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Abundance of insect pests and their effects on biomass yields of single vs. multi-species planted fallows

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Abstract

Indigenous and exotic leguminous shrubs that are promising for planted fallow for soil fertility replenishment in east and southern Africa have been found to harbour many herbivorous insects, giving suspicion that widespread adoption of fallow systems may aggravate insect pests. Studies were conducted on farms in western Kenya from 1999 to 2001 to monitor the abundance of herbivorous insects and assess their effects on biomass yields of pure and mixed fallows. The treatments tested were single and two-species mixtures of *Tephrosia vogelii, Sesbania sesban* and *Crotalaria grahamiana* and a natural fallow in a split plot design, with the fallow systems in the main plots and protection vs. no protection against insects in sub-plots spread over six farms. Eighteen insect species belonging to seven orders and 14 families were identified as pests of the fallows with varied abundance and infestation level across the sites. While *Hilda patruelis* and *Amphicallia pactolicus* were most damaging to *C. grahamiana, Mesoplatys ochroptera* was detrimental to *S. sesban*. *T. vogelii* hosted fewer insects than others. Nevertheless the pest infestation did not cause significant biomass yield reduction during the study period. Pest attack was generally greater in villages that had been testing the planted fallows for some years compared with villages that took up the fallows recently. This indicates the potential for increased pest infestation with increased adoption of the system by farmers. Multi-species fallows did not indicate any advantage over single species fallows in terms of either reduced pest incidence or increased biomass production.

Introduction

Short-rotation planted fallows or improved fallows (IF) using leguminous shrubs have been receiving research attention since mid-1980s to mitigate soil fertility depletion in sub-Saharan Africa (Sanchez 1995) and several studies reported encouraging results for this system in east and southern Africa (Jama et al. 1998; Rao et al. 1998; Kwesiga et al. 1999). *Sesbania sesban, Tephrosia vogelii* and *Crotalaria grahamiana* are among the widely used leguminous species in western Kenya. The previous two are indigenous woody plants while the later is leafy exotic shrub. The rotational fallow systems are improving maize yield significantly compared with the continuous maize cropping systems (Kwesiga and Coe 1994; Niang et al. 1996). In the course of scaling-up of the improved fallow system, some pest problems emerged at times causing total failure of the fallows. Several insects are reported to attack the planted fallow species at different growth stages (Singh 1995;

Desaeger 2001; Sileshi 2000). Pests shared by the fallow species and the component crops are raising concerns as they might increase the pest population (Sileshi et al. 2000; Desaeger 2003). Knowledge on the range of insect pests associated with the trees and shrubs used for IFs helps to select appropriate species and design integrated pest management. Recent studies indicated that leaf beetle *Mesoplatys ochroptera* (Chrysomelidae; Coleoptera) causes severe defoliation to *Sesbania sesban* (Sileshi et al. 2000) and larvae of *Amphicallia pactolicus* (Arctiidae: Arctinae; Lepidoptera) defoliates *Crotalaria* species (Karanja and Chege, 1985). No major insect pests were so far reported on *Tephrosia* spp.

The objectives of this study were: (1) to survey and catalogue the insect pests on the planted fallows of *Sesbania sesban* (sesbania), *Crotalaria grahamiana* (crotalaria) and *Tephrosia vogelii* (tephrosia) in western Kenya, (2) to quantify the effect of insect pests on biomass production of planted fallows, and (3) to investigate whether multi-species fallows experience less insect pests than mono-species fallows.

