Performance evaluation of various agroforestry species used in short duration improved fallows to enhance soil fertility and sorghum yields in Mali

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Abstract

The general soil fertility and crop yield decline constraints have guided the Malian agricultural research institute (Institut d′ Economie Rurale, IER), the Sahel Program of the World Agroforestry Centre (ICRAF) and the International Crops Research Institute for the Semi Arid Tropics (ICRISAT) to join efforts and undertake research activities aimed at mitigating the constraints in Mali. Thus, from the year 2000, 14 different trees and shrubs are being tested in improved fallow systems to find which ones perform best to replenish soils and improve crop yields. The results have (i) identified most suited species for 1 or 2 yr improved fallows, (ii) determined their impact on sorghum grain yields and (iii) documented the remnant effects of their impact on soil fertility and crop yields.

Some species (*Indigofera astragalina*, *Crotalaria ochroleuca*, *Crotalaria agatiflora*, *Crotalaria retusa*, *Crotalaria goreensis*, *Crotalaria paulina* et *Tephrosia vogelii*) could not survive more than 1 year the Samanko conditions. Among them, *C. agatiflora* (1944, 1141 and 741 kg sorghum grain yields ha^{-1} respectively in years 1, 2 and 3 after cultivation) and *I. Astragalina* (1343, 1301 and 393 kg sorghum grain yields ha^{-1} respectively in years 1, 2 and 3 after cultivation) would be the best candidates for 1-yr improved fallows. Others such as *Tephrosia* candida, *Sesbania sesban* (Lery, Gache, Kibwezi and Kakamega provenances), *Cassia sieberiana* and *Cajanus cajan* have completed 2-yr duration improved fallows. In 2002, the first year of cultivation, it was the Kenyan provenances of *Sesbania sesban* which performed best with sorghum grain yields over 2 t ha^{-1}. A year later, 2003, there has been a general decrease in crop yield. Again, the Kenyan provenances of *S. seban*, with yields 40% lower than the first year of cultivation, were the worst affected by this decrease. No significant changes were observed in the traditionally tested chemical soil parameters. In conclusion, *C. agatiflora*, *I. astragalina* and the Kenyan provenances of *S. sesban* are well-adapted species for 1-yr improved fallow systems in the Samanko, Mali, conditions

Key words: Agroforestry species, natural resources management, remnant effects, residues, Sahel, soil fertility, sorghum

Introduction

The weather prevailing in the Sahelian zone covering Senegal, Mali, Niger and Burkina Faso is characterized by a short (3 to 4 months), poor and erratic rainy season (400 to 1000 mm/year) with frequent drought spells. Temperatures in the dry season (about nine months) can be as high as 40°C. Population growth rates in this region are among the highest in the world (about 3% per year) and are exacerbated by strong pressure on arable lands, which create ideal conditions

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for over-exploitation of natural resources, leading to degradation.

Soils are affected by nutrients losses estimated at 25 kg N, 3 kg P and 20 kg K annually as well as organic matter losses ranging from 2 to 4% per year. Fertilizer use in the Sahel only increased by 0.6% over the last 10 years, as against 4.4% in other regions such as South East Asia and Europe (FAO, 1999). The region' needs in N, P and K are estimated at approximately 8 tonnes per year, which is 6 times higher than the total annual consumption levels (Sanchez et al., 1997). For the specific case of Mali, N, P and K budgets estimated in 1992 at national level (van der Pol, 1992) were all negative (-25, -20 and -5 kg ha^{-1} respectively) which shows that about 40 to 60% of agricultural income is generated by mining of soil resources. As farmers adopt different soil management strategies on their farms, Kanté et al. (1998) investigated the situation at plot level and confirmed the trends highlighted by van der Pol (1992). Their results also proved that farmers, who are usually taken to be the best managers of their own land, also seem to be the very ones who most impact negatively on soil fertility.

