

## Forage legumes for improved fallows in agropastoral systems of subhumid West Africa.

### III. Nutrient import and export by forage legumes and their rotational effects on subsequent maize

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#### Abstract

In a short-term improved fallow for crop-livestock farming systems of subhumid west Africa, rotational effects from a range of forage legumes on a subsequent maize crop were studied at two sites in south-west Nigeria. Nutrient (nitrogen, phosphorus and potassium) export from the fallows in the form of dry season herbage and subsequent nutrient accumulation in the green manure biomass were correlated with growth patterns of maize subsequently grown on the legume plots. Maize plant height, grain yields and nitrogen content were compared with the response of maize to nitrogen fertiliser after natural fallow.

Up to 120 kg/ha N, 10 kg/ha P and 135 kg/ha K were removed as dry season herbage. Thereafter, within four months of regrowth, up to 144 kg/ha N, 18 kg/ha P and 140 kg/ha K were accumulated to incorporate as green manure before planting a maize crop. Maize grain yield increases due to preceding legumes ranged between 0% and 52% or 147% depending on the sites which showed contrasting fertiliser nitrogen responses for maize grain yield. Nutrient export in legume fallow biomass removed in the preceding dry season apparently did not influence the subsequent yield response of maize. Significant relationships

between rotational effects and patterns of green manure nitrogen release were found only at the site with lower fertiliser nitrogen response. Thus, the high potential of forage legumes to improve subsequent crop growth is influenced by site differences and is not determined by nutrient contribution alone.

#### Introduction

An improvement of existing fallow management systems with sown legumes has the potential to enhance the restoration of soil fertility through the accumulation of organic matter and fixation of atmospheric N<sub>2</sub>, or through an improvement of physical soil properties (Wilson *et al.* 1982). Suitable legumes also have the potential to alleviate feed constraints for cattle, especially during the dry season, through their higher nutritive value compared with the natural fallow vegetation (Minson 1984).

In an attempt to identify forage legumes for a short-term improved fallow system which contributes to both crop and livestock productivity, a range of leguminous species was evaluated in rotation with maize at 2 sites in subhumid south-west Nigeria. In two preceding papers, the potential of the legumes to stay green and improve forage quality and quantity in the dry season (Muhr *et al.* 1999a) whilst still producing green manure and thereby contributing nutrients to a subsequent maize crop (Muhr *et al.* 1999b), was tested. In this paper the study focuses on: i) nutrient export through dry season harvest of herbage; ii) nutrient accumulation during subsequent regrowth of leguminous green manure before crop planting; and iii) the effect on growth and yield of a subsequent maize crop for the different species. The results are compared with the response of maize on the same sites to nitrogen fertilisation after natural fallow.

## Materials and methods

The experiments were carried out at two sites in the derived savanna of south-west Nigeria. The soil at Ibadan (7°30' N, 3°54' E) was an Oxic Paleustalf (USDA classification) with total nitrogen (0.12%) and organic carbon (1.4%) concentrations about double those of the Plinthic Oxidic Haplustoll (USDA classification) at Fashola (8°7' N, 3°20' E), which was a farmer's field (Muhr *et al.* 1999a). At both sites, an average annual rainfall of about 1200 mm is distributed bimodally with a major dry season from November until March.

### Experiment 1

After the onset of the rains in May 1994, 11 herbaceous (*Centrosema macrocarpum* CIAT 5713, *Centrosema pubescens* ILRI 152 [CIAT 5126], *Stylosanthes guianensis* ILRI 164 [CIAT 184 cv. Pucallpa], *Pueraria phaseoloides*, *Mucuna pruriens* [both locally used varieties], *Desmodium ovalifolium* CIAT 13089, *Zornia glabra* CIAT 8279, *Dioclea guianensis* CIAT 7801, *Arachis pintoi* CIAT 17434 [cv. Amarillo], *Aeschynomene histrix* CIAT 9690 [ILRI 12463], *Calopogonium caeruleum* CIAT 8123) and two shrubby (*Flemingia macrophylla* CIAT 17403, *Cratylia argentea* CIAT 18516) legumes were sown on 4 × 5 m plots in a randomised complete block design with 4 replications (for more details see Muhr *et al.* 1999a). Natural fallow was included as a control. Herbage, consisting of both legumes (without shed leaves) and natural vegetation, was harvested and removed in the mid dry season (January 1995). Harvested plots were allowed to regrow during the rest of the dry and the beginning of the wet season, before the regrowth was incorporated as green manure into the soil immediately before sowing maize mid-May 1995. After incorporation of the green manure by rotor-tiller at Ibadan and traditional hoe at Fashola, a low input maize hybrid was sown on ridges 60 cm apart at 55 555 plants/ha with 2 seeds per hill which were thinned to one plant 5 weeks after sowing (WAS). Maize received 50 kg/ha K as muriate of potash and 26 kg/ha P as single superphosphate and was weeded once 5 WAS.

