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Alley Cropping and Crop Yield Enhancement with *Sesbania*

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ALLEY CROPPING AND CROP YIELD ENHANCEMENT WITH SESBANIA

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INTRODUCTION

Alley cropping, also known as hedgerow intercropping, relies on the use of fast-growing leguminous shrubs to supply nutrients, wood, fodder and edible products. It has attracted many practitioners despite being a relatively new technology. This can be attributed to certain advantages the system has for low-input agriculture. For example, on sloping lands, alley cropping minimizes soil erosion and runoff and increases soil productivity.

The alley cropping concept was developed at the International Institute of Tropical Agriculture (IITA) in the late 1970s (Wilson and Kang, 1982). However, hedgerow agroforestry similar to alley cropping has been practiced by traditional farmers in Africa and Asia (Okigbo and Greenland, 1977; Metzner, 1987). Much research has been conducted on alley cropping shrubs such as Leucaena and Gliricidia in the lowland humid tropics (Wilson and Kang, 1982). Unlike Leucaena, Gliricidia or Calliandra, very little research has been conducted on Sesbania with respect to its use for alley cropping.

Sesbania is a promising shrub for alley cropping because 1) it is easy to establish, 2) it grows rapidly, 3) it coppices at high altitudes (>2000 m), and 4) it provides wood, fodder and green manure (Dutt and Pathania, 1987; Chapman and Myers, 1987; Yamoah, 1988; Rotar and Evans, 1983; IITA, 1984; Hughes and Styles, 1987; Tran Van Nao, 1983; Tothill, 1987). Nevertheless, Sesbania is also short-lived and reportedly susceptible to nematodes and crop pests (Rotar and Evans, 1983; NAS, 1980; Balasubramanian and Sekayange, 1988; Duguma et al., 1988). This paper assesses the suitability of Sesbania as an alley cropping species with special reference to the highland region of Rwanda. Areas for further research are indicated.

ESTABLISHMENT

A common method of establishing Sesbania for alley cropping on sloping land is to use 3- to 4-month-old tubed plants. This method assures a continuous row of shrubs along the contours, which is necessary to check erosion. Direct seeding is possible but only on level land where erosion is not a problem. Propagation by cuttings is under experimentation (Oduol and Akunda, 1988) and therefore not yet widely used by farmers. Sesbania nodulates naturally in the highland region of Rwanda where the Farming Systems Research Project (FSRP) is active. Inoculation with rhizobia, therefore, is not necessary. However, an initial application of manure (2.5 - 5.0 t/ha) accelerated growth by more than 15% and produced healthy plants resistant to dieback (Yamoah et al., 1987).

Growth response by Sesbania to phosphorus (P) application has been reported (Dutt and Pathania, 1987). Height and diameter breast high (dbh) of Sesbania receiving 50 g of single super-phosphate per tree were 4.0 and 27.6% greater, respectively, than trees receiving 0 g. In practice, manure and fertilizer are applied to food crops grown in the alleyways but not to Sesbania.

Inoculation of Sesbania with vesicular-arbuscular mycorrhizal (VAM) fungi, Glomus fasciculatum and Glomus mosseae significantly improved nodulation and growth of Sesbania in sterile soils (Habte and Aziz, 1987). VAM inoculation, liming and application of rock phosphate may improve growth of Sesbania in acid soils where P deficiency is common.

Alley width is a function of slope on steep hillsides and should not exceed 8 m to effectively improve soil fertility. In the FSRP zone of operation, optimum alley width is 6 m for 5% - 10% slope even though farmers prefer to use wider (>8.0 m) alleys. Alley widths < 6.0 m are unacceptable to farmers regardless of slope because arable land is scarce.

The acute shortage of farmland also requires that farmers intercrop or relay-crop Sesbania with food crops during shrub establishment. Nevertheless, we found that peas more than potatoes, beans and

wheat retarded early growth of Sesbania (Fig. 1). Peas exhibit an aggressive growth habit even on impoverished soil with minimum management, making it a stronger competitor than Sesbania. We advise farmers, therefore, not to plant peas with Sesbania during the initial growth phase. Sesbania intercropped with cereals such as maize, sorghum and wheat exhibits unrestricted growth.

In the Ivory Coast, Osseni et al. (1987) reported that pineapple more than grass inhibited growth of Sesbania. Possible reasons were low pH, presence of nematodes and the effect of residual herbicides. The above study concluded that Sesbania rostrata was not adapted to the well-drained soils of the Southern Ivory Coast.

Studies conducted by Arshad and Hussain (1987) in Pakistan showed poor growth, low dry matter yield and minimal nodulation of Sesbania under saline soil conditions. For example, Sesbania height was 100, 89.5 and 56% of controls, respectively, at electrical conductivities (EC) of 4, 8 and 12 mm hos/cm. Conversely, Sesbania is preferred as a green manure crop in India's rice culture because it thrives on heavy and waterlogged soil and tolerates soil salinity as well (Rotar and Evans, 1983). Further research is needed to resolve the issue of Sesbania tolerance to saline soils. In Africa, salinity problems affecting Sesbania performance are most likely to exist along the coast.

