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Sicklepod in improved fallow management: Distribution in natural habitat, diversity and phenology

R. O. Awodoyin and Sola Ogunyemi
Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan, Nigeria

Abstract

Increasing weed infestation is the primary factor leading to fallow farming, but has not received as much attention as the rejuvenation of soil fertility. Studies were carried out in the early and late growing seasons in 1997 on-farm at Apete in Ibadan, Nigeria, to ascertain the suitability of sicklepod (*Senna obtusifolia*), a pantropic weed species in improved bush fallow management and in green manuring. Studies included: a) distribution relative to other weed species at seedling recruitment (April) and flowering (July) stages in two locations, and b) monitoring of phenology in the natural habitat. Results showed that though the two study locations contrasted with regards to soil fertility parameters, they were not significantly different with regards to the density of sicklepod. The site average indicated that in April the flora were co-dominated by a number of species with sicklepod accounting for only 23% of the total number of seedlings recruited per m^2 of the soil seed bank. However, in July sicklepod dominated the flora accounting for about 81% of the total number of plant survivors per m^2. The phenological study revealed that sicklepod produced flowers only in the late rainy season. Adaptation to a wide range of soils, delayed flowering/fruiting and good dominance property imply that sicklepod could be used as a green manure and improved bush fallow plant.

Key words: Bush fallow, density, frequency, seedling survival, *Senna obtusifolia*

Introduction

Though increasing weed infestation is thought to be a primary factor responsible for fallow of crop fields, it has not received as much attention as the conservation and restoration of soil (de Rouw, 1995). Ruthenberg (1980) reported that fallowing has been the most effective traditional method of getting rid of unwanted vegetation including troublesome perennial grasses like *Imperata cylindrica* and *Cynodon dactylon*. During the fallow phase, canopy of vegetation re-growth as well as mulch from fallen leaves/branches provides cover over the soil and discourage germination of weed seeds (weed break), discourage weed seedling establishment (smother plant) and interrupt the continuous re-seeding of the field (Moody, 1975; de Rouw, 1995).

Due to declining arable land resulting from population increase and attendant urbanisation, industrialisation, continuous cultivation, minimal nutrient replenishment, noxious weed infestation and reduced fallow period now characterize the farming systems in sub-Saharan Africa (Kang and Wilson, 1987; Kotschi, 1990; Wortman and Eledu, 1999). Tree-based and shrub-based improved fallow management strategies have been suggested as alternatives to the natural fallow systems (Akobundu, 1993). Crotalaria (*Crotalaria ochroleuca*), Mucuna (*Mucuna pruriens*), Lablab (*Dolichos lablab*), Pigeon pea (*Cajanus cajan*), Tephrosia (*Tephrosia vogelli*) and Sesbania (*Sesbania* sp.) are among the shrubs that have been introduced as green manure plants to improve crop yields and control weeds (Kotschi, 1990; Akobundu, 1993; Kwesiga and Beniest, 1998; Abayomi *et al.*, 2001; Miiro *et al.*, 2002).

In the present study sicklepod (*Senna obtusifolia)* was investigated as an improved bush fallow plant. Sicklepod is regarded as a weed problem of many crops including soybean [*Glycine max* (L.) Merr.], cotton [*Gossypium hirsutum* L], lima bean [*Phaseolus lunatus* L.] and peanut [*Arachis hypogea* L.] (Elmore, 1989). Notwithstanding, the robust growth of the plant and its deep penetrating root system may make it an ideal improved bush fallow plant. The young leaves and shoots of sicklepod are used as potherbs, mild laxative and anthelmintic in many parts of Africa (Dupriez and De Leener, 1989; Yagi *et al*, 1998; Schippers, 2000). Understanding the biology and ecology of a plant, especially as related to seedling recruitment from soil seed bank, seedling establishment in a natural habitat and seasonal changes in development (phenology) are pertinent to its utilization in bush fallow management. In this report we discuss the field distribution of sicklepod in terms of density, frequency and seedling survival as related to other herbaceous weed species at seedling recruitment and flowering stages to understand its suitability as a bush fallow and green manure plant. Also discussed is its phenology and general species diversity.

