Stocking density effect on the performance and weed smothering ability of an annual Legume, *Senna Obtusifolia* (L.) Irwin and Barneby

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Abstract

Sicklepod (Senna obtusifolia) was grown at densities 200(D1), 133(D2), 100(D3), 80(D4), 66(D5) and 0(D6) plants/m² in a randomized complete block design to assess the effect of proximity of neighbours on the performance and weed smothering ability of the plant in the instance of utilizing it in intensive fallow management. At 14 weeks after planting the low-density plants (D5) were short (124.7±1.2cm), produced highest number of branches (14.7±1.4) that started at a low height (5 cm) and had highest mean shoot dry matter/plant (73.46±5.16g). The high-density plants (D1) were tall (156.9±0.5 cm), produced low number of branches (7.7±0.4) that started at 100 cm height and had significantly low mean shoot dry matter/plant (28.27±1.09g). The test densities were fairly similar in the mean shoot dry matter/m² and weed biomass. Nevertheless, the D1 plot was significantly better than other plots in weed control and dry matter yield per unit area. The densities strongly related to all the growth parameters and shoot yield of S. obtusifolia, except the shoot dry matter yield/m². The strong negative correlation coefficient (r = -0.93) between density and weed biomass indicates that the effectiveness of S. obtusifolia in suppressing weed seedlings increased with increasing density. Heliophytic weeds like Chromolaena odorata, Euphorbia heterophylla, Lantana camara and Acalypha segetalis were encountered only on low-density (D4 and D5) plots where adequate light intensities reached the soil surface.

Key words: Bush fallow, dry matter accumulation, growth, helioplastic response, sicklepod, weed suppression.

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Introduction

Of so many beneficial effects of shrubby plants which include, among others, food, fibre and ethnotherapeutic uses in the treatment of various ailments, the benefits in the protection of soils against erosion, fixing of atmospheric nitrogen, nutrient recycling, enhancement of soil organic matter, control of nematodes, green manuring, prevention of germination of weed seeds (weed-break) and suppression of growth of weeds (weed smother) are of utmost importance in crop production activities (Waterhouse and Norris, 1987; Kang and Ghuman, 1991; Holt, 1995; Desaeger and Rao, 2001). Some low-growing plants regarded as weed, *including Crotalaria juncea, C. retusa, Indigofera spictata, Mucuna pruriens, Tephrosia sp., Targetes erecta, Tithonia diversifolia, Chromolaena odorata* and *Sesbania sesban* have been identified for inclusion in improved bush fallow as alternative to shifting cultivation for nutrient replenishment, alleviation of weed pressure, control of soil nematodes, etc. (Akobundu, 1993; Chairidchai, 2000). *Senna obtusifolia* (L.) Irwin and Barneby (Syn. *Cassia obtusifolia* L.) could be another candidate plant for sown bush fallow. Though *S. obtusifolia* is regarded as a weed of wasteland, natural bush fallow and roadsides in West Africa (Ghazanfar, 1989) and it is reported as the number one weed of soybeans, peanuts, cotton and lima bean in 11 out of 13 states in Southern United States (Teem *et al.*, 1980), a cursory observation of the plant on the field reveals that it is fast-growing, deep-rooting and forms a

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dense canopy cover, which are some of the attributes a good fallow plant must possess to effectively recycle nutrients from subsoil and suppress the growth of noxious weeds (Holt, 1995). Hauser *et al.* (1975) reported rapid biomass accumulation and dense canopy cover in sicklepod. Working in an area dominated by the plant in Southwestern Nigeria, Awodoyin and Ogunyemi (2003) reported that in the early growing season (April) the plant constituted 23% of the flora, but accounted for about 81% of the flora in the late growing season (July). They further reported that the Shannon-Weiner index values (H`) for the community averaged 2.08 and 0.96 in the early season and late season respectively. These indicated co-dominance (random interaction) of the flora by a number of plant species in the early growing season and dominance by a plant, which was the sicklepod, in the late growing season. Sicklepod is probably one of the Cassias listed among the woody plants of dry regions that could be grown for mulch and green manure (Dupriez and De Leener, 1989).

Sicklepod thrives on a wide range of habitats. Elmore (1989) reported that it has rapid germination at a wide range of soil temperatures (24-26°C) and soil pH levels (3.2-7.9). Awodoyin and Ogunyemi (2003) reported that the densities of sicklepod at two sites with significantly contrasting soil nutrients and pH values were not significantly different. The plant is drought resistant, capable of survival on poor soils and has restricted flowering/fruiting period (Dupriez and De Leener, 1989; Awodoyin, 2001).

Sicklepod is a multipurpose plant. It is used as a purgative and anthelminthic (Hutchinson and Dalziel, 1958) and the seeds could be a good source of protein for poultry and famine food for human consumption (Cock and Evans, 1984). Dupriez and De Leener (1989) reported that sicklepod is in the process of domestication in parts of Africa for its leafy shoot with breeding attention focussed at selecting varieties that have mild taste and possess leaflets that separate readily from the stalks. The density of sicklepod plants in the natural habitats averaged 109.20 plants/m^2 (Awodoyin, 2001).