Soil fertility decline is a major constraint to land productivity in the Sahel. Recent research findings have showed that under similar rainfall and moisture conditions, current land productivity levels could increase five times with an adequate fertilizer regime (Penning de Vries and Djiteye, 1982; Breman, 1998). Active soil erosion as a consequence of natural resource degradation, the rate of which is estimated to be ten times faster than soil formation, affects 72% of arable land. Indeed, fine particles and other fine elements carried away through the erosion processes are 2.5 times richer than the remaining soil. This is an additional land productivity limiting factor in the region. Moreover, the low productivity of major crops has led to an extension of agricultural areas into marginal lands not suitable for farming which, in turn, reduces the size of pasture areas. This situation further exacerbates the already strained relationships between farmers and pastoralists.

Sound soil fertility management is today a prerequisite. Traditional practices based on long duration fallows, crop rotation and use of organic fertilizers (domestic waste, manure, compost, etc.) have become either inappropriate or very difficult to implement due to several technical and socio-economic constraints affecting our production systems (Bationo and Mokwunye, 1991). Unfortunately, the use of mineral fertilizers which was for years considered as an efficient means of increasing crop yields has showed limitations and is not affordable by the majority of African farmers.

It is increasingly confirmed that soil fertility management in the Sahel should necessarily be achieved through the use of organic and mineral fertilizers whereby organic matters could provide the nitrogen needed while phosphorous and other nutrients shall be provided by mineral fertilizers.

The general soil fertility decline trend observed in the Sahel has guided the Institut d'Economie Rurale (IER), the Sahel Programme of the world Agroforestry Centre (ICRAF/Sahel) and the International Centre for Research on Crops in Semi Arid Tropical Zones (ICRISAT) to launch joint research activities aimed at finding appropriate solutions to the soil fertility decline constraint. Thus, starting from the year 2000, a series of introduction trials of different agroforestry species and provenances were initiated at the ICRISAT Samanko Research Station, Mali, in an improved fallow system.

The general objective is to identify fast growing species, which keep their foliage in the dry season while producing large amounts of quality biomass, which can be used as nutrients by plants when incorporated in the soil. This practice improves crop yields after the fallow period. Specific objectives include, among others, (1) to identify nitrogen-fixing woody and non-woody species capable of producing large amounts of high quality biomass to speed up regeneration of the fertility of soils under fallow, (2) to reduce soil fertility maintenance cost through increased use of locally available materials (organic matter and rock phosphates), and (3) to detect the pace at which symptoms of deficiencies in major mineral nutrients (N, P, K) occur during the cropping phase after the fallow period. Specific recommendations can then be made for better soil fertility management after the fallow period.

Materials and methods

Site

The trial was established in 2000 at the Samanko Agronomic Research Station (331 m of altitude, 8°04′ North and 12°54′ West) located 25 km South-West of Bamako. Local soils are light, generally brown-yellow, of a tropical ferruginous washed-type with a pH ranging from 4.5 to 6.0 and poor in organic matter. The weather on site is characterized by one single rainy season from June to October followed by a long, dry and cold (December to February) and hot (from March to

May) season. The rains are erratic, with downpours at the onset of the season, pounding on bare soils without any plant cover and affected by intense erosion due to the heavy rainfall impact, which significantly reduces water infiltration. Rainfall levels recorded vary considerably over time and space. The region has recorded over the last thirty years a gap of about 100 mm of isohyets. Rainfall levels recorded between 2000 and 2003 are 919 mm, 978.9 mm and 1159.5 mm respectively.

Plant material

The material used includes 14 non coppicing pluri-annual species and provenances. The list is presented in Table 1 below.

Establishment /Conduct of the trial

The trial was conducted in a plot, which, after several years of cropping, was planted to sorghum without any fertilizer application in 1999, that is, one year before the trial. Plants were produced in a nursery during 4 months and had a height of 1 m for *Sesbania* and *Crotalaria* and 50 cm for *Tephrosia* at planting. They were planted after ploughing at 10 to 15 cm depth using a tractor at the beginning of the rainy season with a 0.75 m spacing between lines and 0.50 m on the line for a total population of 26,667 plants per hectare. Net plots are 6 m × 6 m or 36 sq. meters. Plots were weeded at trial installation year in order to mitigate the impact of weed competition and they were protected from animal intrusion.