### Experiment 2

On an adjacent field, 4 × 4 m plots in a randomised complete block design with 4 replications were demarcated in May 1994, and

natural fallow vegetation was allowed to establish. Harvest of the plant cover in the mid-dry season, sampling and incorporation into the soil of the fallow vegetation prior to sowing maize as well as fertilisation of maize with P and K were carried out as in Experiment 1. In addition, 5 levels of N fertiliser (0, 30, 60, 90 and 120 kg/ha N) were applied to the maize in bands, 50% at sowing and another 50% five weeks later. After weeding 5 WAS, self sown guinea grass (*Panicum maximum*) started to overgrow maize plants at Ibadan, so a total herbicide was applied by knapsack sprayer provided with a device which protected the maize plants from the herbicide.

### Data collection and plant analyses

Starting 5 WAS, the height of 10 randomly selected maize plants was measured at 10-day intervals. Maize plants of 2 central rows (3 in Experiment 2) were harvested 15 WAS separately for stover, husks (plus empty cobs) and grain, and dry matter determined by drying at 60°C for 48 h. Subsamples of grain and bulked subsamples of stover plus husks were ground through 1 mm sieves and analysed for N, P and K.

N in herbage and maize plants was analysed by the micro-Kjeldahl method followed by colorimetric determination in a continuous-flow analyser (Technicon). For analysis of P and K, plant samples were wet-digested with a mixture of HClO<sub>4</sub>-HNO<sub>3</sub>. P was then determined colorimetrically by the Vanado-Molybdate method in a continuous-flow analyser (Technicon) and K by flame photometry (ITA 1979).

Due to a stem borer infestation in maize at Ibadan, incidence (%) of seriously damaged plants was estimated 11 WAS by counting plants which showed stalk rot and broken tassels or ears. At harvest, the percentage of stem length which was tunnelled was estimated on 10 harvested plants.

### Statistics

After submission of single observation data to ANOVA, multiple comparisons of means were made with HSD according to Tukey-Kramer at P<0.05. The effect of N on the height of the maize plants was tested separately at different times without considering within-subject effects. A covariance analysis of grain yield with incidence of stem borer damage was carried out in

order to test its effect on results of the maize harvest at Ibadan. N response of maize grain yield was modelled by linear regression analysis. Linear correlation analysis between maize response and selected parameters of nutrient fluxes within the improved fallow system was complemented by graphical examination for other than linear relationships.

## Results

### Dry season nutrient export

Higher quantities of macronutrients were exported in dry season herbage at Ibadan than at Fashola (Figure 1), except for *M. pruriens*, *C. argentea* (N, P and K) and natural fallow (P and K). At both sites, highest amounts of N, P and K were found for *S. guianensis*, exceeding 100 kg/ha for N and K but ranging below 10 kg/ha for P. These amounts were significantly ( $P < 0.05$ ) higher than in the natural fallow control except for P at Fashola. A high contribution by the associated natural vegetation to the nutrient export from the legume plots was observed for legumes with low herbage yield. The accumulation of 86 kg/ha N by the natural fallow control at Ibadan was striking, compared with 25 kg/ha N at Fashola.

### Nutrient accumulation in green manure

The contribution of the natural fallow vegetation to the nutrient accumulation by total herbage was generally higher in green manure (May; Figure 2) than in dry season herbage (January; Figure 1). Figures 2A and 2B include results of green manure N which had been reported for most, but not all, of the tested species by Muhr *et al.* (1999b). Except for *C. argentea*, accumulation of N, P and K in total plant biomass of legume treatments as well as natural fallow was again higher at Ibadan than at Fashola. *F. macrophylla* accumulated the highest amount of N (at both sites), P and K (at Fashola).

### N response of maize after natural fallow

In Experiment 2, the height of maize plants at different times showed significant ( $P < 0.05$ ) N responses starting 68 and 56 DAS at Ibadan and Fashola, respectively (Figure 3). At the last two measuring dates, the quadratic response of maize plant height to N fertiliser was stronger at Fashola than at Ibadan. Growth of maize plants was faster at Ibadan, where plants, except at 0 kg/ha N, reached maximum height by 58 DAS.