MANAGEMENT

Survival and Growth

In the short term, germination, growth and survival of Sesbania are generally better than with other leguminous shrubs (Holden and Volk, 1987; Yamoah et al., 1987). Survival and height of Sesbania are compared with other leguminous species in Table 1. The height of five-month-old Sesbania sesban (2.87 m) was significantly greater than the height of other species. In the highland areas of Rwanda, heights of eight-month-old Sesbania, Leucaena, Calliandra and Markhamia were 3.86, 1.80, 1.41 and 0.43 m, respectively (Yamoah et al., 1987).

Dutt and Pathania (1987) recorded Sesbania heights of 3.99, 4.35 and 6.75 m after 6, 12 and 18 months of growth, respectively. The addition of 20 g single superphosphate per tree significantly increased the growth.

Sesbania is susceptible to insects and other crop pests (NAS, 1980). According to Holden and Volk (1987), young seedlings of Sesbania were devastated by the bean beetle, Ootheca mutasis. Kumar and Joshi (1987) reported that Sesbania grandiflora was susceptible to grey leaf spot (Pseudocerospora sesbaniae) (P. Henn).

Sesbania plants in the Central Plateau region of Rwanda (1600 m) exhibit yellow leaf discoloration similar to that reported by Kumar and Joshi (1987). Low soil fertility and disease incidence as well as leaf hopper infestations are suspected causes for poor growth and subsequent plant dieback. In the same environment, an unidentified Coleoptera defoliates Sesbania. Therefore, depending on pest population and other environmental factors, it may be erroneous to correlate height of Sesbania with good performance.

In the Buberuka Highlands of Rwanda (altitude > 2000 m), however, disease incidence on Sesbania is less pronounced during the first 6 to 8 months of shrub establishment. Leaf chlorosis first appears after 12 months and following two to three cuttings. As more leaves become chlorotic, photosynthesis is reduced and the plant dies. Therefore, biomass and nutrient yield, particularly nitrogen, decline over time with an attendant increase in mortality (Fig. 2).

Nematode Susceptibility

Sesbania is reported to harbor nematodes (NAS, 1980; Rotar and Evans, 1983). Balasubramanian and Sekayange (1988) attributed poor survival and growth of Sesbania to nematode infestation in the lowland region of Rwanda. Assessment of nematode populations in 2- to 3-year-old Sesbania stands in the Rwandan highlands showed significantly fewer nematodes at > 5.0 m from Sesbania hedgerow than at 2.5 m away from the hedges (Fig. 3). Nematode population at the base of the hedges was less but not significantly different from population at 2.5 m. The reduced nematode population at the base of the hedges could be due to the presence of grass bands that tend to repel nematodes. No relationship was established between nematode population and survival of Sesbania. On the contrary, Schmidt Leplaideur and Lassailly (1986) asserted that Sesbania rostrata controlled nematode population in rice farms. Mucuna and Azadirachta indica could also be intercropped with Sesbania to reduce nematode population.

Pruning

Pruning Sesbania in alley cropping systems usually begins 8 to 12 months after planting or when there has been adequate root establishment to facilitate coppicing. Regeneration and dry matter yield of Sesbania depend on the species and site characteristics. In Hawaii, Sesbania sesban cut at 0.50 m yielded 20 t/ha dry matter with 5 to 6 cuttings during the first year (Evans and Rotar, 1987). In southwestern Nigeria, mean nitrogen yield of Sesbania grandiflora was 26.3, 37.1 and 53.2 kg/ha for 25, 50 and 100 cm cutting heights, respectively. Percent survival was 19.8 and 80.2% for 3- and 6-month cutting frequencies (Duguma et al., 1988). Survival was unaffected by cutting height. In Zambia, biomass production for Sesbania macrantha was 278, 63 and 22 g/plant for 0.50-, 0.25- and 0.10-m cutting heights, respectively (Holden and Volk, 1987).

In the low-elevation areas of Rwanda (1400 m to 1800 m), survival of Sesbania sesban declined sharply with cutting frequency (Balasubramanian and Sekayange, 1988). Cutting height was 0.50 to 0.60 m with four cuttings per year beginning 9 months after planting. Stand density was reduced by 27.5, 52.5 and 82.5% following the second, fourth and sixth cuttings, respectively. Corresponding figures for Calliandra calothyrsus and Leucaena leucocephala were 0.0, 5.6, 8.8% and 1.9, 3.1 and 3.8%. Based on this information, Sesbania is not recommended for use in alley cropping systems in the low-altitude zones of Rwanda (Balasubramanian and Sekayange, 1988). In high-altitude zones, however, Sesbania sesban coppices fairly well after cutting. Cutting 12-month-old Sesbania at 0.5 m resulted in over 80% plant mortality as compared to less than 5% when the Sesbania was cut at 1.5 m. However, cutting at 1.5 cm resulted in excessive shading of intercropped beans with a concomitant reduction in yield (Graf and Yamoah, unpublished). In that study, bean yield from plots in which Sesbania was cut at 0.5 m was four times greater than the yields from plots in which Sesbania was cut at 1.5 m (Fig. 4). When cutting height at the same location was maintained at 1.0 m, only 10% of Sesbania sesban died after three cuttings in two years (Yamoah and Burleigh, 1988). In general, cutting 0.50 m above ground is discouraged in Rwanda as plant death rapidly ensues, principally with plants that are 12 months old or more.