Table 1. Species which do not sprout following cutting, tested under improved fallows at Samanko in 2000

Species	Provenances	Countries
Cajanus cajan	Samanko	Mali
*Cassia sieberiana***	Fada	Burkina Faso
Crotalaria agatiflora	South Nyanza	Kenya
Crotalaria goreensis	Samanko	Mali
Crotalaria ochroleuca	Seaya	Kenya
Crotalaria paulina	G.B.K.	Kenya
Crotalaria retusa	Samaya	Mali
Indigofera astragalina	Ségou	Mali
Sesbania sesban	Lery	Burkina Faso
Sesbania sesban	Gachie	Kenya
Sesbania sesban	Kibwezi	Kenya
Sesbania sesban	Kakamega	Kenya
Tephrosia candida	Mararana	Madagascar
Tephrosia vogelii	Yaounde	Cameroon

In 2002 and 2003, after planting, aerial biomass was cut low and separated as wood and leaf and quantities obtained were recorded. Leafy biomass was incorporated at ploughing to provide nutrients to the crop (sorghum ICSV 400). The sorghum was planted at intervals of 0.75 m between lines and 0.30 m on the line, thinned to two plants per hill for a total population of roughly 89,000 plants per hectare. Additional mineral fertilizer (40 kg of P ha^{-1}) was applied as super triple phosphate 15 days after planting. An initial weeding regime was done one week after planting, followed by another one month after.

Soils samples were taken at 0–20 cm and 20–40 cm depth in five locations following the 2 diagonals of each plot. For each depth, the 5 samples were well mixed and a representative 500 to 800 g sample was taken to analyze standard chemical parameters (water pH, N, P, K, Ca, Mg, CEC, C and organic matter). Samples were taken on the year of trial installation before crops were planted and also every year at the end of the cropping season after harvest.

Data collected during the fallow period include the rate of survival of species and provenances (by mere counting) and production of litter using wooden traps with a 1 m × 0.50 m or 0.50 m^2 metal sieve at the bottom, placed in three locations diagonally in each plot. Litter was collected every 15 days starting from the 5th month after planting and only in the dry season. At each collection date, the litter was oven-dried at 40°C before the dry weight was computed using an electronic scale.

Experimental design

A randomised complete block design was used, with 3 replications. Continuous sorghum treatments and natural fallow were added to the list of species, which gave a total of 16 treatments:

- T1: *Tephrosia candida*
- T2: *Sesbania sesban* (Lery)
- T3: *Indigofera astragalina*
- T4: *Crotalaria ochroleuca*
- T5: *Sesbania sesban* (Gachie)
- T6: *Crotalaria agatiflora*
- T7: *Sesbania sesban* (Kibwerzi)
- T8: *Crotalaria retusa*
- T9: *Sesbania sesban* (Kakamega)
- T10: *Crotalaria goreensis*

T11: *Cassia sieberiana*
T12: *Cajanus cajan*
T13: *Crotalaria paulina*
T14: *Tephrosia vogelii*
T15: *Natural fallow*
T16: *Continuous cropping*

Statistical analysis

All data collected were input using Microsoft Excel 2000 and converted into PRN text files. The analysis of variance was then performed with the SAS software version 6.12. Mean Treatment means were compared through the least small significant difference (Lsd) at a 5% confidence interval.

Results

Some species did not survive in the dry season of year 1 (2000) and corresponding plots were cropped from 2001. Other plots were planted in 2002, after a two-year fallow period.

Species used after one single year of fallow

The following species did not survive more than one year of fallow: *Indigofera astragalina*, *Crotalaria ochroleuca*, *Crotalaria agatiflora*, *Crotalaria retusa*, *Crotalaria goreensis*, *Crotalaria paulina* and *Tephrosia vogelii*. In the aspect of leaf biomass production at the end of the fallow phase, *C. paulina* and *T. vogelii* were especially the best species with annual average production of dry matter of 2.5 t ha^{-1} while *I. astragalina* and *C. ochreleuca* had the lowest production (Table 2). For sorghum grain yields after the fallow period, Table 2 indicates a production of about 2 t ha^{-1} in 2001 for *C. agatiflora* which also yielded dry leaf biomass almost similar to that of the best two species. The following species then came next, in decreasing order: *C. paulina*, *I. astragalina* and *T. vogelii*. In 2002, not only a global sorghum grain yield decline was recorded but a new classification of treatments was also made. Thus, in 2002, *C. paulina* was the best yielder, followed by C. goreensis and *C. agatiflora*. In all cases, *C. retusa* and continuous cropping produced the lowest levels. The general yield decline was further exacerbated in 2003, after 3 years of uninterrupted cropping. *C. agatiflora*, *C. paulina* and *T. vogelii* were the most affected by yield drops (Figure 1).