Materials and methods

The studies were conducted in a bush fallow ecosystem at Apete near Ibadan, Nigeria. Ibadan (7° 24'N; 3° 54'E; altitude 234 m above sea level) is located in the rainforest-savanna transition zone of southwestern Nigeria. White (1983) described the vegetation as 'Guineo-Congolian rainforest: drier type' whose floristic composition is a mosaic of lowland rainforest trees and secondary grassland. Ibadan is underlain by rocks of pre-cambrian basement complex. The rainfall pattern is bimodal with peaks in June and September and a brief dry spell in August. Eight-month wet season (March-October) and four-month main dry season (November-February) characterize the area. The rainfall:evaporation ratio for Ibadan approximates 1.0. A total rainfall and total pan-evaporation of 1285.8 mm and 1213.8 mm respectively were recorded in 1997.

Field assessment of the distribution of sicklepod was done at two sites in the bush fallow vegetation using systematic sampling technique (Greig-Smith, 1964; Kent and Coker, 1996). The sites were subjectively located based on the preponderance of sicklepod in the flora. The studies included estimation of density, frequency and seedling survival. Assessment was done in April 1997 at the onset of rainy season which is the period of active seedling emergence for the soil seed bank, and in July 1997 when the vegetation was well established and sicklepod had commenced flowering.

In each site, a plot (20 m x 25 m) was marked out. Within each plot four transects were laid across the slope at 5 m intervals from 2.5 m point along the baseline. Five permanent sampling points were located along each transect at 5 m intervals to have a total of 20 sampling points in each plot. The sampling was non-destructive. A 50 cm x 50 cm wooden quadrat was laid at each sampling point. All herbaceous plants that rooted within the quadrat were identified and counted.

Estimation of density, frequency and seedling survival

Density for each species was estimated as the number of individuals per unit area. Percentage frequency for each species was estimated by relating the number of quadrats that had each species with the total number of quadrats investigated (Greig-Smith, 1964; Kent and Coker, 1996). Percentage seedling survival was calculated as the number of surviving seedlings in the late season assessment compared to the number recruited from soil seed bank in the early season assessment.

The data for all herbs other than sicklepod were pooled. The density and percent seedling survival for sicklepod and other herbs at the two sampling periods (April and July) in the two sites were compared using two-level nested analysis of variance (Sokal and Rholf, 1969).

Phenology

The phenology of *S. obtusifolia* was monitored in the study area by making records of the developmental stages on the field. This is implicated in the control time for the plant to prevent accumulation of the seeds in the soil seed bank (Mortimer, 1990).

Measures of diversity

The number of plant species (S), number of individuals of each species (ni) and total number of individuals of all species (N) encountered in each of the twenty quadrats were used as primary data to compute the diversity indices [S=species richness; H`=Shannon-Wiener index; J`=Equitability or Evenness index] for the two sites at the two periods (Whittaker, 1975; Kent and Coker, 1996). While Shannon-Wiener diversity index (a measure of species richness and relative abundance) indicates the likelihood of random interaction among species within an assemblage, equitability index indicates even or uneven representation of the species encountered in an assemblage. The variable S indicates the number of species encountered in an assemblage. The indices J' and H' were calculated according to Kent and Coker (1996) as:

$$J` = H`/\text{In}\ S$$

$$H` = -\sum_{i=1}^{s} [pi.\text{In}\ pi]$$

where S = the number of species
pi = proportion of individuals (ni/N)
In = log base n ($\log_n$); log base 10 ($\log_{10}$) was used in this study

The differences between the two sites with regards to the indices of species diversity were studied using two-level nested ANOVA (Sokal and Rholf 1969). The sites represented the group and periods represented the subgroup.

Soil sampling

In June 1997, soil samples were collected at each of the 20 sampling points in each site from 0-15 cm depth using a Gallenkamp SLR-580 soil auger. The samples were bulked by site and analyzed for pH (in 0.01M $CaCl_2$), percentage organic carbon (Walkley-Black titrometric method), percentage total nitrogen (Kjeldhal method), and percentages sand, silt and clay (hydrometry method) (IITA, 1979; Odu *et al.*, 1986). Analyses were conducted in the analytical laboratory of the Department of Agronomy, University of Ibadan. The sites were compared by the analysis of variance (Sokal and Rholf, 1969).

