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# Groundnut / cassava / maize intercrop yields over three cycles of a fallow / crop rotation with planted *Senna spectabilis*, *Flemingia macrophylla* and *Dactyladenia barteri* on Ultisol

S. Hauser

International Institute of Tropical Agriculture (IITA), Humid Forest Eco-regional Centre, Mbalmayo, B.P. 2008, Messa, Yaoundé, Cameroon. Email s.hauser@cgiar.org

**Abstract**

Three cycles of two years fallow followed by slash-and-burn land preparation and one year of groundnut / cassava / maize intercropping were conducted with *Senna spectabilis*, *Flemingia macrophylla* and *Dactyladenia barteri* as planted hedgerow fallows and a no-tree control on an Ultisol in southern Cameroon. The experiment had been continuously cropped to maize / cassava intercrop for five years previous to the first two-year fallow phase. Lack of crop yield response to planted fallow lead to introducing a two-year fallow phase to determine if planted tree fallow can improve soil fertility and yields over a no-tree control.

Groundnut grain yields were unaffected by fallow system in 1998 and 2001 and the sum of the three cropping years. Maize grain yield was unaffected by fallow system in 1998. In 2001 and 2004 maize grain yield was highest in the *S. spectabilis* system. Total maize grain yield across the three cropping years was higher in the *F. macrophylla* and *S. spectabilis* systems than in the *D. barteri* system. Cassava root yields were in all years and the sum of the three years unaffected by fallow system. Cassava root (1998, 2001) and groundnut grain (2001) yields had significant spatial responses to the distance from hedgerows, with yield increases with increasing distance from hedgerows. Annual biomass production of hedgerow prunings during cropping phases ranged from zero (*D. barteri*) to 3.4 Mg $ha^{-1}$ (*S. spectabilis*). During the growth of groundnut and maize, hedgerows produced < 1Mg $ha^{-1}$ in 1998, < 0.6 Mg $ha^{-1}$ in 2001 and < 0.8 Mg $ha^{-1}$ at any individual pruning. Combined relative crop yields over the three cycles were lower in planted fallow than in the no-tree control. The N export with groundnut and maize grain and cassava roots, as an indicator of crude protein production was lower in the planted hedgerow fallow systems than in no-tree control. The planted fallow hedgerow system appears unsuitable to improve crop yields because the nutrient supply from prunings is low due to their low biomass production. Yet on short distances, the spatial response of cassava and groundnut indicates competition between hedgerows and crops, which was most pronounced on cassava and groundnut in the *S. spectabilis* system. The crop combination appears incompatible as benefits realized by the maize were outweighed by losses in groundnut.

## Introduction

In West and Central Africa, tree-based planted fallow, specifically alley cropping, was developed as an alternative to slash and burn bush fallow systems. The system was designed to replace real fallow phases, thus increased land use frequency to approach continuous food production. In alley cropping usually leguminous trees are planted in rows with 3-6 m distance between rows. Trees are pruned during the cropping season to reduce competition and provide nutrients from decomposing mulch. During phases when crops cannot be grown (dry season) the trees grow to accumulate biomass and nutrients for the next cropping cycle. Most alley cropping experiments have been conducted on relatively fertile Alfisols (Kang et al. 1995a) on experimental stations and in most of these cases it was shown to be a productive system, permitting continuous food crop production.

On West and Central African Ultisols and Oxisols and under farmer conditions yield increments of maize due to hedgerows were not up to 10 % of those realized on-station on Alfisols (Hauser et al, in press). In contrast to results from experimental stations, farmers have largely abandoned the continuous use of planted tree fallows for food crops and included real fallow phases. In southern Cameroon, Kanmegne and Degrande (2002) introduced real fallow phases in a *Calliandra calothyrsus* system after having encountered "several shortcomings" when cropped every year. However, no research data are available on planted tree fallow systems with real fallow phases.

In southern Cameroon and other parts of the Congo basin, intercrops of groundnut, maize and cassava along with a large number of minor crops are of paramount importance in smallholder farming systems (Büttner & Hauser, 2003). However, groundnut, a major source of protein for the local population, has not received much attention within planted fallow and alley cropping research. Schroth et al. (1995) found increased groundnut yields in alley cropping in Cote d'Ivoire on an Acrisol, and concluded that groundnut should be included in the set of crops tested in alley cropping trials. A recent review of the literature on tree-based fallows in West and Central Africa revealed that less than 10% of the comparisons with natural fallow were made in intercropping systems, none of which had more than 2 crops (Hauser et al, in press). Smallholder agriculture, however, is dominantly intercropping in rather complex systems with three or more crops.