Materials and methods

Study site

A survey of insect pests of planted fallows was conducted in seven districts (Kisumu, Vihiga, Butere/Mumias, Siaya, Kakamega, Tesso and Kisii) and biomass loss was assessed on 12 farms located in eight villages (Nyabeda, Miro, Marenyo, Ebukanga, Emwatsi, Dudi, Khumusalaba and Lela) spread over four administrative districts (Kisumu, Vihiga, Butere/Mumias and Siaya) in western Kenya. The study area is part of Lake Victoria basin and highlands of East and Central Africa at an elevation ranging from 1200 to 1800 m above sea level and has tropical sub-humid climate. Although the rainfall amount and distribution differs within sites and Districts of the study area, rainfall in the region ranges from 1400 to 1800 mm and occurs in two seasons from mid-March to July (long rains) and from September to December (short rains). The landscape is gently undulating, dominated by Acrisols, Nitosols and Ferralsols (FAO/UNESCO) (Andriesse and Van der Pouw 1985). The soils are very deep (>4 m), well drained and have clayey texture throughout the profile. The soil characteristics of the experimental sites are presented in Table 1.

Survey of insect pests on planted fallows

Insects attacking crotalaria, tephrosia and sesbania were surveyed on plantings established by researchers and farmers on farms. The insects feeding on these species were collected using a sweep net, aspirator and by handpicking. The

Table 1. Physical and chemical properties of the soils of farms where planted fallows were evaluated in western Kenya.

Experimental sites	PH	Exchangeable cations ($cmol_c\ kg^{-1}$)			Extractable P (ppm)	Organic C (%)	Particle size (%)		
		Ca	Mg	K			Sand	Silt	Clay
Experiment 1									
Nyabeda (Okoyo)*	5.3	6.1	1.8	0.2	2.7	1.47	23	24	53
Marenyo (Omondi)	5.0	3.0	1.1	0.2	2.9	1.34	39	10	45
Khumusalaba (Amos)	5.2	3.4	1.2	0.1	1.6	1.37	47	18	35
Dudi (Hadulo)	5.2	4.2	1.4	0.2	2.1	1.20	25	22	53
Miro (Odiaga)	5.1	3.7	1.8	0.1	1.0	1.38	25	22	53
Emwatsi (Jerusha)	5.2	3.6	1.4	0.1	1.2	1.5	45	20	35
Experiment 2									
Lela (Samuel)	4.7	2.7	1.4	0.19	2.2	1.46	35	25	40
Lela (Ocheing)	4.8	2.6	1.5	0.22	1.6	1.55	37	25	38
Ebukanga (Omutoka)	5.3	4.6	1.9	0.02	1.5	1.92	37	25	38
Ebukanga (Omukato)	5.4	6.1	2.3	0.03	1.9	2.05	35	29	36
Mutumbu (Oketch)	5.4	4.8	1.8	0.34	2.9	1.39	15	21	64
Dudi (Kisimba)	5.2	4.4	1.8	0.31	2.7	1.56	23	24	53

*Names in the parenthesis are farmers' names collected insects were killed in a jar containing ethyl acetate. Leaf beetles, aphids and thrips were preserved in 70% alcohol, and moths were dried and mounted. Some of the insects collected at nymph or larval stages were reared in the laboratory until the adults emerged. The collected specimens were identified at the National Museum of Kenya.

Assessment of biomass loss due to insects

The experiments meant to assess biomass loss had eight treatments: pure fallows of sesbania, crotalaria, tephrosia and 2-species mixtures of sesbania + crotalaria, sesbania + tephrosia, crotalaria + tephrosia, and control plots of natural fallow and continuous maize. The 'Experiment 1' was conducted during 1999–2000 replicated over six farms and the 'Experiment 2' during 2000–2001 at six other farms. Each plot was 20 m by 20 m divided into two sub-plots for imposing two treatments: protection and no protection against insect infestation. The net plot for each sub-plot was 18 m × 8 m after leaving a 2-m buffer zone between them. The experiment was a split plot, with the fallow systems in the main plots and protection vs. no protection against insects in the sub-plots. For single species fallows, fresh weight from each sub-plot was taken in the field. To determine dry weight, subsamples of wood and leaf were taken to the station. After sun drying, the samples were oven dried at 60 °C for constant weight. Biomass yield in mixed species fallows was calculated on individual species basis following similar procedure and later combined to calculate the overall yield at sub-plot level for each treatment mixed system. Analysis of variance (ANOVA) was conducted using Genstat statistical package. Data analysis was conducted according to split plot design with fallow species as the main plot factor and insecticide treated and untreated as sub-plots. Standard errors of the difference in means (S.E.D.) were reported for comparison of treatment means. Treatment differences were considered significant at $p \leq 0.05$.