Soil analysis data are presented in Table 3. They show a significant difference between 0–20 cm and 20–40 cm horizons for all parameters studied. Generally, horizon 0–20 cm is the most acid and richer in phosphorous, potassium and carbon than horizon 20–40 cm. CEC is however slightly higher in the 20–40 cm horizon. A comparison between treatments shows that *C. goreensis*, *C. ochroleuca*, *C. agatiflora* and *T. vogelii* produced a higher P content in the 0–20 cm layer. For all other parameters and at all

Table 2. Production of dry leaf biomass by agroforestry species which do not stand the cutting process and their impact on sorghum yields after a one-year fallow at Samanko station, Mali

Species	Leaf Biomass	Sorghum grain yield (kg ha^{-1})			
		2001	2002	2003	Aggregate
Indigofera astragalina	304	1343	1301	394	3037
Crotalariat ochroleuca	732	1065	836	417	2318
Crotalaria agatiflora	2215	1944	1141	741	3826
Crotalaria retusa	1768	787	680	301	1768
Crotalaria goreensis	1870	1157	1187	463	2807
Crotalaria paulina	2571	1389	732	324	2445
Tephrosia vogelii	2420	1343	848	509	2700
Natural fallow	na	972	899	444	2311
Continuous cropping	na	694	565	370	1630
Probability	0, 0001	0.28	0.17	0.144	0.16
LSD	487.93	964.93	572.46	288.93	1284.20
CV (%)	16.16	46.9	36.34	37.95	35.35

na: not available.

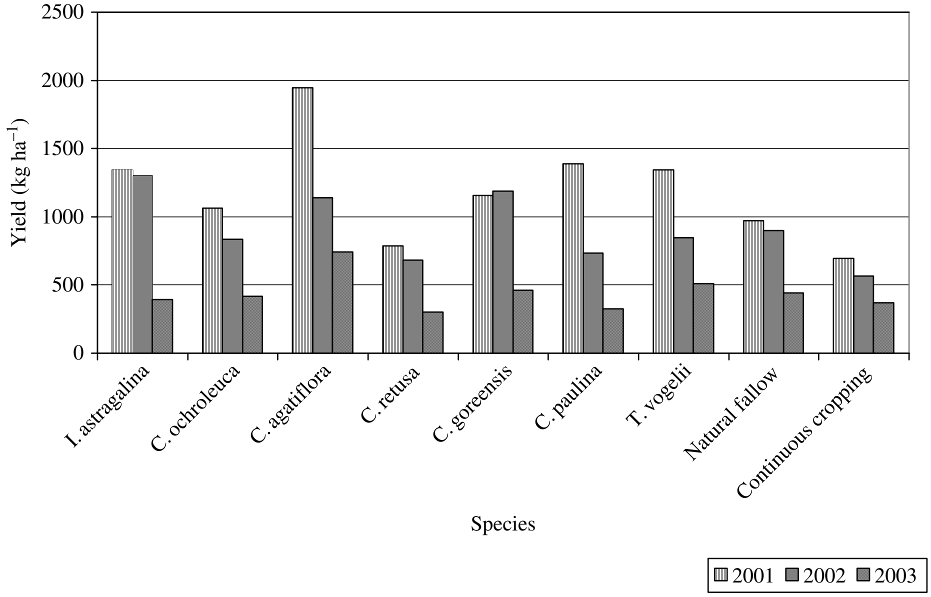

Figure 1. Sorghum yield trends after a one-year improved fallow at the Samanko station, Mali.

horizons, only *C. agatiflora* produced results comparable with those at the initial state, before the trial was established.