This paper reports on the continuation of a long-term experiment, started in 1990. The experiment was continuously cropped to a maize / cassava intercrop for five years. Crop yield response was significantly and consistently positive only in *Flemingia macrophylla* alley cropping system. The main reason for insignificant responses to application of prunings from *Dactyladenia barteri* was probably the low amount of biomass produced and hence an insufficient amount of nutrients supplied, while a relatively high biomass production of *Senna spectabilis* was apparently attained through strong competition with the crops. Consequently the system was changed to a rotational alley cropping / fallow system, to allow the trees to produce biomass and accumulate nutrients in a real fallow phase. A rigorous pruning regime was introduced in the cropping phase to overcome strong competition of hedgerows with the crops. This system was maintained through 3 cycles of two years fallow and 1 year cropping of the most commonly grown intercrop in southern Cameron: groundnut/cassava/maize to determine if planted hedgerow fallow can out-yield the natural fallow.

**Materials and methods**

The trial was established on Ultisol at the research farm of the International Institute of Tropical Agriculture (IITA), Humid Forest Eco-regional Center, Mbalmayo, southern Cameroon (3°51' N, 11°27' E) in 1990, on land, manually cleared from secondary forest. Biomass was burned *in situ*, and remaining wood was stacked and burned again. Average annual precipitation is 1513 mm with a bimodal distribution. Rains start in mid-March. A short dry season follows from mid-July until the end of August. The main rainy season is from September to the middle of November. The trial was a randomized complete block design, replicated three times, with three hedgerow species, *Senna spectabilis, Flemingia macrophylla* and *Dactyladenia barteri* versus a no-tree control. Hedgerows were established in May 1990. Cropping started in April 1991. Plots measured 28 m x 6 m and had five hedgerows planted at an interrow distance of 6 m and an intrarow distance of 0.25 m. Biomass was not burned during the 5 years of continuous maize cassava cropping.

Land preparation was by slash and burn after the burn, the soil surface was cleaned in the traditional manner using cutlasses and hoes, removing weeds and roots. The ash was distributed in the interrow space after the burn. Plots were planted to a local groundnut (*Arachis hypogaea*) variety at a density of approximately 20 $m^{-2}$, maize (*Zea mais*) cv. CMS 8704 and cassava (*Manihot esculenta*) cv. 8017. Maize and cassava were planted in alternating rows parallel to the hedgerows starting with cassava at a distance of 0.5 m from the hedgerow at 1m intrarow distance to attain 1 plant $m^{-2}$ of cassava. Maize was planted at 0.5m intrarow distance with 2 seeds per stand (4 plants $m^{-2}$)

Hedgerow pruning and weeding
The hedgerows were pruned when deemed necessary, thus not all species were pruned at the same time. Weeding was conducted once during the groundnut growing phase, at groundnut harvest and in November of each cropping year.

Harvest
Groundnuts and maize were harvested between 91 and 110 DAP, depending on climatic conditions. Groundnut was harvested in 6 sections of 0.75cm along transects perpendicular to the hedgerows. Maize and cassava were harvested by line according to distance to the hedgerows.

To compare the total crop yields of all crops between fallow systems, the cumulative yield over the three years was calculated for each crop relative to the control (control yield = 1) and the mean of the relative yields was calculated to receive an index of production. This was done considering each crop of equal importance and with the most probable weighting according to the importance accorded to each crop by farmers. Maize is the least important crop in this system and was retained at factor 1, cassava is the second most important crop and was assigned the factor 2, groundnut is the most important crop with a factor of 3.

*Statistical analyses*
Data were analyzed in SAS release 8, using proc GLM for comparison of treatments. Least square means (lsmeans) were calculated and pair-wise comparisons (pdiff) conducted. The positions, within transects for groundnut harvest and the maize and cassava lines at different distance to the hedgerows were treated as nested. Different years were compared using the repeated function and Wilks lambda as the criterion. Percent data were 'square root of arcus sinus' transformed according to Sokal & Rohlf (1995). The probability of differences between lsmeans is quoted up to a level of $p = 0.1$ to allow readers individual judgment. The conventional level of $p<0.05$ is considered as significant.

