Merina (S)	23.42 ^b	7.56 ^a	69.02 ^b
		Dangalma (S)	39.81 ^a	6.34 ^{ab}	57.85 ^{bc}
		Ndiongolor (S)	53.08 ^a	4.63 ^{bc}	42.29 ^{cd}
		Pire (S)	53.14 ^a	4.63 ^{bc}	42.23 ^{cd}
		Kabrousse (S)	57.49 ^a	4.20 [']	38.31 ^d
		Gomblora (BF)	44.30 ^a	5.50 ^{bc}	50.20 ^{cd}
		Dem (BF)	46.33 ["]	5.30 ^{bc}	48.37 ^{cd}
		c v (%)	26.80	19.70	17.60
Total	<i>P. biglobosa</i> <i>F. albida</i>			6.79^{abc}	93.21 ^a
		Merina (S)	17.90 ^c	8.16 ^a	73.94 ^b
		Dangalma (S)	28.93 ^{bc}	7.20 ^{ab}	65.20 [']
		Ndiongolor (S)	49.43 ^a	5.03 ^d	45.54 ^{cd}
		Pire (S)	49.08 [']	5.06 ^d	45.86 ^{cd}
		Kabrousse (S)	57.79 ^a	4.69 ^d	38.01 ^d
		Gomblora (BF)	40.62 ^{ab}	5.90 ^{bcd}	53.47 ^c
		Dem (BF)	44.87 ["]	5.48 ^{cd}	49.65 ^{cd}
		c v (%)	23.10	15.10	13.70

* : (BF) : Burkina Faso ; (S) : Senegal

For each plant part, values in the same column followed by the same letter do not differ significantly at p = 0.05.

Table 5. Proportion of **nitrogen** derived from atmosphere (Nd_{fa}), fertilizer (Nd_{ff}) and soil (Nd_{fs}) in different plants parts of *Parkia biglobosa* and seven *Faidherbia albida* provenances cultivated in pots containing 20 kg of non sterile soil using A value method.

Plant parts	Tree species	Provenances*	Nd _{fa} (g pl. ⁻¹)	Nd _{ff} (g pl. ⁻¹)	Nd _{fs} (g Pl. ⁻¹)
Leaves	<i>P. biglobosa</i> <i>F. albida</i>	Merina (S) Dangalma (S) Ndiongolor (S) Pire (S) Kabrousse (S) Gomblora (BF) Dem (BF) c v (%)	0.05 ^d 0.06 ^{cd} 0.16 ^b 0.14 ^b 0.22 ^a 0.09 ^{bcd} 0.13 ^{bc} 36.20	0.030 ^a 0.020 ^a 0.020 ["] 0.020 ["] 0.020 ^a 0.010 ^a 0.020 ^a 28.20	0.33 ^a 0.16 ^b 0.18 ^b 0.15 ^b 0.14 ^b 0.13 ^b 0.14 ^b 28.6
Stems	<i>P. biglobosa</i> <i>F. albida</i>	Merina (S) Dangalma (S) Ndiongolor (S) Pire (S) Kabrousse (S) Gomblora (BF) Dem (BF) c v (%)	0.01 ^d 0.02 ^{cd} 0.07 ^{bc} 0.08 ^b 0.12 ^a 0.04 ^{bcd} 0.06 ^{bcd} 52.00	0.008 ^a 0.008 ^a 0.007 ^a 0.008 ^a 0.008 ["] 0.006 ["] 0.0078 32.40	0.11 ^a 0.07 ^b 0.08 ^b 0.08 ^b 0.07 ^b 0.06 ^b 0.06 ^b 31.00
Roots	<i>P. biglobosa</i> <i>F. albida</i>	Merina (S) Dangalma (S) Ndiongolor (S) Pire (S) Kabrousse (S) Gomblora (BF) Dem (BF) c v (%)	0.09 ^b 0.13 ^{ab} 0.29 ^{ab} 0.22 ^{ab} 0.30 ^a 0.18 ^{ab} 0.18 ^{ab} 50.20	0.020 ^a 0.030 ["] 0.020 ^a 0.020 ^a 0.020 ["] 0.020 ["] 0.020 ^a 34.60	0.33 ^a 0.24 ^{ab} 0.21 ^{ab} 0.21 ^{ab} 0.17 ^b 0.18 ^b 0.20 ^{ab} 33.20
Total	<i>P. biglobosa</i> <i>F. albida</i>	Merina (S) Dangalma (S) Ndiongolor (S) Pire (S) Kabrousse (S) Gomblora (BF) Dem (BF) c v (%)	0.15 ["] 0.21 ^c 0.51 ^{ab} 0.44 ^{abc} 0.63 ^a 0.31 ^{bc} 0.36 ^{abc} 42.60	0.050 ^a 0.050 ^a 0.050 ^a 0.040 ^a 0.050 ^a 0.040 ^a 0.040 ^a 34.10	0.77 ^a 0.47 ^b 0.46 ^b 0.43 ^b 0.39 ^b 0.39 ^b 0.38 ^b 27.40

* : (BF) : Burkina Faso ; (S) : Senegal

For each plant part, values in the same column followed by the same letter do not differ significantly at p = 0.05.

Nitrogen derived from fertilizer and soil

The proportion of **nitrogen** uptaken from fertilizer by ail *F. albida* provenances was **very** low. It ranged from 4.69% in the provenance of kabrousse to 8.16% in that of Merina. The proportion of **nitrogen** derived from **soil** (%Ndfs) was higher in the provenances of Merina and Dangalma than in the other provenances species. However, there was no **significant difference** between the provenances in term of amount of **nitrogen** derived from fixation and soil.

CONCLUSION

F. albida from Merina and Dangalma presented a **very** low N₂ fixation. The provenance of Kabrousse was that with the higher NFP. It should be selected for improving the **soil fertlity** so far *F. albida* is considered as a **nitrogen** fixing tree with an important **agronomic** characteristic.

However, it is necessary to **estimate** the N₂ fixation in field condition of the provenance of Kabrousse. This is the aim of the renewed **contract** (contract no. 6375/R2/RB) we have initiated.

We **also** keep in mind the another approach which involve grafting the provenances of Merina and Dangalma **onto** that of Kabrousse or grafting the provenance of Kabrousse **onto** *Acacia seyal*. This is also initiated in the second renewal of the contract.