Leaf removal and pruning during dry periods also kills Sesbania. However, partial pruning results in severe shading of intercrops, particularly if alleys are narrow (<6 m). Prior to cutback, crop shading is a problem also in alleys wider than 6 m. Figure 5 shows yield of sweet potatoes in 8-m alleys of Sesbania sesban before cutting back (Gahamanyi, unpublished). Potato yields from rows bordering the hedgerows were reduced by nearly 50% relative to yields from middle rows.

Selection of shade-tolerant crops may be possible. Preliminary studies conducted by FSRP indicated the following ranking of food crops in decreasing order of shade tolerance: pole bean > potato > dwarf bean > maize (Yamoah, 1988).

CROP YIELD

Sesbania leaves are well established as nutrient sources for crop production (NAS, 1980; Hughes and Styles, 1987; Hussain et al , 1987; KREDP, 1985; Rotar and Evans, 1983; IITA, 1984; Tran Van Nao, 1983; Otieno, 1987; Duguma et al., 1988; Holden and Volk, 1987; Chapman and Myers, 1987). However, there is little information on crop yield performance in alley cropping settings with Sesbania.

Sesbania cannabina used as a green manure crop in Australia accumulated 110-180 kg N/ha in the tops. Sesbania prunings increased rice yield and nitrogen uptake more than other legumes tested in the study (Table 2) (Chapman and Myers, 1987),

The capability of Sesbania leaves to supply plant nutrients was also demonstrated in a pot experiment by Hussain et al. (1987). Compared to control, green manuring with Sesbania and Leucaena significantly increased dry matter yield of maize (Table 3). The residual effect of green manure on wheat yield was significant mainly in pots that received manure at 15 to 20 t/ha. Similar yield responses for rice have been reported by Singh and Sinha (1962) and Bhardwaj et al. (1981) in India.

At IITA in Nigeria, alley cropping rice with Sesbania rostrata resulted in significant yield increases (Table 4). Sesbania prunings also increased N uptake by 38% relative to control where no prunings were added (IITA, 1984). Sesbania rostrata was selected for this study because it regenerates after pruning, withstands waterlogged conditions and nodulates profusely.

Maize yield was not associated with height and frequency of pruning Sesbania grandiflora (Duguma et al., 1988). However, cowpea yields from alleys where Sesbania grandiflora was pruned at 0.25 m were significantly greater than yields from alleys pruned at 1.0 m (Fig. 6). Sesbania grandiflora was declared

inappropriate for alley cropping in the lowland humid tropics of southwestern Nigeria because it scored the highest percent mortality and produced less biomass than Leucaena and Gliricidia. In Rwanda, wide alleys (6 to 8 m) reduced yields less than narrow (2 to 4 m) (Yamoah and Burleigh, 1988) (Fig. 7). Yield reduction in the narrow alleys evidently was due to intercrop shading and loss of cultivable space. Nevertheless, narrow alleys appear more effective than wide alleys for erosion control, especially on steep lands.

Indirectly, Sesbania affects pole bean yields by providing stakes. Bean growers in the Rwandan highlands readily welcome alley cropping with Sesbania primarily because of stake production, which occurs 5 to 8 months after planting. But farmers also complain that Sesbania attracts and harbors birds destructive to maize and sorghum.

Crop yield loss is proportional to rate of disease development. Preliminary study of maize rust development at FSRP indicated that the proportion of infected leaves/plant, numbers of uredina/plant and area under disease progress curve (AUDPC) from maize in open fields were significantly greater than those from maize in 2-, 4-, 6- and 8-m alleys (Fig. 8). Compared to middle rows, rust development on maize in border rows was significantly less (Yamoah and Burleigh, 1988).

In the United States, Sesbania exaltata is considered a troublesome weed in cotton. Sesbania populations at 3223, 6456, 16,114 and 32,228 plants/ha suppressed intercropped seed cotton (var 'Stoneville 213') yield by 19, 25, 45 and 53%, respectively. Yield reduction was attributed to shading, particularly at Sesbania densities of 32,228 plants/ha (Bryson, 1987).

CONCLUSION

Sesbania is a suitable species for alley cropping systems because it is easy to establish, grows fast and gives N-rich organic material for crop yield enhancement. Variability in coppicing is a major drawback to Sesbania for long-term alley cropping systems. Regeneration of Sesbania after cutting depends on the environment, the pruning management imposed and the species. Insects and nematodes also affect longevity and productivity of Sesbania. In general, frequent cutting and low cutting heights accentuate mortality. For alley cropping, Sesbania sesban is superior to other species.

The following research areas are suggested in order to promote widespread use of Sesbania for alley cropping: 1) pruning management in different agroecological settings; 2) combination of Sesbania with other leguminous shrubs in a hedgerow; 3) screening of germplasm for species that are able to withstand intensive prunings under adverse conditions and; 4) effect of nematodes on survival and growth of Sesbania as well as on yield performance of intercrops in alley cropping systems.