Results

Results of the soil chemical analyses showed that the two study sites were contrasting in nutrient status (Table 1). One of the sites is less fertile and the soil is acidic (pH = 3.9), and the second site is relatively fertile with the soil nearly neutral (pH = 6.4). The two sites were significantly ($P < 0.001$) different in pH values. The organic carbon and the total nitrogen contents of soil in the fertile site was significantly ($P < 0.001$) higher than that in less fertile site. Assessment of the particle size distribution in the soils showed that the two sites were significantly ($P < 0.05$) different with regards to soil texture. The less fertile site had sandy clay soil and the fertile site had clay loam soil (Table 1).

The two sites were not significantly different with regards to the density of sicklepod and other herbs at the two sampling periods (Table 2). However, the density estimate of sicklepod in July was significantly ($P<0.001$) lower than the density in April. The density of other herbs was also significantly ($P<0.01$) lower in July than the estimate in April (Table 2).

Percentage seedling survival between the two periods was very low among other herbs (3.04%) but relatively high for sicklepod (23.05%) (Table 3). Sicklepod seedlings accounted for only about 23% of the total number of seedlings recruited in every square meter in the early season (April). At flowering (July), however, the seedlings accounted for about 81% of the total number of plant survivors in every square meter.

Table 1. Soil properties of the two natural ecosystems of Senna obtusifolia. (Values shown are mean ± S.E.; n=3).

Soil characteristics	Less fertile site	Fertile site	F-Values	LSD .05 (4df)
pH (0.1N $CaCl_2$)	3.90±0.09	6.40±0.12	287.69***	1.28
Organic Carbon(%)	1.36±0.06	3.12±0.13	116.00***	1.72
Total N(%)	0.010±0.002	0.31±0.05	34.61**	0.24
Sand (%)	47.00±3.22	26.00±1.44	33.22**	16.23
Silt (%)	11.00±1.00	43.00±3.18	90.25***	28.70
Clay (%)	42.00±3.60	31.00±1.85	7.81*	11.27
Textural class	Sandy clay	Clay loam	-	-

ns - not significant *; **; *** - significant at 5%;1%; and 0.1% probability level respectively.

Table 2. Density (plants m^{-2}) of Senna obtusifolia in relation to other herbs in the two study sites at seedling recruitment (April) and flowering (July) stages. Values shown are mean ± S.E. (n=20).

Species	Sites	April	July	Period mean
S. obtusifolia	Less fertile	492.00±50.99	108.00±9.63	300.4
	Fertile	567.20±49.30	110.40±7.2	339.2
	Site mean	530.40	109.20	-
Other herbs	Less fertile	1845.60±303.68	12.00±4.16	928.8
	Fertile	1716.00±396.64	40.00±5.92	878.0
	Site mean	1780.8	26.0	-

$LSD_{0.001}$ (period); *Senna obtusifolia* = 11.00; Other herbs = 66.22.

Table 3. Mean percentage seedling survival of Senna obtusifolia in relation to other herbs in the two study sites. Values shown are mean ± S.E. (n=20).

Sites	% survival		
	S. obtusifolia	Other herbs	Species mean
Less fertile	25.30±2.55	3.50±0.38	14.40
Fertile	20.80±0.51	2.60±0.35	11.45
Site mean	23.05	6.1	

$LSD_{0.05}$ (species) = 3.42 $LSD_{0.001}$ (sites) = 8.34.

Though the percentage seedling survival was slightly better on less fertile site than the fertile site, the difference between the two sites was not statistically significant (Table 3). Nonetheless, the percentage seedling survival among sicklepod seedlings was significantly ($P<0.001$) better than the survival among seedlings of other herbs (Table 3).

In the early season, in less fertile site, sicklepod, *Sida acuta* and *Amaranthus spinosus* were most encountered with 100%, 75% and 75% frequency values respectively. However, in the fertile site, sicklepod and *S. acuta* were the most encountered with 100% and 60% frequency values respectively. In the late season, only *S. obtusifolia* and *S. acuta* had fairly high frequency values (Table 4).

In the less fertile site in the early season, *S. acuta* had the highest density followed by sicklepod and *A. spinosus*. In the late season, sicklepod became dominant with *S. acuta* and *A. spinosus* trailing far behind (Table 4). In the fertile site in the early season, sicklepod and *S. acuta* were numerically co-dominant. However, in the late season sicklepod predominated in the flora (Table 4).

In the natural ecosystem, it was observed that mass seedling recruitment in sicklepod and other annuals took place in March/April. The seedlings were actively growing until July when they commenced flowering.