Fallow management

In the first experiment, fallows were established at the start of the 1999 long rains by direct seeding of 3–5 seeds per hole at a spacing of 1.5 m × 0.75 m. Plant spacing for the second experiment during 2000–2001 was modified to 1.0 m × 0.75 m. Plants were thinned to one plant per location one month after germination. Mixed fallows were planted in alternative rows. Due to slow initial growth, *S. sesban* was sown simultaneously with maize while the other species were sown 2 months after maize germination. Protected sub-plots were sprayed with Karate (17.5 g/l *lambdacyhalothrin* in 1.75 E.C) at the rate of 2.6 ml/l of water. At seedling stage protected sub-plots were sprayed once every month for 3 months and later on spraying was done whenever infestation was noticed.

Insect pest abundance and damage potential

Leaf beetle (*M. ochroptera*) infestation of sesbania was monitored during the 1999–2000 and 2000–2001 fallow seasons at all the twelve farms. Adults, eggs and larvae were counted at monthly interval from 15 randomly selected trees in the sub-plots. *Amphicallia pactolicus* on crotalaria were counted in the same manner. Infestation of flower thrips (*Megalurothrips sjostedti*) on tephrosia and crotalaria fallows was monitored at mid flowering stage. Ten randomly selected flowers of approximately similar age were collected in plastic bags from each sub-plot and placed overnight in a deep freezer. To ease the recording process Thrips were counted after the flower samples were dissected in water allowing them to float. The observation was conducted for 5 weeks.

Hilda patruelis (groundnut hopper) infestation was assessed on four randomly selected rows of crotalaria in pure and mixed stands in both the protected and unprotected sub-plots. From each row, number of plants that turned yellowish and lodged and those that showed symptoms of infestation was counted. Plants that are lodged were tagged with coloured threads for further follow up. Total number of plants died due to *H. patruelis* infestation based on previous surveys and symptoms on the plants were recorded and percent infestation calculated.

Results

Insect pest abundance and damage potential

A total of 18 species belonging to seven orders and 14 families were identified as pests of the three planted fallows used in this study (Table 2). There was considerable variation in composition, abundance and level of infestation in different villages of the study area. Most of the insects collected were associated with crotalaria and sesbania while only a few were found feeding on tephrosia. Several insects were shared between the fallow species and leguminous seasonal crops grown in the area. For example flower feeding thrips *M. sjostedti* is shared by tephrosia, sesbania and beans. Pod sucking bugs such as *Nezara viridula* and *Anoplocnemis* spp. are also pests of beans and pigeon pea. *H. patruelis* is a major pest of groundnut and is hosted by sesbania and tephrosia but most damaging to *C. grahamiana*. Abundance and infestation was greater in villages where IF system was being tested for sometime. Thus, planted fallows in Emwatsi, Dudi and Ebukanga villages located in Vihiga and Butere/Mumias Districts where they were already under test for some years experienced more insect infestation compared with those in Lela, Nyabeda and Mutumbu villages located in Kisumu, Siaya and Butere/Mumias Districts, respectively, where they were established for the first time (Table 3).

In 1999 we observed *H. patruelis* (Homoptera: Tettigometridae) infestation of crotalaria for the first time in Kenya. In 1999, severe outbreak of this pest had caused complete failure of fallows in villages where crotalaria was planted intensively. Infested plants turned yellow, wilted and died usually in a row. It is difficult to see *H. patruelis* using naked eye but their presence can be recognized from the movement of black ants tending the nymphs and constructing galleries for their easy belowground movement. *H. patruelis* nymphs in return supply the ants with honeydew. In the absence of *H. patruelis*, the ants were found debarking crotalaria branches. Greatest infestation (70%) was observed at Emwatsi farm whereas Miro and Nyabeda farms had lower infestation at 10% and 24%, respectively (Figure 1). Similarly, during the 2000–2001 season, 100% infestation was recorded in Omutoka and Omukato farms located at Ebukanga (with intensive IF history) and the lowest (12%) was at Mutumbu (Figure 1).