Finally, according to Sanchez (pers. comm.), alley cropping works better in areas with nutrient-rich subsoils than in areas with acidic subsoils. As a long-term technology, subsoil characteristics will obviously determine future performance of alley cropping systems. Research, therefore, is needed to assess the effect of different soil types on survival, growth and nutrient cycling efficiency of Sesbania and other potential alley shrubs.

ACKNOWLEDGMENT

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Table 1. Survival and height growth of nine MPT in the elimination trial five months after planting at Tumbi, Tabora.

Name of species	Survival	Height
	%	m
Acacia cincinate	90	0.77
Acacia torulosa	83	0.94*
Acacia leptocarpa	64	0.98*
Leucaena leucocephala	100	1.21*
Acacia albida	87	0.68
Sesbania sesban	99	2.87**
Acacia julifera	88	1.07*
Acacia brassii	83	0.94*
Acacia auriculiformis	70	1.09*

Table 2. Rice grain yields (t/ha at 14% moisture).

Treatment	Urea N (kg/ha) at permanent flooding:	1980		1982		1983	
		0	100	0	100	0	100
1. Bare fallow		1.1dc[1]	4.9b	1.2bcd	5.2ab	1.7d	5.7cd
2. Soybean (grain), residues returned[2]		1.8a	5.0ab	1.8ab	5.3ab	2.3b	5.9bc
3. Soybean (green manure)		1.8a	5.1a	1.6abc	5.1ab	2.3b.	6.2ab
4. Soybean (tops removed)		1.3c	5.0ab	1.1cd	4.8b	1.8cd	5.6cd
5. Green gram (grain), residues returned[3]		1.3c	4.9b	0.9cd	4.8b	2.1bc	5.4d
6. Sesbania (grain), residues returned[3]		1.5b	5.0ab	2.1a	5.9a	3.4a	6.3a
7. Sorghum/rice (grain), residues returned[3]		1.0d	4.6c	0.6d	4.5b	1.9cd	5.5d

[1]Between wet season treatments, means followed by the same lower case letter are significantly different at $P<0.05$.
[2]Green manure as for treatment 3 in first two cropping cycles.
[3]All plant tops were removed in first cropping cycle.
Source: Chapman and Myers, 1987.

Table 3. Effect of Leucaena and Sesbania leaves on crop yields and N-uptake (results are g/pot).

Treatments	Crop yields			N-uptake		
	Maize	Wheat	Total	Maize	Wheat	Total
1. C	40.9c[1]	13.6b	54.5	0.30c	0.22c	0.52
2. NPK	139.3a	13.3b	152.6	1.02a	0.22c	1.24
3. L5	122.3ab	13.8b	136.1	0.87b	0.23bc	1.10
4. L10	125.3ab	14.9ab	140.2	0.93b	0.25b	1.18
5. L15	144.9a	16.1ab	161.0	1.10a	0.28ab	1.38
6. L20	121.4ab	17.0a	138.4	0.91b	0.30a	1.21
7. S5	105.5b	12.9b	118.4	0.79b	0.21c	1.10
8. S10	124.0ab	13.5b	137.5	1.01a	0.23bc	1.24
9. S15	138.0a	15.0ab	153.0	1.11a	0.26b	1.37
10. S20	105.3b	16.7a	122.0	0.88b	0.30a	1.18

[1]Means not followed by the same letter within a column are not significantly different from each other.
Source: Hussain et al., 1987.

Table 4. Effect of Sesbania rostrata prunings and urea on rice yield (kg/ha) in a hydomosphic soil at IITA.

Sesbania prunings (t/ha)[2]	1982 trial with rice (variety ITA 117) N fertilizer[1]		1983 trial with rice (variety ITA 212) N fertilizer	
	None	Added	None	Added
0	5760	7610	3010	4790
3	6850	7890	4480	4710
4	7820	7950	4670	4420
Means	6810	7820	4050	4640

LSD (5%) for comparing means between treatments for 1982: 1080
LSD (5%) for comparing means between treatments for 1983: 670

[1]Urea was applied in two splits of 60 kg N/ha each at 8 and 12 WAP.
[2]Total of two prunings collected at 8 and 12 WAP; 3 t/ha in plots planted at spacings of 10 cm x 200 cm, and 4 t/ha in plots planted at 10 cm x 150 cm spacings.
Source: IITA, 1984.