Sicklepod produced fruits/seeds from late July/early August till November/December when the entire vegetation had dried up. Dispersal is passive and it occurs in November/December when the pods had dried, dehisced and shriveled to release the seeds within locality of the mother plants. Dehiscing occurred on the convex suture of the pod.

In the early season the overall species richness [S] values in less fertile and fertile sites were 14 and 19 respectively, while in the late season they were 8 and 10 respectively (Table 5). The species richness per quadrat was greater in the early season [less fertile site=4.80±0.30; fertile site=4.20±0.24] than in late season [less fertile site=2.40±0.20; fertile Site=2.35±0.17] (Table 6). The values of H' in April were significantly ($P<0.001$) greater than in July, but not significantly different between sites. The equitability index (J') followed the same trend (Table 6).

Discussion

The density of sicklepod and other herbs were very high in April, the period of active seedling recruitment. The low density in the late season may be attributed to the mortality of earlier emerged seedlings. Seedling mortality could be explained by a density-dependent thinning (Mortimer, 1990). Misra *et al.* (1992) reported high seedling mortality after emergence of early cohorts of weed species in slash and burn agriculture in northeast India. The mortality among the population of sicklepod could be explained by the density-dependent thinning, while the mortality among other herbs could be explained by the interaction of density-dependent thinning and domination of the flora in the late season by sicklepod. The ability of sicklepod to form a uniform ground cover might greatly reduce the photosynthetically active radiation (PAR) reaching the ground surface, a condition that does not support seedling recruitment and growth. Holt (1995) indicated that the use of smother crops and narrow spacing exploits plant's light response to promote crop growth and suppress weed growth.

Though the study sites were contrasting with regards to soil properties, the two sites were not significantly different with regards to the density of sicklepod. This probably demonstrates the adaptation of sicklepod to wide range of pH and soils and it may account for its superior competitive ability and success as a weed of many field crops (Dupriez and De Leener, 1989; Elmore, 1989; Patterson, 1993).

The relatively low diversity index in the less fertile site in the early season indicated preponderance of a species while the relatively high diversity index in the fertile site indicated that the species were randomly distributed in the assemblage (Whittaker, 1975; Kent and Coker, 1996). In the less fertile site, *Sida acuta* had the highest number of individuals per m^2 while in the fertile site, sicklepod, *S. acuta*, *Ipomoea mauritania*, *I. involcurata*, *Boerhavia erecta* and *Chromolaena odorata* are well represented in the assemblage. The higher evenness index in the fertile site (0.790) than the less fertile

Table 4. Floristic difference among weeds as shown by frequency (%) and density (plant m^{-2}) in the two study sites at seedling recruitment (April) and plant flowering (July) stages. (Density values are mean ± S.E.; n=20).

Species		Less fertile site				Fertile site			
		April		July		April		July	
	*Common names	Frequency	Density	Frequency	Density	Frequency	Density	Frequency	Density
Alternanthera sessilis	Sessile joyweed	25	33.6±18.1	-	-	-	-	-	-
Amaranthus spinosus	Thorny pigweed	75	333.6±100.9	20	7.2±3.8	-	-	-	-
Boerhavia erecta	Red spiderling	25	41.6±17.3	5	1.6±1.6	25	132±71.7	-	-
Calopogonium mucunoides	Calopo	-	-	-	-	10	61.6±44.8	10	1.6±1.1
Centrosema pubescens	Centrosema	20	15.2±7.7	15	2.4±1.3	20	52.8±25.4	15	3.2±1.9
Chromolaena odorata	Siamweed	30	68.8±28.2	5	2.4±1.8	30	181.6±88.5	5	1.6±1.6
Cleome viscosa	Spider plant	10	112.8±93.2	10	2.4±1.8	20	76.0±38.1	10	3.2±2.2
Commelina benghalensis	Tropical spiderwort	30	47.2±23.5	-	-	15	24.0±13.5	-	-
Euphorbia heterophylla	Wild poinsettia	-	-	-	-	25	77.6±36.8	-	-
Ipomoea involucurata	Morning glory weed	-	-	-	-	25	240±148.9	10	1.6±1.1
I. mauritania -	-	-	-	-	-	10	104±71.9	10	2.4±1.8
Luffa aegyptiaca	Loofah gourd	-	-	-	-	15	33.6±23.4	10	1.6±1.1
Momordica charantia	African cucumber	20	11.2±5.7	10	1.6±1.1	5	27.2±22.7	-	-
Phyllanthus amarus	-	-	-	-	-	5	14.4±14.4	-	-
Physalis angulata	Wildcape gooseberry	25	38.4±16.5	-	-	20	49.6±30.9	5	1.6±1.6
Portulaca oleracea	Common purslane	-	-	-	-	5	45.6±45.6	-	-
Senna obtusifolia	Sicklepod	100	492±50.9	100	108±9.63	100	567.2±49.3	100	110.4±7.2
S. occidentalis	Coffee senna	15	35.2±19.7	-	-	5	5.6±5.6	-	-
Sida acuta	Broomweed	75	954.4±251.3	75	24±5.4	60	531.2±127.1	60	17.6±3.8
Spigelia anthelmia	Worm bush	20	112.8±62.8	-	-	10	24.8±17.8	-	-
Synedrella nodiflora	Nodeweed	15	35.2±19.7	-	-	-	-	-	-
Trianthema portulacastrum	Horse purslane	-	-	-	-	10	34.4±27.2	-	-