## Results

*Biomass production of the hedgerows*
The total annual pruning biomass in 1998 was 1.31 Mg $ha^{-1}$ in *F. macrophylla* and 3.37 Mg $ha^{-1}$ in *S. spectabilis* ($p = 0.062$). *Dactyladenia barteri* did not produce any biomass worth pruning. During the 2001 – 2002 cropping season, the total biomass produced by *S. spectabilis* was higher than that of *D. barteri* ($p<0.001$) and that of *F. macrophylla* ($p=0.002$). The total biomass produced by *S. spectabilis* and *F. macrophylla* was lower in 2001/02 than in 1998/99. During the 2004/05 cropping season biomass production was 2.72 Mg $ha^{-1}$ in *S. spectabilis,* significantly more than in *D. barteri* (0.57 Mg $ha^{-1}$, $p<0.006$) and in *F. macrophylla* (1.42 Mg $ha^{-1}$, $p=0.030$).

*Groundnut yield*
Groundnut plant density, grain yield, straw yield and harvest index were not affected by the fallow species in 1998 and 2001 (Table 1). In 2001, across the three hedgerow systems, groundnut grain yield was significantly lower at 0 to 0.75m distance than at any distance further

away from the Table 1: Plant density (plants $m^{-2}$), grain yield (Mg $ha^{-1}$), straw yield (Mg $ha^{-1}$) and harvest index (%) of groundnut, Mbalmayo, southern Cameroon, 1998, 2001, and 2004.

| | Plants $m^{-2}$ | Grain Mg $ha^{-1}$ | Straw Mg $ha^{-1}$ | Harvest Index |
|---|---|---|---|---|
| Mean 1998 | 17.9 | 0.341 | 1.734 | 16.3 |
| Mean 2001 | 15.2 | 0.683 | 1.840 | 27.0 |

hedgerows. The cumulative groundnut grain yield of the three cropping years followed the order *F. macrophylla* (1.50 Mg $ha^{-1}$) < *S. spectabilis* (1.73 Mg $ha^{-1}$) < *D. barteri* (1.88 Mg $ha^{-1}$) < control (2.05 Mg $ha^{-1}$) and was not affected by the fallow system. In 2004, the *F. macrophylla* system produced significantly lower grain yields than any other system (Table 2).

Table 2: Plant density (plants $m^{-2}$), grain yield (Mg $ha^{-1}$), straw yield (Mg $ha^{-1}$) and harvest index (%) of groundnut, Mbalmayo, southern Cameroon, 2004.

| Fallow species | Plants $m^{-2}$ | Grain Mg $ha^{-1}$ | Straw Mg $ha^{-1}$ | Harvest Index |
|---|---|---|---|---|
| *Senna spectabilis* | 18.4 | 0.643 | 1.815 | 26.2 |
| *Dactyladenia barteri* | 18.2 | 0.761 | 2.128 | 26.3 |
| *Flemingia macrophylla* | 16.5 | 0.478 | 1.431 | 25.6 |
| No-tree control | 20.7 | 0.753 | 1.979 | 27.6 |
| pairwise comparison | | | | |
| Flemingia vs Control | 0.004 | <0.001 | 0.013 | ns |
| Flemingia vs Dactyladenia | ns | <0.001 | 0.003 | ns |
| Flemingia vs Senna | ns | 0.024 | Ns | ns |