Table 2. Insect pests associated with crotalaria, sesbania and tephrosia planted fallows in western Kenya.

Species	Order/family	Damage caused	Host
Lepidoptera			
Amphicallia pactolicus	Arctiidae	Leaf defoliation	Crotalaria
Amphicallia spp.	Arctiidae	Leaf defoliation	Crotalaria
Etiella spp.	Pyralidae	Feeding in the pods	Crotalaria and tephrosia
Coleoptera			
Megalognatha reflecta? Lab.	Chrysomelidae/Galerucinae	Leaf defoliation	Crotalaria
Peophila bivittata ALL.	Chrysomelidae/ Halticinae	Leaf defoliation	Crotalaria, tephrosia
Diplognatha spp.	Scarabidae/Cetoniinae	Feeding on the barks	Crotalaria,
Mylabris dicincta	Meloidae	Feeding on flowers	Sesbania
Mylabris spp.	Meloidae	Feeding on flowers	Crotalaria,
Ootheca sp	Chrysomelidae	Feeding on leaves	Sesbania
Carpohilus dimidiatus F.	Nitidulidae	Feeding on seeds	Crotalaria
Orthoptera			
Phymateus species	Pyrgomorhidae	Leaf defoliation	Sesbania
Diptera			
	Sciaridae	Leaf rollers	Crotalaria, sesbania
Hemiptera			
Anoplocnemis spp.	Coreidae	Pod sucking	Crotalaria, sesbania
Chalicodoma spp.	Megachilidae	Sap sucking	Crotalaria
Nezara viridula L.	Pentatomidae/Pentatominae	Pod sucking	Crotalaria, sesbania
Homoptera			
Hilda patruelis Stål	Tettigometridae	Sap sucking	Crotalaria, sesbania, tephrosia
Aphis fabae Scopoli	Aphididae	Sap sucking	Crotalaria, sesbania
Bemisia spp.		Sap sucking	Crotalaria
Thysanoptera			
Megalurothrips sjostedti. Trybom	Thysanoptera: Thripidae	Flower feeding	Tephrosia, crotalaria, sesbania

Table 3. Severity of infestation of planted fallows by major insect pests on farms during 1999–2000 and 2000–2001 in western Kenya.

	Pest infestation level					
	1999–2000			2000–2001		
Pest species	High	Medium	Low	High	Medium	Low
H. patruelis	Emwatsi, Dudi	Marenyo, Khumusalaba	Nyabeda, Miro	Ebukanga, Dudi		Lela, Mutumbu
A. pactolicus	Emwatsi	Khumusalaba	Nyabeda, Dudi, Miro		Ebukanga, Dudi	Lela, Mutumbu
M. ochroptera	Emwatsi	Dudi, Marenyo	Miro, Khumusalaba, Miro, Nyabeda		Dudi, Ebukanga, Dudi	Mutumbu, Lela
Leafhoppers		Khumusalaba	Marenyo, Miro, Emwatsi, Nyabeda			Ebukanga, Mutumbu

During the first experimental period (1999–2000), infestation of sesbania foliage by *M. ochroptera* was generally high at most farms, although the degree of infestation varied considerably across sites. For example, greater infestation was noted in Emwatsi village of Vihiga where IF system had been experimented intensively for the past 5 years while no infestation was recorded at Odiaga and Okoyo farms in Nyabeda and Miro villages located in Siaya District where improved fallows are currently being tested. The trend of beetle infestation in single and multi-species fallows was similar (Figures 2a and b). Infestation generally started from July with slightly greater level in plots where sesbania was intercropped with crotalaria. Greatest infestation (68%) was observed in August and September with no significant difference among treatments. The infestation declined from December onwards. During the second experiment (2000–2001), peak infestation was noted in September with an average of 50% (Figure 2b). As in the previous year, there was no significant difference among the single and multi-species fallows. The infestation declined gradually from October onwards. Despite the infestation by *M. ochroptera*, there was no significant reduction