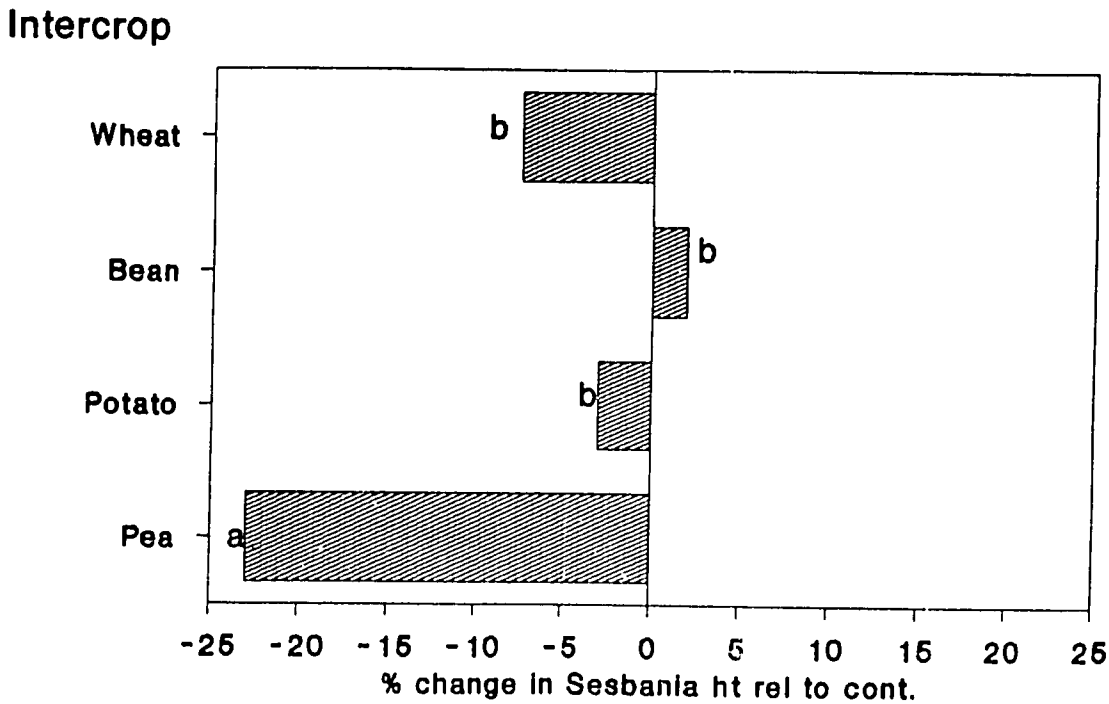


Fig. 1. Intercrop effect on height growth of Sesbania.

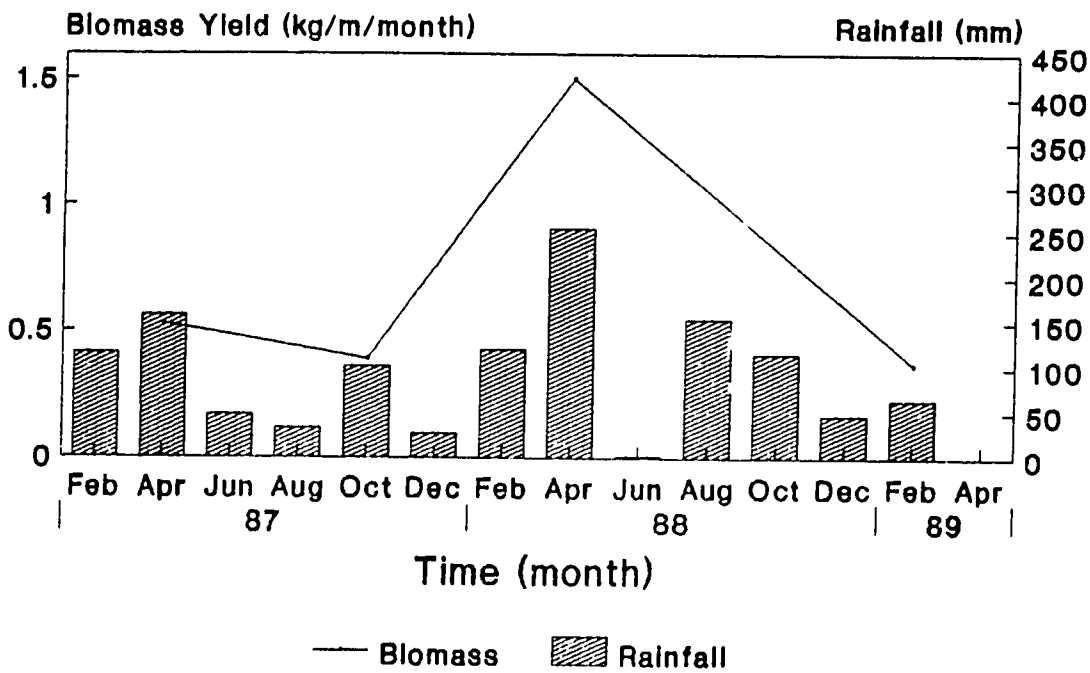


Fig. 2. Productivity of Sesbania over time.