* Common names are according to Akobundu and Agyakwa (1998).

site (0.697) in April further indicates that tendency for a single species dominance was not as pronounced in the relatively fertile environment as in the marginal environment.

The lower diversity index in the late season (July) than early season (April) is indicative of dominance of the flora by a single species. At the two sites in July, sicklepod was the dominant species accounting for about 81% of the total number of individuals in each of the two sites. The ability of sicklepod to form a uniform total ground cover might greatly reduce the photosynthetic active radiation (PAR) reaching the ground surface, thus impairing the growth of other plant species. The low eveness index (J') at the two sites in late season (0.467 and 0.412) further demonstrates the dominance of the flora by a species, which in this study was sicklepod.

The dominance of the flora by sicklepod in the late season presents the plant as a superior competitor over other associated weed species. This suggests that sicklepod may serve as a smother plant, suppressing other plants growing in association with it. The delayed seed production till late rainy season implies that sicklepod can easily be controlled in the vegetation by uprooting the plants or ploughing it under before flowering and fruiting. Therefore, the plant can be used in green manuring without the danger of increasing its seed load in the soil seed bank. Few stands of sicklepod may be spared for seed collection. The fruits may be harvested as from the brown stage of ripening when the seeds would have all matured (Awodoyin, 2000). The danger of loading the immediate and distal soil seed banks with seeds of sicklepod is quite low. Sicklepod produces only 2,800-8,200 passively dispersed seeds per plant (Retzinger, 1984). The innovative use of sicklepod as fallow plant may be readily acceptable to farmers in West Africa because of its many ethnobotanical values in the region. (Gbile, 1986; Dupriez and De-Leener, 1989; Yagi *et al.*, 1999; Schippers, 2000).

Table 5. Overall diversity indices for plant species in the two study sites at the two sampling periods.

Variables	Less fertile site		Fertile site	
	April	July	April	July
Species richness (S)	14	8	19	10
Shannon-Wiener Index (H')	1.840	0.971	2.325	0.948
Eveness index (J')	0.697	0.467	0.790	0.412

Table 6. Mean values per quadrat of diversity indices of plant species in April and July at two sites. Values shown are mean ±S.E. (n=20).

Sites		S		H'		J'	
		Mean	S.E.	Mean	S.E.	Mean	S.E.
Less fertile	April	4.80	0.30	1.216	0.580	0.798	0.029
	July	2.40	0.20	0.609	0.065	0.723	0.043
Fertile	April	4.20	0.24	1.225	0.050	0.873	0.016
	July	2.35	0.17	0.589	0.051	0.714	0.029
$LSD_{0.05}$(period)		0.64	-	0.16	-	0.004	-

S = Species richness; H' = Shannon-Wiener Index; J' = Equitability or Evenness index .

Conclusion

Assessment of distribution of sicklepod in edaphically contrasting sites in southwestern Nigeria in the forest-savanna transition zone revealed that the plant is adapted to a wide range of soils. It dominated the flora at the contrasting sites in the late growing season. Therefore, it is an ideal "smother plant" to suppress other heliophytic weed species. The delayed flowering/fruiting period of the plant implies that it can be used as a green manure and mulch interplant without the fear of multiplying its seeds in the soil seed bank. The plant could be cut back or ploughed under at flowering for *in-situ* mulch generation and green manuring to raise the organic matter status of poor soils and alleviate the problem of weed infestation.

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