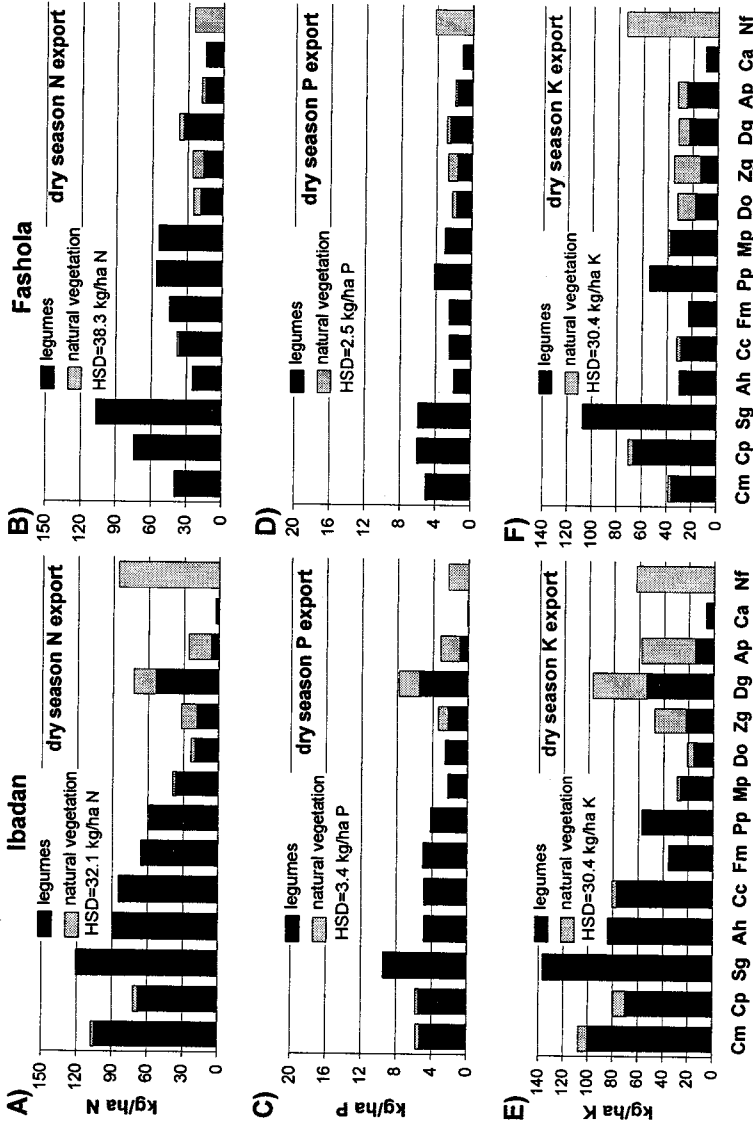
Maize grain yield increased linearly with increasing N levels (Figures 4A; 4B). At Ibadan, where a grain yield of 3.3 t/ha DM was obtained without N fertiliser, the response was much weaker than at Fashola. The same held true for N yield in total maize plants (Figures 4C; 4D) with no response ( $P > 0.05$ ) to N fertiliser at Ibadan, but a clear linear response ( $P < 0.05$ ) at Fashola. While maximum grain yield at Fashola exceeded that at Ibadan, maximum N yield was similar at both sites.

### Effect of forage legumes on maize growth and yield

In Experiment 1, the height of maize plants was found to differ significantly between different legume plots from 58 days after sowing (DAS) onwards at Ibadan ( $P < 0.01$ ) and from 35 DAS onwards at Fashola ( $P < 0.001$ ; Figure 5). At Ibadan, tallest maize plants at 68 DAS followed *C. caeruleum* (180 cm) and *C. macrocarpum* (178 cm) but these were not significantly taller ( $P < 0.05$ ) than those following natural fallow (163 cm). Differences were clearer at Fashola, where again maize after *C. caeruleum* (179 cm), followed by *S. guianensis* and *A. pintoii* (176 cm), reached the highest, and natural fallow and *D. ovalifolium* (134 cm) the lowest values. With the exception of the last measuring date, maize plants were taller at Ibadan than at Fashola.

In contrast, grain yields were generally higher at Fashola (Figures 6A; 6B). Highest yields at Ibadan were obtained for maize following *Z. glabra* (3.7 t/ha) which improved maize grain yields by 52% ( $P > 0.05$ ) over the control treatment (natural fallow) (2.5 t/ha). At Fashola, yields of most of the improved fallow treatments exceeded the control (1.9 t/ha), with differences being significant ( $P < 0.05$ ) for *S. guianensis* (4.7 t/ha), *C. caeruleum* and *A. pintoii*. *S. guianensis* improved maize grain yield by 147% compared with the control.

N yield in maize grain plus stover and husks (Figures 6C; 6D) paralleled grain yields. Only yields following *Z. glabra* (116 kg/ha N) at Ibadan, and *C. caeruleum* (115 kg/ha N) and *S. guianensis* (105 kg/ha N) at Fashola were significantly ( $P < 0.05$ ) higher than the respective control treatments (maize after natural fallow). Increases over controls were 35 kg/ha N (*Z. glabra*) and 58 kg/ha N (*C. caeruleum*) at Ibadan and Fashola, respectively.



**Figure 1.** Amounts of N (A, B), P (C, D) and K (E, F) exported by dry season harvest of forage legumes and natural vegetation at Ibadan and Fashola. (HSD according to Tukey at  $P < 0.05$  for nutrient export in legumes plus natural vegetation. Cm = *C. macrocarpum*, Cp = *C. pubescens*, Sg = *S. guianensis*, Ah = *A. histrix*, Cc = *C. caeruleum*, Fm = *F. macrophylla*, Pp = *P. phaseoloides*, Mp = *M. pruriens*, Do = *D. ovalifolium*, Zg = *Z. glabra*, Dg = *D. guianensis*, Ap = *A. pintoi*, Ca = *C. argentea*, Nf = natural fallow).