Species submitted to a two-year fallow

Table 4 presents the results of litter production for species which were submitted to a two-year fallow before being planted anew in 2002. Litter production fluctuated from one year to another with an increase noted for *T. candida*, *S. sesban* (Kibwezi and Kakamega) and *C. sieberiana* and a slight drop for *S. sesban* (Lery and Gaché) and *C. cajan*. In all cases, *Cajanus cajan* produced the highest amount of litter. Cumulated data for the two years show the best species as being *C. cajan* > *T. candida* > *C. sieberiana*.

For sorghum grain yields in 2002 (first year of cultivation), *Sesbania sesban* provenances were the best species, with annual average production above 2 t ha^{-1} (Table 5). Such yields are at least 3.5 times higher than that of the continuous cropping and almost twice higher than that of the natural fallow. Despite significant leaf biomass produced during the fallow phase, *C. cajan* proved to be the least productive in the first year, with grain yields lower than that of the natural fallow. This may be explained by the fact that litter produced during the fallow phase may not have been entirely maintained in the plot and that the species suffered from a high mortality rate in the dry season just before the trial was planted, due to termite attack. In 2003, the second year of cultivation, a sorghum yield drop was noted as compared to the previous year for all treatments. This was particularly noted on Sesbania *sesban* Kenyan provenances, with yields 40% lower than the previous year of cultivation (Figure 2). In addition, mean different treatments are not statistically different at a 5% threshold (table 5). The above results could partly be due to the very nature of the biomass produced by such species as it is high in N, with a very low C:N ratio and a low lignin content. All these features contribute to a rapid decomposition rate (Table 6).

Similarly, the significant leaf biomass obtained from *C. sieberiana* (about 4 times higher than that of the other species) only produced lower yield compared to the natural fallow. It therefore could be suggested to use *C. cajan* for a one (not two) year fallow species.

As the amount of biomass produced is very important for plant nutrition after the fallow phase, samples were taken for more in-depth analysis to determine their content in mineral elements and also to pinpoint some chemical characteristics strongly correlated with the decomposition rate (Table 6). Such data were used to estimate amounts of nutrients released in the soil by each species (Table 7).

Table 3. Results of soil analysis in the 1st year of cultivation after a one-year fallow

	pH		P		K		Ca		Mg		CEC		Corg	
	20[1]	40[2]	20	40	20	40	20	40	20	40	20	40	20	40
			mg kg^{-1}				meq 100 g^{-1}						%	
Indigofera astragalina	5.07	5.15	4.06	1.47	0.30	0.21	1.09	1.23	0.41	0.49	1.99	2.17	0.33	0.24
Crotalaria ochroleuca	4.71	4.96	3.45	1.40	0.35	0.23	0.81	1.01	0.36	0.44	1.86	2.04	0.33	0.25
Crotalaria agatiflora	4.85	5.22	4.09	1.99	0.34	0.23	1.25	1.59	0.50	0.55	2.41	2.66	0.39	0.25
Crotalaria retusa	4.87	5.05	3.11	1.34	0.28	0.21	0.79	0.81	0.38	0.36	1.76	1.83	0.30	0.23
Crotalaria goreensis	4.99	5.14	3.15	1.10	0.36	0.20	0.98	1.14	0.40	0.47	1.99	2.11	0,36	0.27
Crotalaria pencilla	5.04	5.09	3.56	1.52	0.29	0.22	0.79	1.11	0.34	0.48	1.69	2.08	0.33	0.27
Tephrosia vogelii	4.93	5.16	3.00	1.17	0.32	0.23	0.90	1.15	0.39	0.46	1.85	2.13	0.34	0.27
Natural fallow	4.76	4.97	3.05	1.25	0.30	0.22	0.91	1.16	0.41	0.47	1.90	2.15	0.33	0.26
Continuous cropping	4.81	5.06	3.01	1.55	0.29	0.23	0.85	0.97	0.36	0.40	1.85	1.92	0.32	0.24
Initial state	4.52	4.77	2.36	1.28	0.20	0.13	1.04	1.60	0.40	0.56	2.09	2.73	0.46	0.36
P treatment	0.062		0.211		0.050		0.124		0.407		0.057		0.004	
P depth	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
LSD treatment	0.251		0.881		0.064		0.391		0.128		0.410		0.050	
LSD depth	0.055		0.207		0.011		0.058		0.026		0.082		0.009	
CV treatment (%)	3.0		24.6		15.1		21.9		17.3		11.9		9.8	
CV depth (%)	2.8		23.9		11.2		13.5		14.9		9.9		7.4	

[1] 0–20 cm depth; [2] 20–40 cm depth.