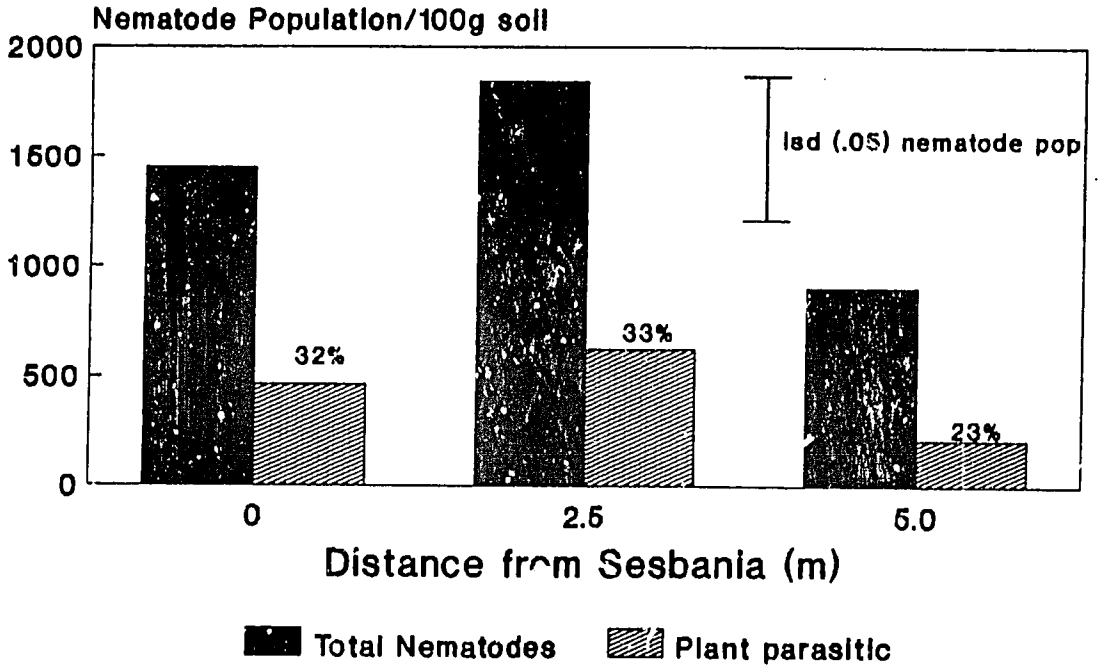
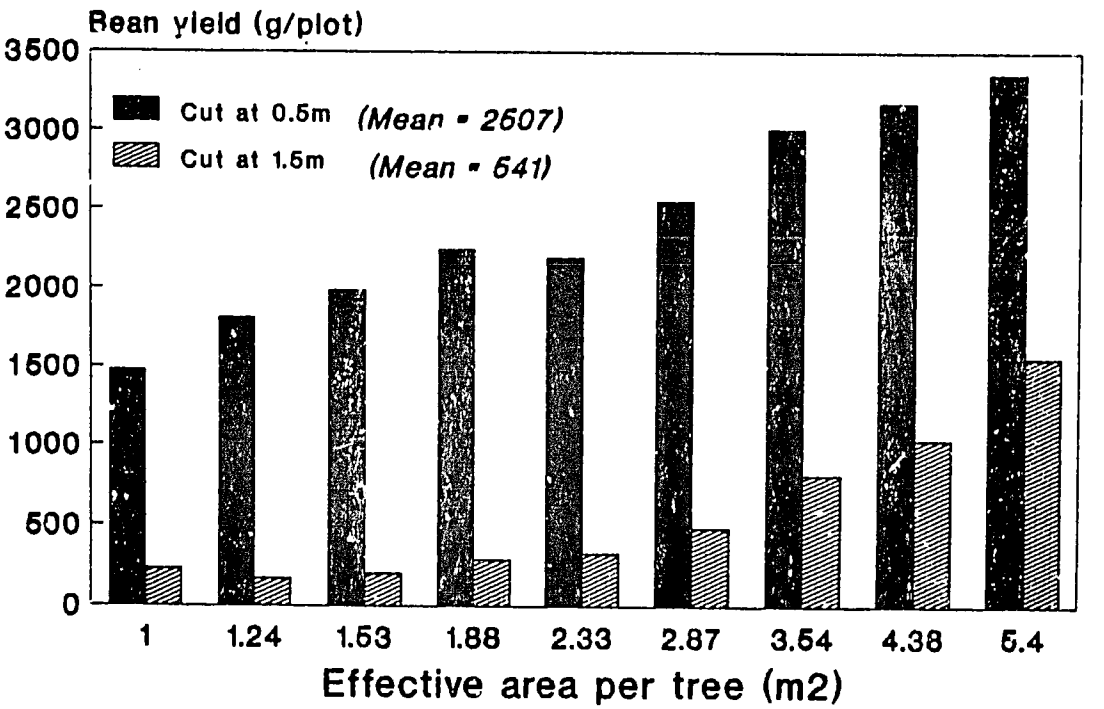
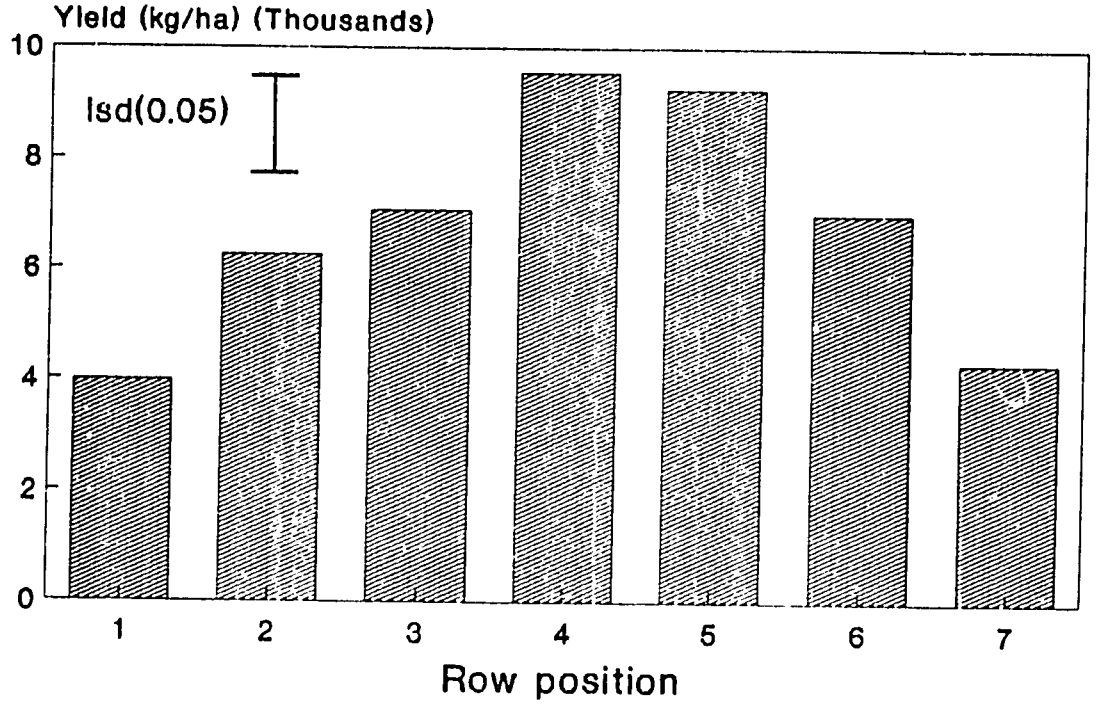