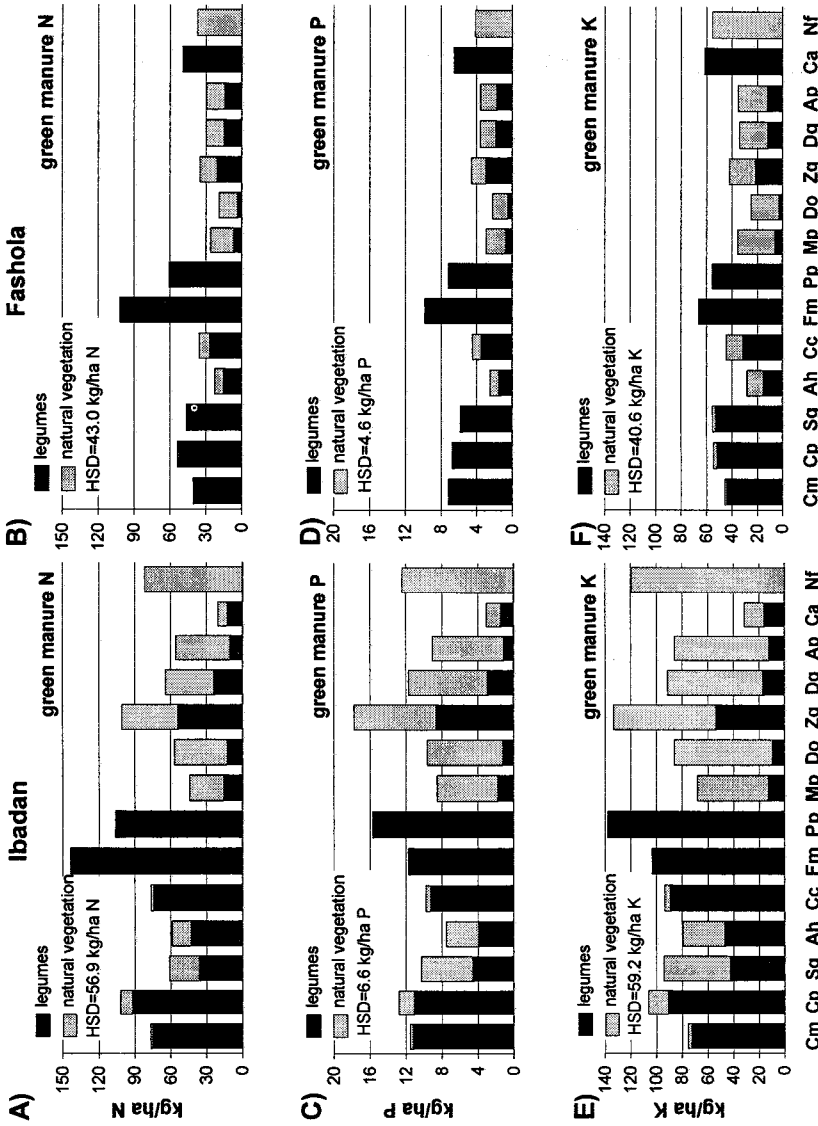


Figure 2. Amounts of N (A, B), P (C, D) and K (E, F) in green manure (forage legumes and natural vegetation) incorporated into the soil before sowing maize at Ibadan and Fashola. (HSD according to Tukey at  $P < 0.05$  for nutrients in legumes plus natural vegetation. Cm = *C. macrocarpum*, Cp = *C. pubescens*, Sg = *S. guianensis*, Ah = *A. histrix*, Cc = *C. caeruleum*, Fm = *F. macrophylla*, Pp = *P. phaseoloides*, Mp = *M. pruriens*, Do = *D. ovalifolium*, Zg = *Z. glabra*, Dg = *D. guianensis*, Ap = *A. pintoi*, Ca = *C. argentea*, Nf = natural fallow).

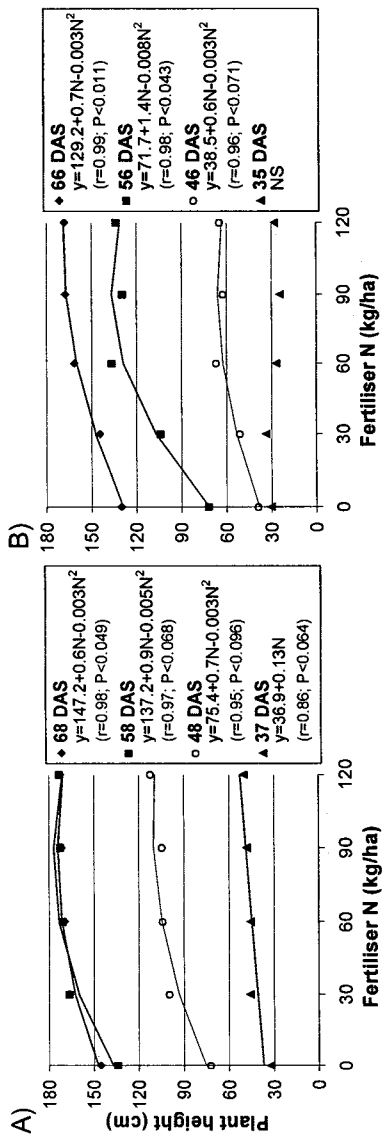
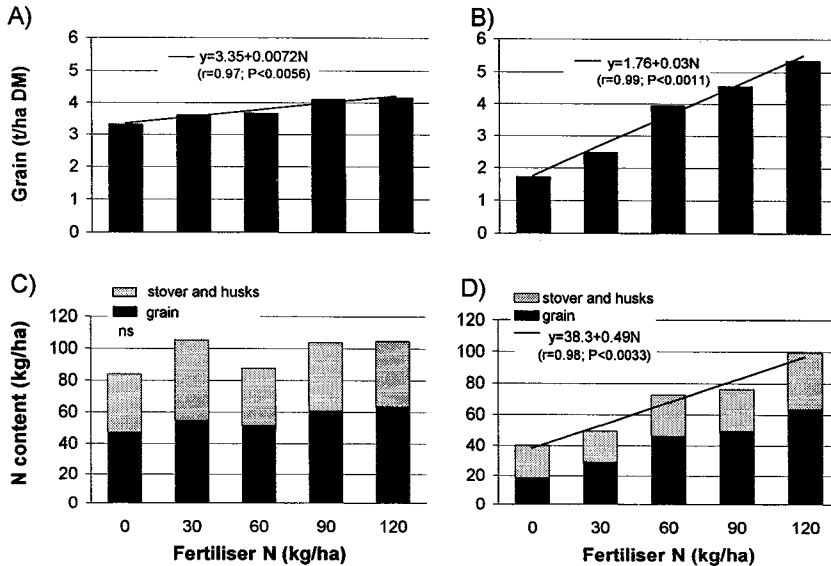