Table 4. Litter and leaf biomass production by species in trial 1 which were used in a two-year fallow at the Samanko station, Mali

Species	Litter 2000	2001	Cumulated litter	Leaf biomass (2002)	Grand total
	kg ha^{-1}				
Tephrosia candida	1940.2	2453.6	4393.8	309.6	4703.3
Sesbania sesban (Lery)	1214.4	934.4	2148.9	1180.5	3329.4
Sesbania sesban (Gaché)	1407.8	842.7	2250.4	274.3	2524.8
Sesbania sesban (Kibwezi)	973.8	1458.9	2432.7	774.2	3206.9
Sesbania sesban (Kakamega)	1234.7	1245,3	2480.0	309.5	2789.5
Cassia sieberiana	738.9	3058.7	3797.6	4281.2	8078.7
Cajanus cajan	4676.9	3855.1	8532.0	208.3	8740.3
Natural fallow	na	na	na	582.1*	582.1*
Continuous cropping	na	na	na	248.8*	248.8*
Probability	0.0001	0.0005	0.0001	0.0001	0.0001
LSD	541.71	1137.8	994.29	682.68	1329.3
CV (%)	17.49	32.32	15.02	43.45	15.67

* Shows the weight of biomass from the grass cover; na: not available.

Table 5. Sorghum yields after a two-year fallow with the species of trial 1 (conducted at the Samanko station, Mali)

Species	Grain Yields		Residues	
	2002	2003	2002	2003
	kg ha^{-1}			
Tephrosia candida	1369.3	740.74	6496	1210.83
Sesbania sesban (Lery)	2135.4	833.33	6440	1622.35
Sesbania sesban (Gaché)	1937.3	763.89	5951	1462.42
Sesbania sesban (Kibwezi)	2307.5	856.84	6444	1900.00
Sesbania sesban (Kakamega)	2036.6	763.89	6193	1563.24
Cassia sieberiana	1060.5	694.45	4664	1356.44
Cajanus cajan	1241.4	625.00	4553	1291.58
Natural fallow	1249.0	810.19	6060	1717.33
Continuous cropping	565.2	462.96	3252	1282.15
Probability	0.0001	0.060	0.06	0.024
LSD	573.59	368	2179	618.7
CV (%)	21.45	30.93	22.62	26.8

In general, *T. candida* and the four *S. sesban* provenances exhibit very high nitrogen contents (>3.5%), acceptable potassium contents and low lignin contents, to the exception of *T. candida*. They also have the lowest ratios, which account for the biomass decomposition rate (C: N, lignin:N and (lignin + phenolic composites):N). It should be noted, however, that phosphorous and magnesium rates are very low in all species. These results no doubt justify the use of *S. sesban* and *T. candida* which produced very good sorghum yields.

Soil analysis data (Table 8) are quite similar to those obtained with species used during only one year of fallow. Generally, horizon 0–20 cm is more acid, richer in phosphorous, in potassium and in carbon but with a CEC lower than in horizon 20–40 cm ($p < 0.001$). Treatments differ one from the other in their potassium and carbon content (0–20 cm). *T. candida* and *S. sesban* (Lery) exhibit more P than others, followed by the three *S. sesban* provenances (Kakamega, Gachié and Kibwerzi). All treatments showed improvements as compared to the initial situation before the fallow phase. Regarding CEC, the soil initial state and *S. sesban*-based treatments (Lery and Kibwerzi) produced better results than other treatments in the 20–40 cm layer. However, soil carbon content at the initial state is higher as compared to all other treatments.