Fig. 3. Nematode population as influenced by Sesbania hedgerows.



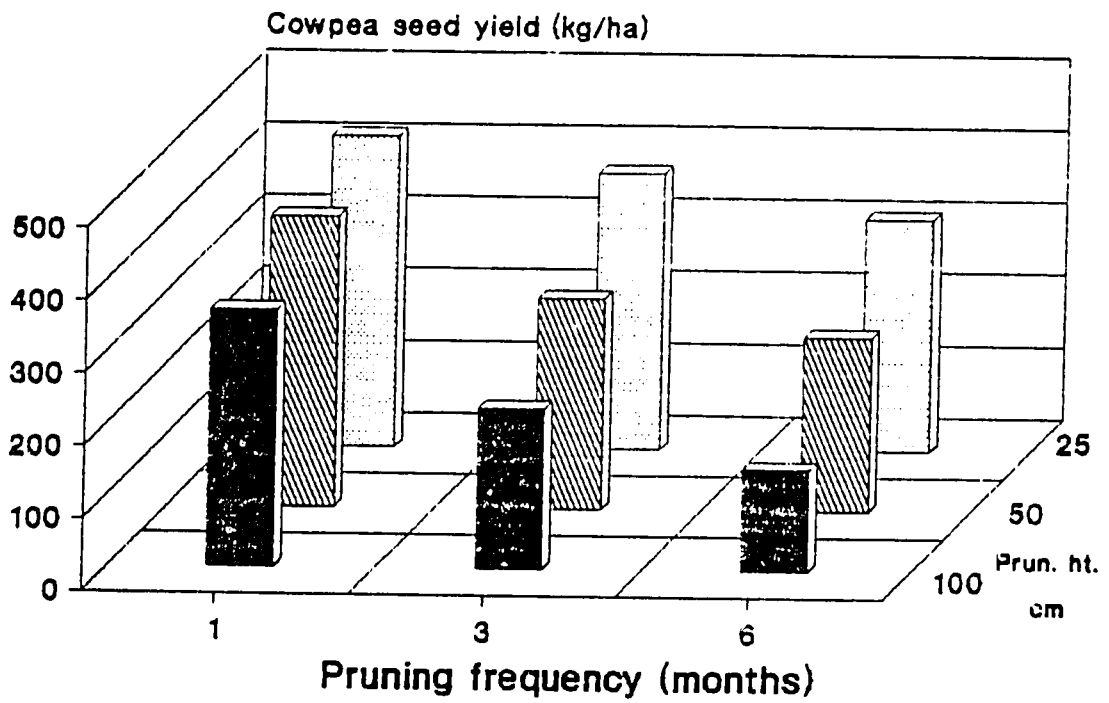
Source: Graf and Yamoah, unpublished

Fig. 4. Effect of pruning height on bean yield in a systematic design.



Source: File of Gahamanyi, aboretum Rwanda.

Fig. 5. Row position and yield of sweet potato in alley cropping.



Source: Duguma et al 1988

Fig. 6. Effect of pruning regime of Sesbania on grain yield of alley-cropped cowpea..