*Maize yield*

In 1998, the *F. macrophylla* system achieved the highest marketable cob density, being different form that in the *D. barteri* ($p = 0.019$) and *S. spectabilis* ($p = 0.059$) systems. The maize grain yield was lowest in the *D. barteri* and highest in the *F. macrophylla* ($p = 0.059$) system (Table 2). In 2001, marketable cob density was 18% lower than in 1998, with the *D. barteri* system outyielding the *S. spectabilis* and no-tree control systems. Grain yield was the highest in the *S. spectabilis* and *D. barteri* systems, outyielding the no-tree control and the *F. macrophylla* systems. In 2004 marketable cob density was unaffected by fallow system. The grain yield was highest in *S. spectabilis*, outyielding all other systems, *F. macrophylla* outyielded *D. barteri*. The sum of marketable cobs followed the order *D. barteri* (3.7 $m^{-2}$) < control (3.8 $m^{-2}$) < *S. spectabilis* (4.1 $m^{-2}$) < *F. macrophylla* (4.3 $m^{-2}$) and was not affected by the fallow system. The cumulative maize grain yield of the three years was lowest in *D. barteri* (4.33 Mg $ha^{-1}$) followed by the control (4.76 Mg $ha^{-1}$). Cumulative maize grain yield in *F. macrophylla* (5.02 Mg $ha^{-1}$) and *S. spectabilis* (5.23 Mg $ha^{-1}$) were significantly higher than in *D. barteri* ($p = 0.03$ and $p = 0.01$, respectively).

Table 4: Maize grain yield (Mg $ha^{-1}$), Mbalmayo, southern Cameroon, 1998, 2001 and 2004.

| Fallow species | Grain 1998 | Grain 2001 | Grain 2004 | Grain cumulative |
|---|---|---|---|---|
| *S. spectabilis* | 1.67 | 1.41 | 2.15 | 5.23 |
| *D. barteri* | 1.52 | 1.38 | 1.43 | 4.33 |
| *F. macrophylla* | 2.10 | 1.15 | 1.77 | 5.02 |
| No-tree control | 2.05 | 1.07 | 1.64 | 4.76 |
| pairwise comparison | | | | |
| Control vs. *Senna* | ns | 0.0014 | 0.005 | ns |
| Control vs. *Dactyladenia* | 0.076 | 0.0048 | Ns | ns |
| Control vs. *Flemingia* | ns | ns | Ns | ns |
| *Flemingia* vs. *Dactyladenia* | 0.059 | 0.086 | 0.028 | 0.03 |
| *Flemingia* vs. *Senna* | ns | 0.031 | 0.018 | ns |
| *Dactyladenia* vs. *Senna* | ns | ns | <0.001 | 0.01 |

*Cassava yield*

Cassava tuberous root yields were unaffected by the fallow systems in all three years. In 2001, cassava tuberous root yields was 30% lower than in 1998. In 2004 tuberous root yields were lower than in 2001 (Table 4). The cumulative cassava root yield of the three years was highest in *F. macrophylla* (18.23 Mg $ha^{-1}$) followed by the control (16.05 Mg $ha^{-1}$), *S. spectabilis* (15.96 Mg $ha^{-1}$) and *D. barteri* (15.53 Mg $ha^{-1}$). The difference between the root yield in *F. macrophylla* and all other systems failed the F-test at p=0.0596.

Table 7: Tuberous root yield (Mg $ha^{-1}$) cassava cv 8017, Mbalmayo, southern Cameroon, planted in 1998, 2001 and 2004.

| Fallow species | 1998 | 2001 | 2004 | Total |
|---|---|---|---|---|
| *S. spectabilis* | 6.93 | 4.66 | 4.37 | 15.96 |
| *D. barteri* | 6.44 | 4.56 | 4.53 | 15.53 |
| *F. macrophylla* | 7.86 | 5.24 | 5.13 | 18.23 |
| No-tree control | 6.69 | 5.08 | 4.28 | 16.05 |
| Mean | 6.98 | 4.88 | 4.58 | |

In 1998, cassava root biomass production had a significant fallow system by distance from hedgerows interaction: in the *S. spectabilis* system biomass production increased with distance from hedgerows, while no such spatial response was found in the other systems (Figure 1). In 2001, cassava had a similar spatial response to the distance from the hedgerows, yet not for individual hedgerow species. Across the three species, root yields were the highest at 2.5 m distance from the hedgerows.