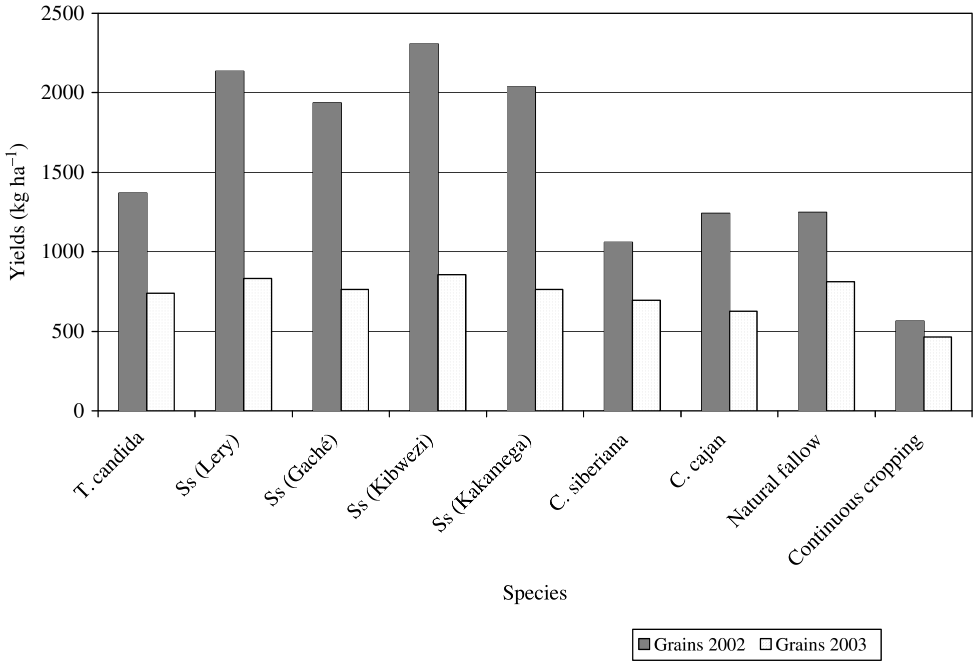

Figure 2. Sorghum yield trends after a two-year improved fallow at the Samanko station, Mali.

Table 6. Major fertilizing elements and some biochemical characteristics of species used in a one-year fallow

Species	N	P	K	Mg	PP	Lignin	C:N	Lig :N	(Lig+PP) :N
T. candida §	3.50	0.20	1.60	na	3.10	14.60	na	4.20	5.10
S. sesban (Lery)	3.60	0.13	1.92	0.30	2.01	3.85	13.16	1.07	1.63
S. sesban (Gaché)	3.80	0.20	2.16	0.24	1.67	5.63	12.38	1.48	1.92
S. sesban (Kibwezi)	3.55	0.16	1.92	0.34	2.01	5.90	12.94	1.66	2.23
S. sesban (Kakamega)	3.95	0.16	1.92	0.29	2.03	9.04	11.82	2.29	2.80
C. sieberiana	2.10	0.10	0.69	0.21	9.44	14.21	22.94	6.77	11.26
C. cajan	2.85	0.16	1.12	0.20	3.58	13.88	16.24	4.87	6.13
Natural fallow	1.70	0.12	2.78	0.23	1.32	5.66	23.41	3.33	4.11
Continuous cropping	2.05	0.11	2.22	0.37	1.31	6.29	19.02	3.07	3.71

§ From Niang et al. (2002); na: not available; PP: phenolic composites.

Conclusion

From these preliminary results, it can be concluded that there are certainly possibilities to implement a one-year fallow period with species such as *I. astragalina*, *C. paulina* and *C. agatiflora* in areas where rainfall varies between 700 and 800 mm per year to produce annual mean yields of about 1.5 t ha^{-1} in the first year of cultivation.

In the first year (2002), Kenyan *Sesbania sesban* provenances outyielded all other species, with annual average production above 2 t ha^{-1}. In 2003, a yield decline was recorded as compared to the previous year; this particularly affected *Sesbania sesban* Kenyan provenances which only produced 40% of their previous year levels. Results obtained elsewhere in East Africa confirm the significant drop in yields in the second year of cultivation of improved fallows using species not sprouting following cutting (personal observation made during field visits in Zambia, Paramu Mafongoya (2004): personal presentation). These results could be due to a loss of nitrogen (NO3 and NH4) through lixiviation on sandy and light soils (Mafongoya et al., 2003). It can then be concluded that such species could be used for just one cereal crop after a fallow period on sandy soils.