Figure 3. Height of maize plants of different age (DAS = days after sowing) as affected by fertiliser-N supply at Ibadan (A) and Fashola (B); (linear or quadratic regression equations [n = 5] given if P<0.10).



**Figure 4.** Grain yields (A, B) and N contents in grain, stover and husks (C, D) of maize plants as affected by fertiliser-N supply at Ibadan (A, C) and Fashola (B, D); (linear regressions with  $n = 5$ ).

### Maize pests

About 11 WAS, maize plants were infested with stem borer, *Eldana saccharina* (Walker) (Lepidoptera, Pyralidae), at Ibadan. Average incidence of seriously damaged plants was 30% in Experiment 1 with significant block effects ( $P < 0.001$ ), and 25% in Experiment 2 with significant treatment effects ( $P < 0.05$ ). At harvest, 13% of stem length was tunnelled in Experiment 1 with significant block and treatment effects ( $P < 0.01$ ), and 15% in Experiment 2 with significant treatment effects ( $P < 0.01$ ). Due to the presence of significant treatment effects, covariance analysis of maize grain yield could be performed only with stem borer incidence 11 WAS in Experiment 1. Means of grain yield, however, were not adjusted since adjusted values hardly differed from non-adjusted values. In comparing treatments, stem borer damage was higher in those with higher grain yield.

### Interactions with above-ground nutrient fluxes

The export of macronutrients (N, P and K) in dry season herbage did not influence grain yield nor above-ground N content of subsequently grown maize at either site (Table 1). In contrast, the accumulation and incorporation into the soil of green manure biomass (DM) and its corresponding

amounts of N, P and K, correlated positively with maize grain yield ( $P < 0.01$ ) and above-ground N content ( $P < 0.05$ ) at Ibadan, but not at Fashola.

The performance of maize after different fallow treatments could also be related to selected characteristics of leguminous green manure decomposition (Table 1), which had been reported in a previous paper for 6 of the 13 legume species of the present study as well as for the natural fallow control (cf. Muhr *et al.* 1999b). Faster decomposition of both green manure dry matter ( $k_{DM}$ ) and N ( $k_N$ ) was significantly related to lower grain yields ( $P < 0.01$ ) and N content of maize ( $P < 0.05$ ) at Ibadan, with no significant effect at Fashola. N released from decomposing green manure had no clear effect on maize until 8 WAS. In contrast, N released between 9 and 12 WAS significantly ( $P < 0.05$ ) improved both grain yield and above-ground N content of maize at Ibadan.

### Discussion

#### N contribution to maize

Yield increases in subsequent crops, which otherwise could be obtained only by application of N fertilisers, are a key benefit from introducing legumes into cropping systems (Peoples *et al.*

**Table 1.** Pearson's correlation coefficients (r) between maize grain yield, above-ground N content in maize and nutrient fluxes in an improved fallow system based on legumes for dry season forage and subsequent use as green manure.

Nutrient fluxes	Maize grain yield (t/ha DM)		Maize N content (kg/ha N)	
	Ibadan	Fashola	Ibadan	Fashola
Dry season harvest of herbage (legumes + natural vegetation) (n = 14) (Figure 1)				
N export (kg/ha N)	0.23	0.43	0.10	0.40
P export (kg/ha P)	0.28	0.08	0.40	-0.12
K export (kg/ha K)	0.29	0.22	0.23	0.33
Green manure (legumes + natural vegetation) to maize (n = 14) (Figure 2)				
DM (t/ha) <sup>1</sup>	0.77** <sup>2</sup>	0.15	0.64*	0.23
Biomass N (kg/ha N)	0.70**	0.19	0.59*	0.25
Biomass P (kg/ha P)	0.77**	0.12	0.67**	0.19
Biomass K (kg/ha K)	0.72**	0.08	0.56*	0.14
Green manure decomposition during 3 months of maize growth (legumes only) (n = 7) <sup>1</sup>				
DM decomposition rate (k <sub>DM</sub> )	-0.88**	0.22	-0.79*	0.08
N decomposition rate (k <sub>N</sub> )	-0.93**	0.33	-0.86*	0.22
N release week 0-4 (kg/ha N)	-0.07	0.34	0.14	0.25
N release week 5-8 (kg/ha N)	0.47	0.32	0.60	0.60
N release week 9-12 (kg/ha N)	0.89**	0.02	0.79*	-0.03