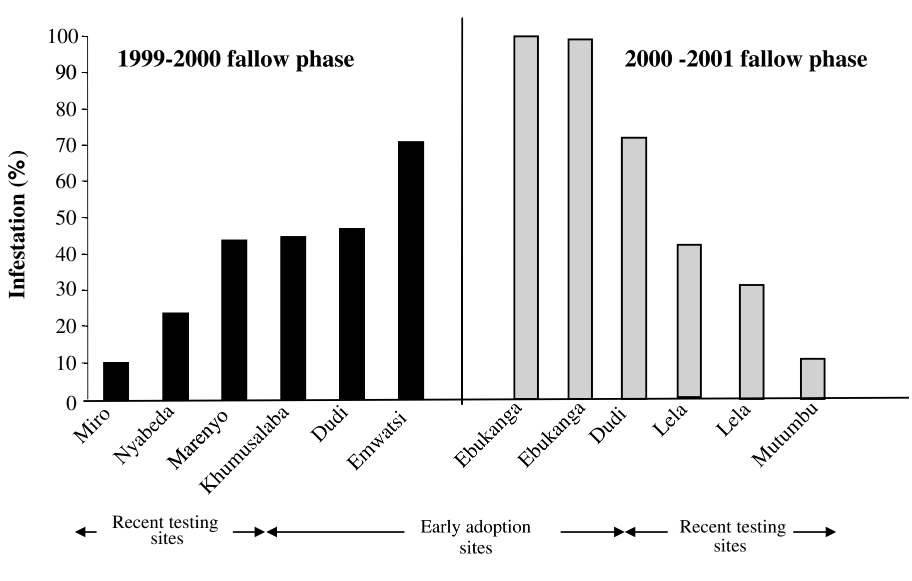

Figure 1. *Hilda patruelis* infestation of *C. grahamiana* fallow recorded at different farms in two experiments conducted in western Kenya.

in sesbania foliage yield. Similar to the situation in the first experiment, mixed fallows did not result in significant reduction of *M. ochroptera* infestation.

A. pactolicus was among the major defoliators of crotalaria fallow. Though crotalaria is an exotic species to East Africa, it was found to be a preferred host of *A. pactolicus* over the past few years. The larvae preferred to feed on flowers and immature pods but in the absence of these parts they also consumed the leaves. Thus availability of food source can increase the damage potential of crotalaria in the near future. Though farmers rated *A. pactolicus* as the number one pest of crotalaria, its abundance and damage in our experiments was not significant.

Megalognatha reflecta (Coleoptera, Chrysomelidae) was first noted in May 1999 in experimental plots at Khumusalaba village in fewer numbers on crotalaria flowers and sesbania leaves causing no serious damage to either. A year later in May 2000, these beetles were found to defoliate sesbania, crotalaria, and beans (*Phaseolus vulgaris*) in several locations where crotalaria fallows were grown. In farmers' fields at Esabwali, the beetles were first seen on voluntary seedlings of crotalaria that came up from the previous fallows. Following weeding, the beetles moved to beans and defoliated the crop causing circular holes, a characteristic damage symptom by most leaf beetles. In experimental plots at Khwisero village in Butere/Mumias District, the leaf beetles severely attacked crotalaria mainly feeding on flower buds and flowers.