Table 7. Amounts of nutrients released by agroforestry species after the fallow period

Species	Quantities (kg ha^{-1})			
	N	P	K	Mg
Tephrosia candida	164.61	9.40	75.25	na
Sesbania sesban (Lery)	119.86	4.32	63.92	9.98
Sesbania sesban (Gaché)	95.94	5.05	54.53	6.06
Sesbania sesban (Kibwezi)	113.85	5.13	61.57	10.90
Sesbania sesban (Kakamega)	110.19	4.46	53.56	8.09
Cassia sieberiana	169.65	8.08	55.74	16.96
Cajanus cajan	249.10	13.98	97.89	17.47
Natural fallow	9.90	0.69	16.18	1.33
Continuous cropping	5.10	0.27	5.52	0.92
P	0.0001	0.0001	0.0001	0.0001
CV (%)	18.32	17.70	21.49	19.60
LSD	35.044	1.628	19.240	3.078

Table 8. Results of soil analysis conducted in the first year of cultivation after a two-year fallow

	pH		P		K		Ca		Mg		CEC		Corg	
	20[1]	40[2]	20	40	20	40	20	40	20	40	20	40	20	40
	mg kg^{-1}				meq 100 g^{-1}						%			
Tephrosia candida	4.94	4.90	3.18	0.93	1.34	0.20	1.04	1.02	0.50	0.44	2.18	2.04	0.35	0.25
S. sesban (Lery)	4.93	5.15	2.60	1.09	1.33	0.18	1.21	1.49	0.46	0.55	2.18	2.43	0.39	0.28
S. sesban (Gachié)	4.85	5.08	2.72	1.12	035	0.18	0.97	1.17	0.41	0.50	1.96	2.14	0.36	0.26
S. sesban (Kibwerzi)	4.92	5.05	2.65	1.07	0.33	0.19	1.10	1.39	0.42	0.55	2.09	2.36	0.36	0.26
S. sesban (Kakamega)	5.06	503	2.52	1.14	0.38	0.23	0.87	1.06	0.37	0.47	1.87	2.13	0.34	0.28
Cassia siberianna	4.91	5.31	2.77	0.82	0.28	0.18	0.94	1.04	0.55	0.47	2.04	2.01	0.40	0.25
Cajanus cajan	5.04	5.16	2.72	1.05	0.29	0.15	0.88	1.08	0.37	0.43	1.81	1.96	0.33	0.26
Natural fallow	4.76	4.98	3.05	1.24	0.30	0.21	0.91	1.16	0.41	0.47	1.91	2.15	0.33	0.26
Continuous cropping	4.81	5.07	3.01	1.55	0.29	0.23	0.85	0.96	0.36	0.40	1.85	1.92	0.32	0.24
Initial state	**4.52**	**4.77**	**2.36**	**1.28**	**0.20**	**0.13**	**1.04**	**1.60**	**0.40**	**0.57**	**2.09**	**2.72**	**0.46**	**0.36**
P treatment	0.062		0.211		0.050		0.124		0.407		0.057		0.004	
P depth	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
LSD treatment	0.251		0.881		0.064		0.391		0.128		0.410		0.050	
LSD depth	0.055		0.207		0.011		0.058		0.026		0.082		0.009	
CV treatment (%)	3.0		24.6		15.1		21.9		17.3		11.9		9.8	
CV depth (%)	2.8		23.9		11.2		13.5		14.9		9.9		7.4	

[1] 0–20 cm depth; [2] 20–40 cm depth.

Soil physical and chemical properties did not change significantly one year after the cultivation of fallows. Agroforestry species are particularly efficient in supplying nitrogen to crops as they have high nitrogen contents. Considering the significant contribution of this nutrient in the soil, it would be recommended analyze fresh soil samples in order to monitor trends in the profile and develop strategies for a more efficient use.

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