<sup>1</sup>Data from litter bag decomposition study for 7 out of 14 treatments: *C. macrocarpum*, *C. pubescens*, *S. guianensis*, *A. histrix*, *C. caeruleum*, *F. macrophylla*, natural fallow (herbs, grasses and naturalised legumes) (Muhr *et al.* 1999b).

<sup>2</sup>\* and \*\* = significant at P<0.05 and P<0.01, respectively.

1995). At Fashola, where the relationship between N fertiliser and grain yield was found to be linear with a steep slope up to 120 kg/ha N (Figure 4A), forage legumes contributed the equivalent of up to 96 kg/ha fertiliser-N (*S. guianensis*; Figure 7B). At Ibadan, only *Z. glabra* (52 kg/ha N) and *P. phaseoloides* (35 kg/ha N) contributed significant amounts of N fertiliser-equivalents (Figure 7A). Since the control (maize after natural fallow) in Experiment 1 was the same treatment as maize at 0 kg/ha N in Experiment 2, maize grain yields would also have been expected to be similar. This was the case at Fashola (2.0 vs 1.7 t/ha), but not at Ibadan (3.2 vs 2.5 t/ha) (Figures 4A; 4B vs Figures 6A; 6B). Taking into account the rather weak N response between 0 and 120 kg/ha N at Ibadan, the derivation of N-fertiliser equivalents must be interpreted with some caution at this site.

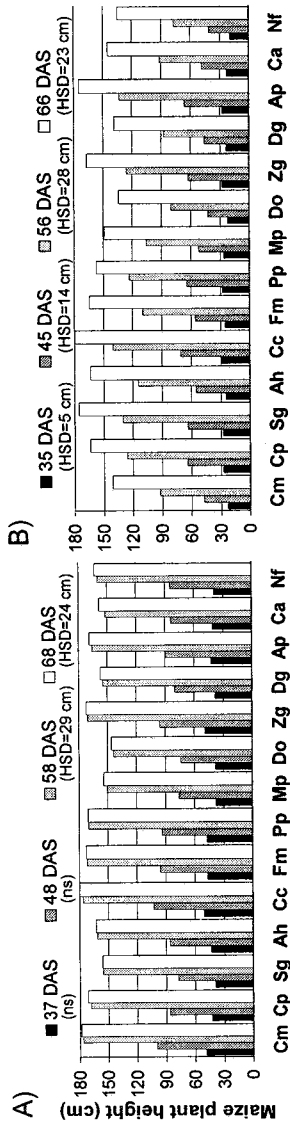
The apparent N contributions of the tested legumes to maize compare well with results reported for short-term improved fallows under similar climatic conditions. Burle *et al.* (1992) found fertiliser-N equivalents of 30–80 kg/ha N for herbaceous cover crops at two sites in Brazil. In summarising the same experiments, Lathwell (1990) indicated that grain yield increases in maize with improved vs natural fallow were as

high as 112%. Similar responses were found by Jost *et al.* (1996) in Ghana and agree with the upper limit of 147% in the present study. The lack of positive effects of legume incorporation prior to maize sowing, as experienced for several species at Ibadan, has also been reported (*e.g.* Brockington *et al.* 1965; Utomo and Setijono 1989; Boonman 1993). Yamoah *et al.* (1991) considered the adverse effects (*e.g.* soil acidification) of decomposing materials on growth of young plants were possible reasons for yield reductions of subsequent crops in the highland region of Rwanda.

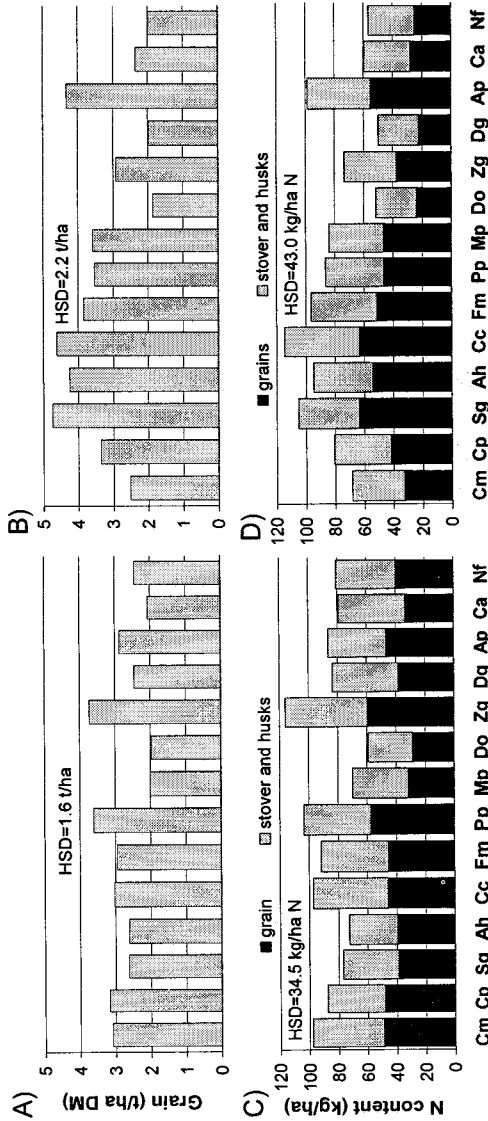
#### Site differences in maize yield response