Biomass yield

Averaged over the farms, wood yields from the protected and unprotected treatments were not significantly different in both the experiments (Tables 4 and 5). There was no effect of pest management on biomass in most treatments except in the case of sesbania which produced

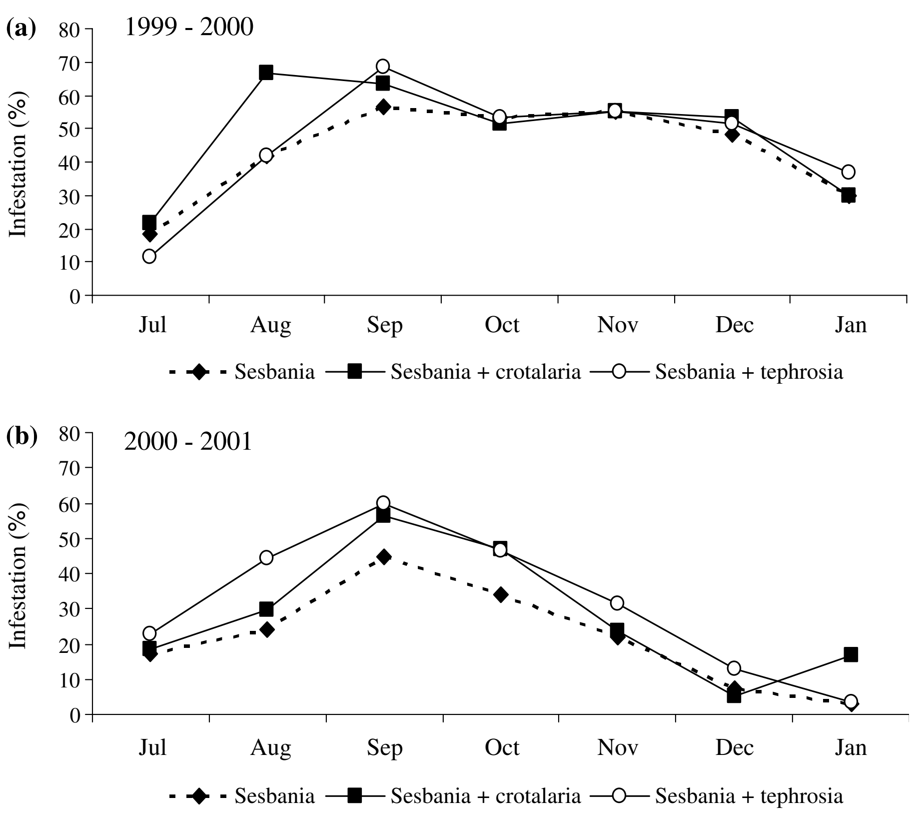

Figure 2. Leaf beetle (*Mesoplatys ochroptera*) infestation of *Sesbania sesban* planted as pure or mixed with *Crotalaria grahamiana* or *Tephrosia vogelii* observed at six different farms in western Kenya.

slightly increased higher yield in the presence of moderate infestation by *M. ochroptera*. Nevertheless, averaged over different sites, insecticide application did not result in significant increase in biomass yield. Differences among fallow systems were significant ($p < 0.01$) only in the first experiment.

The total biomass harvested nine months after sowing ranged from 4 to 7 t ha^{-1}. In the absence of severe pest infestation, protection did not give any yield advantage over the unprotected sub-plots. Pure tephrosia fallow gave significantly lower yield compared with the other fallow systems except the natural fallow in unprotected sub-plot. Mixed fallows also did not increase the biomass yield. As the level of pest infestation was not severe during the experimental period, the effects of fallow types (single or multi-species) on pest infestation did not come out clearly.

Foliar biomass harvested from different treatments was in the range of 0.5–1.5 t ha^{-1}. Although treatment differences were not significant, foliar biomass of crotalaria-based systems (pure and mixed with sesbania or tephrosia) in the unprotected treatments was less compared with the protected treatments. Biomass yields of all other treatments increased in the unprotected sub-plots. Similar to other parameters, treatment effect was significant at each sub-plot level in the first experiment while no significant difference was noted during the second experiment.