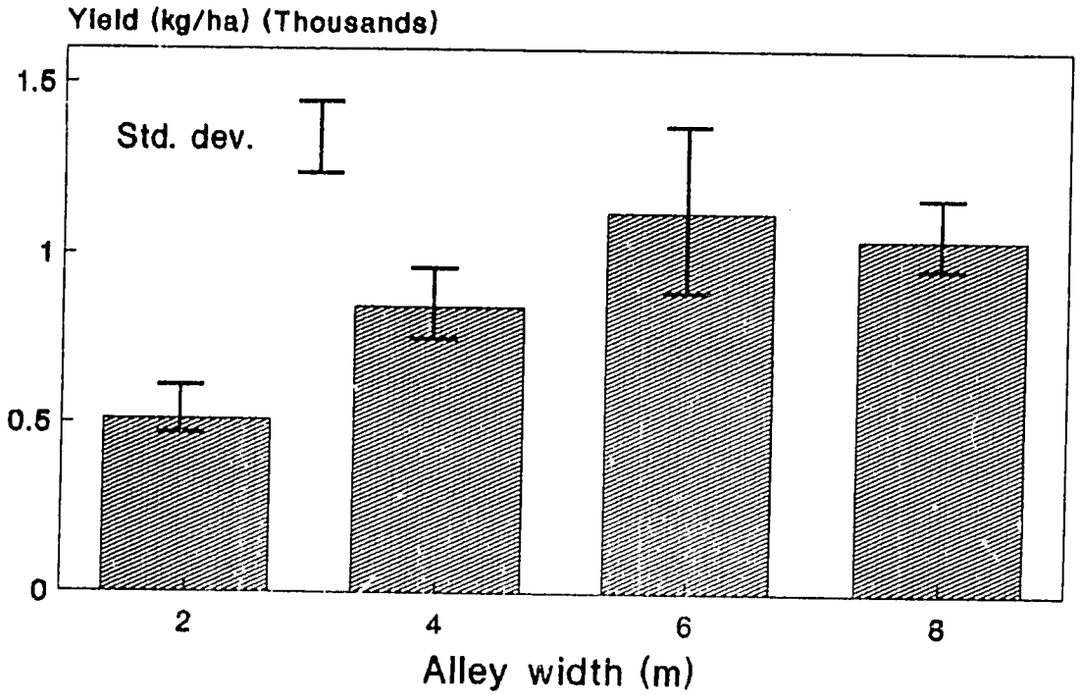


Fig. 7. Effect of alley width on bean yield.

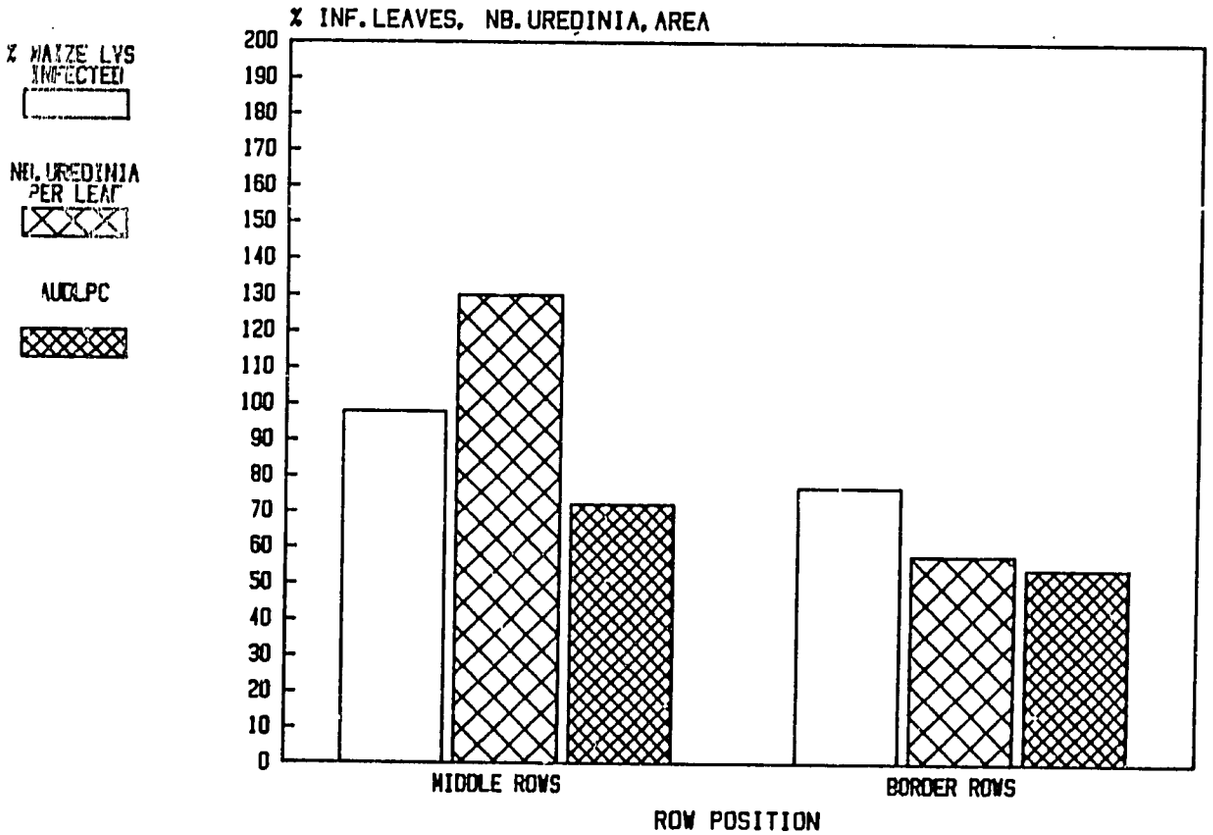


Fig. 8. Effect of Sesbania alleys on development of Puccinia sorghi.