In our study, the relatively high soil fertility, plus a high N accumulation in the natural fallow vegetation, may have reduced the N limitation for maize at Ibadan relative to Fashola, resulting in lower responses to N and preceding legumes. A similar case has been reported for a mulch system with *Sesbania sesban* prunings which showed no improvement relative to the N-rich natural fallow species *Chromolaena odorata* (Ngiumbo and Balasubramanian 1992). Very close to the Ibadan site, Akintunde (1992) found the N response of maize grain yields to be slightly larger (2.6 t/ha

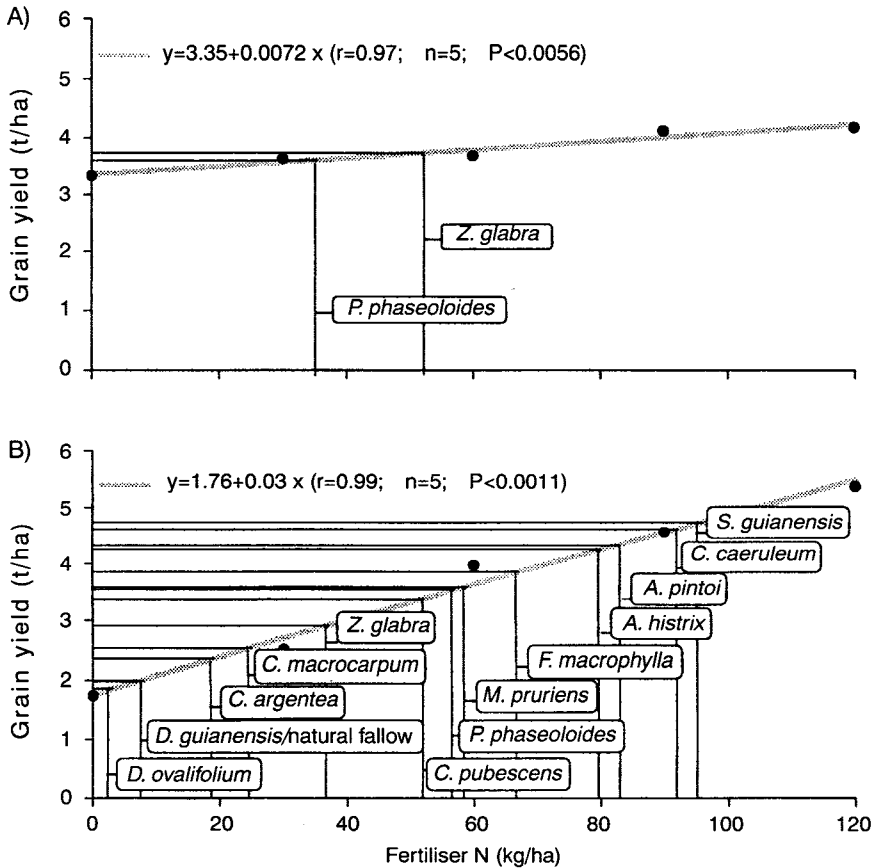




**Figure 5.** Height of maize plants of different age (DAS = days after sowing) as affected by preceding fallow vegetation at Ibadan (A) and Fashola (B). (HSD according to Tukey at  $P < 0.05$ . Cm = *C. macrocarpum*, Cp = *C. pubescens*, Sg = *S. guianensis*, Ah = *A. histrix*, Cc = *C. caeruleum*, Fm = *F. macrophylla*, Pp = *P. phaseoloides*, Mp = *M. pruriens*, Do = *D. ovalifolium*, Zg = *Z. glabra*, Dg = *D. guianensis*, Ap = *A. pintoi*, Ca = *C. argentea*, Nf = natural fallow).



**Figure 6.** Grain yields (A, B) and N contents in grain, stover and husks (C, D) of maize plants as affected by preceding fallow vegetation at Ibadan (A,C) and Fashola (B,D). (HSD according to Tukey at  $P < 0.05$ . Cm = *C. macrocarpum*, Cp = *C. pubescens*, Sg = *S. guianensis*, Ah = *A. histrix*, Cc = *C. caeruleum*, Fm = *F. macrophylla*, Pp = *P. phaseoloides*, Mp = *M. pruriens*, Do = *D. ovalifolium*, Zg = *Z. glabra*, Dg = *D. guianensis*, Ap = *A. pintoi*, Ca = *C. argentea*, Nf = natural fallow).