Discussion

The study provided important information on herbivore guilds of promising species for short-term planted fallow systems, the type of damage they cause, and the current level of infestation on farms in western Kenya. It indicated that *H. patruelis* was the most serious pest that can cause death to crotalaria. This polyphagous pest is known to attack groundnut and weeds such as *Conyza sumatrensis* and *Tagetes minuta* (Taylor 1981). Sesbania and tephrosia were also found to host *H. patruelis* (Mchowa and Ngugi 1994; Minja et al. 1999) but this insect did not cause death of these species. Therefore, care must be taken not to allow population build up of this insect and also not to plant susceptible crops after crotalaria fallow. Unfortunately, the effect of *H. patruelis* did not come out clearly in this study, as it was difficult

Table 4. Biomass yields of sesbania, crotalaria and tephrosia planted as single or mixed species fallows on different farms in western Kenya during 1999–2000.

Treatment	Biomass tha^{-1}					
	Wood		Leaf		Total	
	Up	P	Up	P	Up	P
Sesbania	11.9	10.4	1.83	1.61	14.0	12.0
Crotalaria	4.2	5.2	0.61	0.90	5.3	6.7
Tephrosia	2.0	2.2	0.42	0.49	3.0	3.2
Sesbania + crotalaria	7.5	8.2	1.33	1.34	8.9	10.0
Sesbania + tephrosia	6.4	6.1	1.08	0.98	7.6	7.2
Crotalaria + tephrosia	3.3	3.5	0.49	0.64	4.2	4.8
Natural fallow	–	–	–	–	4.2	4.8
Mean	5.9	5.9	0.93	0.99	6.7	6.9
F probability						
Plant protection	0.90		0.54		0.55	
Systems	< 0.01		< 0.01		< 0.01	
Protection × systems	0.40		0.74		0.37	
Standard errors of difference in means (SED)						
Plant protection	0.37		0.10		0.38	
System	1.40		0.21		1.60	
Systems within protection	1.56		0.27		1.73	
Protection at each system	0.74		0.24		0.93	

Up, unprotected against insects; P, protected against insects.

Table 5. Biomass yields of sesbania, crotalaria and tephrosia planted as single or mixed species fallows on farms in western Kenya during 2000–2001.

Treatment	Biomass $t ha^{-1}$					
	Wood		Leaf		Total	
	Up	P	Up	P	Up	P
Sesbania	6.2	6.0	0.98	0.97	7.2	7.0
Crotalaria	5.8	6.2	1.14	1.22	6.9	7.4
Tephrosia	2.9	2.9	0.83	0.59	3.8	3.5
Sesbania + crotalaria	5.5	5.8	1.18	1.44	6.8	7.0
Sesbania + tephrosia	6.2	6.3	1.28	1.16	7.4	7.8
Crotalaria + tephrosia	4.4	5.5	1.03	1.32	5.5	6.8
Natural fallow	–	–	–	–	4.8	5.0
Mean	5.2	5.5	1.07	1.12	6.0	6.4
F probability						
Systems	0.24		0.14		0.30	
Systems within protection	0.35		0.43		0.69	
Protection at each system	0.89		0.05		0.89	
Standard errors of difference in means (SED)						
System	1.48		0.23		1.80	
Plant protection	0.31		0.05		0.20	
Systems within protection	1.57		0.25		1.30	
Protection at each system	0.75		0.13		0.60	

Up, unprotected against insects; P, protected against insects.

to control the insect with the insecticide used in the experiment. Its effect can be devastating so as to cause complete failure of crotalaria fallow as happened on several farms in western Kenya recently. Disappointingly, none of the fallow species are resistant to *H. patruelis*. Hence the pest in the absence of crotalaria might cause considerable damage even to sesbania or tephrosia.