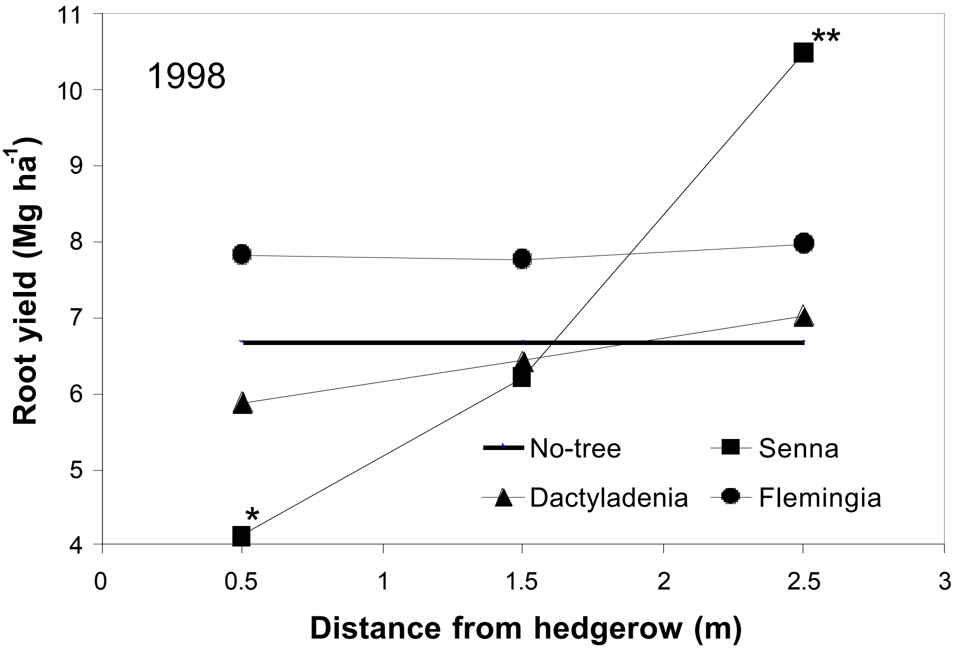


Figure1: Cassava root yield as a function of distance to the hedgerow, 1998, Mbalmayo, Cameroon.

*Relative crop yields and crude protein production over three years*
Although individual crops in some of the planted fallow systems out-yielded the control in some years, the cumulative combined relative yields were lower in all planted fallow systems, when all three crops were considered of the same importance. When differential weightings were assigned (groundnut = 3, cassava = 2 and maize = 1) the relative yield advantage of the control increased (Table 9).

*Relationships*
Correlation analyses did not reveal significant relationships between maize and cassava. Maize grain yield and groundnut grain yield were weakly, yet significantly negatively correlated:
groundnut grain yield = - 0.15 maize grain yield + 0.61; $r^2 = 0.35$; $p < 0.044$ .
No other plant parameters were significantly correlated.
Soil chemical properties were not related to crop yields.

**Discussion**
Planted tree fallows did not attain greater yields than natural fallow. This is in contrast to many publications reporting significant yield advantages on Alfisols (Kang et al 1995b). On Ultisols effects of planted fallow may be limited due to few nutrients available to serve the needs of both trees and crops. Further, the slash and burn land preparation, inevitable in the groundnut cassava maize system may severely compromise potential advantages of tree fallows. However, the annual cropping systems usually reported from Alfisols do probably not produce large quantities of wood but relatively more nutrient rich leaves with good potential to provide nutrients to crops. In real fallow systems trees produce largely wood and some species (such as *Senna spectabilis*) store the majority of nutrients in wood. Thus the option of not burning may not offer an alternative to conserve nutrients as they will not become available over long periods.
The spatial responses of crops indicate that the hedgerow species, despite their low biomass production, compete significantly with cassava and groundnut, the two major crop in the system. How far burning per se has a negative effect on crop production is difficult to assess as this is a matter of the amount of fuel burned and the temperatures attained (Hauser, this issue). However

the relative low amounts of biomass in natural fallow, D. barteri and F. macrophylla are probably not sufficient to cause negative effects. *Senna spectabilis* on the other hand with around 50 Mg $ha^{-1}$ may have caused heat related yield losses.

## Conclusion

Planted tree and shrub fallow need to be designed for specific purposes or crops, capable to positively respond to the changes such tree or shrub species cause in the system. Planted fallow need not primarily serve the purpose of soil fertility replenishment but can be used for entirely different reasons such as producing fire wood, poles, construction material, bee keeping etc. If fallow products contribute to revenue generation yield losses as experienced here may be tolerable. Complex intercrops do not appear to respond positively to planted tree / shrub fallow because the different crops have probably different resource requirements. The results of this rather long-term study do not confirm that planted tree and shrub fallow can accelerate soil fertility replenishment.

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