**Figure 7.** Maize grain yield after different types of fallow vegetation (legumes or natural fallow control) as compared with the fertiliser-N response of maize grain yield after natural fallow on an adjacent field at Ibadan (A) and Fashola (B).

without N fertilisation vs 3.7 t/ha at 120 kg/ha N) than in our study, but the soil fertility was generally lower.

A serious stem borer infestation might have contributed to the relatively low response of maize grain yields to fertiliser N or preceding forage legumes at Ibadan. Greater stem borer damage in the treatments with higher maize grain yields indicated that maize response may have been underestimated at this site. In contrast to grain yield, plant height responded more clearly to both N fertilisation and preceding legumes.

*Nature of rotational effects*

The weak N response (Experiment 2) at Ibadan was associated with highly significant correlations between grain yield and both green manure N input and N release (Experiment 1), even though relatively high grain yields were obtained without

any N fertiliser. In contrast, despite a strong response to both fertiliser N and preceding forage legumes at Fashola, neither maize yield nor N yield was significantly correlated with either N in green manure or N release during its decomposition. It appears that factors other than N effects played an important role particularly at Fashola. This hypothesis is supported by the fact that fertiliser-N equivalents for several legume treatments (*C. caeruleum*, *A. pinto*, *A. histrix* and *M. pruriens*) were far higher than their N input by incorporated green manure (Figures 2A; 2B). This observation is even more striking because N-recovery rates from leguminous N by maize are normally quite low, i.e. in the range of 16–60% (van der Heide *et al.* 1985; Morris *et al.* 1986).

Only limited conclusions regarding the nature of rotational effects can be drawn from our results. Firstly, only above-ground inputs and outputs were considered. Secondly, the root

systems of preceding legumes might also improve physical soil properties thus enlarging the rooting volume for subsequently grown maize (Horst and Haerdter 1994). Thirdly, N which was added as green manure but not taken up by maize, could either be lost due to leaching (Burle *et al.* 1992) or, often to a lesser extent, denitrification (Myers and Wilson 1988). It might, however, also contribute to the build-up of mineralisable soil N thus improving the general N-mineralisation potential (Hagggar *et al.* 1993).

### Sustainability of improved fallows

There was considerable N and K in dry season herbage especially of high yielding species such as *S. guianensis*. When fallows are grazed, the actual export of N, P and K from the land depends on their return to the soil via animals. Modelling the nutrient cycles in tropical pastures, Spain and Salinas (1984) estimated the nutrient export via animals from grazed pastures to be negligible. Recycling of nutrients via grazing animals, however, is limited by various sources of loss. In particular, the return of N via animals is inefficient due to localised excretion patterns causing high N losses (Ledgard and Steele 1992). The nutrient return is generally small if cattle are grazed but not kraaled overnight at the same place (Powell and Mohamed Saleem 1987). If no nutrients are returned via animal faeces, as was the case in our study, the soil would be deprived of small amounts of P and large quantities of K (Figure 1). However, N depletion of the soil might be small since a major part of N in herbage was probably derived by biological N<sub>2</sub> fixation. Similar or even higher amounts of P and K were accumulated in subsequent green manure (Figure 2) and were readily available for the subsequent crop. Negative short-term effects due to P and K export in dry season herbage would not have been detected in the present study (which focused on N effects), since P and K fertiliser were applied to the maize.

Increasing crop yield after the fallow period is a major objective of improved fallow systems. Thus, nutrient exports including P and K by crops will also be higher when compared with cropping systems based on natural fallow. Detailed long-term studies of nutrient balance are necessary to assess the conditions under which those systems can be sustainable with respect to P and K. Experiences with ley systems show that a modest

supply of P and K to preceding legumes is a prerequisite to improve both forage supply for cattle and yields of subsequent crops on a long-term basis (Gibson and Waring 1994).

### Suitability of species

Since both green manure production and maize response differed between sites, it was not surprising that only one species (*C. caeruleum*) achieved production increases in maize of a similar range at both sites. The high yield increase of maize following *Z. glabra* at Ibadan was probably not attributable to *Z. glabra* alone, and some contribution may have come from the high proportion of natural vegetation (including a naturalised legume, *Desmodium scorpiurus*) on these plots. Both *P. phaseoloides* and *C. macrocarpum* can be recommended as pre-maize fallow species for this site, with the latter also showing high nutritive value as a dry season forage (Muhr *et al.* 1999a). *S. guianensis* seemed to be extremely well adapted to the Fashola site; it not only led to highest maize grain yields despite only modest nutrient accumulations in green manure, but also clearly outyielded the remaining species in the dry season (Muhr *et al.* 1999a). *A. pintoi* warrants further consideration as it showed relatively high rotational effects despite low DM and nutrient accumulation in green manure as well as in dry season herbage. Owing to its high potential to build up nutrient-rich green manure quickly, *F. macrophylla* may also have potential as an improved fallow species; however, it has a rather low forage quality for cattle (Thomas and Schultze-Kraft 1990).

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