Obviously, several insects are associated with the fallow species. It is known that several species of bugs (coreidae) attack pods of leguminous plants. For example, *Clavigralla tomentosicollis, C. shadabi, C. elongata* (Hemiptera, Coreidae) attack cowpea and pigeon pea pods, occasionally causing severe damage (Egwuatu and Taylor 1977; Singh and Taylor 1978). One of the pod-sucking bugs observed on crotalaria in large numbers on *C. paulina* in Tesso district was *Anoplocnemis curvipes* (Hemiptera, Coreidae). This insect attacks several legumes such as cowpea (Aina 1975), soybean (Ezueh and Dina 1979) and beans (Singh 1990). Seed stands might suffer from pod-sucking bugs and pod borers but these insects are not important to farmers whose objective of planted fallows is replenishing soil fertility for which foliar biomass production is important. These insects indirectly help to reduce the seed bank of the fallow species, especially if the planted fallow species have a tendency to become weeds. For example, *C. grahamiana* is being observed to grow voluntarily after the fallow seasons are over. There is a tendency of its spread around farms (Mwangi D. and Girma H. unpublished).

A. pactolicus is widely distributed in western Kenya and other insects of the same genus *A. tigris* and *A. solai* were reported to feed on crotalaria (Karanja and Chege 1985). High level of infestation might affect grain yield but their effect on the biomass yield was insignificant during the present study. Nevertheless if the onset of infestation occurs during vegetative stage, the second and third generation larvae have the potential to cause significant biomass loss.

Leaf beetle infestation of sesbania can cause severe defoliation and the insect infestation at seedling stage coupled with nematode infestation at seedling stage can cause significant seedling mortality (Desaeger and Rao 1999). The insect attack at a later stage however may not cause much negative effect on growth as evident from greater biomass yield of sesbania in the unprotected subplots than in the protected plots at some farms.

This was probably due to the compensatory growth of sesbania in response to herbivore attack. This was in agreement with Sileshi's (2000) observation that 25–50% manual leaf defoliation significantly increased the biomass yield of sesbania.

Tephrosia flowers were found to be the best host for thrips (*M. sjostedti*), which are one among many economically important pests of beans (Ingram 1969; Taylor 1969; Annecke and Moran 1982), cowpea (Singh et al. 1990), groundnut (Wightman et al. 1990) and other legumes in Africa. High populations of thrips during the dry period can cause total crop failure of beans (Nyiira 1973). As thrips heavily infested tephrosia fallows throughout the flowering period, there was a risk that leguminous crops grown in close proximity to or in rotation with tephrosia might be affected by them. But more research is necessary to verify the validity of this assumption.

While the planted fallows have advantage of improving soil fertility, they have the inherent disadvantage of creating pest problems depending on the species used and the circumstances. This was clear from the range of pests shared among fallows and crops. For example, leaf beetles and thrips that infested both the planted fallow species and component crops in the system and some of the insects such as *M. reflecta* (Coleoptera, Chrysomelidae) are gaining importance as bean defoliators. Although it was difficult to establish the effect of insect pests on biomass yields of the fallows, this study indicated the ranges of potential pests. Similarly, the pest status of insects given in this study is only indicative but not conclusive. If the planted fallow–crop rotation system with any particular tree species is practiced over time, there could be a shift in the status of different insects.

Performance of the fallows in terms of biomass production was variable from site to site, which probably was due to variability in soil nutrient availability, moisture, and to some extent occurrence of insect pests and nematodes. It is important to note that pest infestation was greater in villages where IF was tried earlier. Intensive use of the fallow species provides abundant food source that facilitates their increased incidence (Rao et al. 2000).

The study did not indicate any significant increase in biomass yield from mixed fallows. Nevertheless, the benefit of diversifying fallow species should not be overlooked. It is apparent from this study that several insects are associated with the fallow species and most of them are known to be pests of leguminous crops. Increased pest incidence in villages where the fallow system was practised for the previous 2–3 years indicates the risk of working with only few leguminous species in rotational fallows. Seedling stage is most vulnerable to the defoliators. *H. patruelis* was undoubtedly the most damaging to crotalaria. Its ability to feed on all the promising fallow species currently planted in western Kenya makes its management difficult compared with host specific insects such as *A. pactolicus* or *M. ochroptera*.

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