In the present study the effects of stand density on the early growth, dry matter accumulation and weed smothering ability of sicklepod in the tropical lowland rainforest are reported.

Materials and Methods

The study was carried out in the crop garden of the Department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria. Ibadan (latitude 7°24`N; longitude 3°54`E; altitude 234m above sea level) is located in the Guineo-Congolian rainforest: drier type whose floristic composition is a mosaic of lowland rainforest trees and secondary grassland (White, 1983). The area is underlain by rocks of pre-cambrian basement complex with soil of ferruginous formation that is low in clay content (Smyth and Montgomery, 1962). Eight-month wet season (March-October) and four-month dry season (November-February) characterize the area. The rainfall pattern is bimodal with peaks in June and September. The mean annual rainfall and number of rainy days over a five-year period (1994-1998) were 1180.6mm and 114 days respectively (Awodoyin, 2001). The mean daily maximum and minimum temperatures of the area over the period were 31.7°C and 22.0°C respectively and the mean monthly maximum and minimum relative humidity were 95% and 55% respectively.

The seeds of sicklepod used for the study were collected from the wild at the dark brown pod stage. The seeds were acid-scarified in Tetraoxosulphate (VI) acid (H_2SO_4) for 10 minutes to obtain uniform seed germination and seedling establishment. The various densities studied were 200(D1), 133(D2), 100(D3), 80(D4), 66(D5) and 0(D6) plants/m^2 obtained by spacing the plants at 5x30 cm, 5x25 cm, 5x20 cm, 5x15 cm, 5x10 cm and zero plantings respectively. The D3 represented the optimum density of the plant as obtained in the natural habitat, the D1 and D2 represented the super-optimum densities and the D4 and D5 represented the sub-optimum densities. The trial which ran for 14 weeks was set up in a randomized complete block design with four replications. Each plot was 2 m x 2 m in dimension. The distance between contiguous plots and contiguous blocks were 50 cm and 1 m respectively.

The field that was under the fallow of *Chromolaena odorata*, was cleared manually and the soil was turned with a hoe. The soil of the study site was sandy clay loam and acidic. It has low organic carbon and nitrogen contents (Table 1). The field was marked with 5 cm intra-row spacing but with varying interrow spacing as indicated above to obtain the various test densities. The seeds were sown three seeds per hole at 2 cm depth. The plot with zero planting (D6) served as control plot to compare the weed control efficiency of the plants at the test densities. At two weeks after planting (WAP), weeds growing on all plots were manually removed and the plants were thinned to one plant per hill.

At harvest (14WAP), five plants, randomly selected in each plot, were assessed for the following parameters:

Table 1: Soil characteristics of the study site

Characteristic	Values
pH (H_2O)	5.7
Organic Carbon (%)	1.9
Total N (%)	0.23
Available P (mg/100gsoil)	5.20
Exch. K (meq/100gsoil)	0.32
Sand (%)	62
Silt (%)	17
Clay (%)	21
Textural class	Sandy clay loam

a) plant height – measured with a meter rule,
b) stem diameter at soil surface – measured with a vernier caliper,
c) number of primary branches,
d) height at 1st branching,
e) dry matter accumulation – the five selected plants were clipped with a secatuer at soil surface and dried at 80°C for 48 hours in a Gallenkemp oven. The oven-dried materials were weighed with a top-loading mettler balance (P1210) to monitor the effect of density on aboveground (shoot) dry matter accumulation.

Weed control efficiency of the plant at the various densities was assessed as follows:

a. *Weed dry matter:* Three 25 cm x 25 cm quadrats were randomly laid within each plot at 14 WAP. All weeds that rooted within each quadrat were clipped at soil surface with a secateur. The weed samples were dried in the oven at 80°C for 48 hours and weighed to determine the dry matter.

b. *Weed spectrum and frequency:* All weeds that rooted within each quadrat were identified and counted. The data from the four blocks were pooled by treatment to have 12 quadrats per treatment. For each treatment, percent frequency of each weed species was estimated based on number of quadrats that contained the species out of the total 12 quadrats.

$$\% \text{ Frequency} = \frac{\text{Number of quadrats with species}}{\text{Total number of quadrats per treatment (12)}} \times 100\ \%$$

The treatments were compared by analysis of variance (ANOVA) and means were separated by least significant difference (LSD) at 5% level of probability (Gomez and Gomez, 1984). Also the test densities were related to the various growth parameters and the weed dry weight by regression analysis. As a result of the wide variation in the dry weight of associated weeds the data were log-transformed for the analysis (Little and Hills, 1978). The significance of the regression equations was verified using students t-test.

Results

Vegetative growth

The plant height decreased with decreasing density per m^2. The farther the distance among neighbours the shorter the plants. The D4 and D5 plants were not significantly different from each other in height but were significantly ($P<0.001$) shorter than the plants grown at the other densities (Table 2). The D1 plants (200 plants/m^2) grew significantly ($P<0.001$) taller than plants at other test densities. The differences among the means of the various densities with regards to plant height were highly significant ($P<0.001$).

Table 2: Effect of density on some growth parameters of *S. obtusifolia* at 14 weeks after sowing. (Values are means ± S.E.; n=20)

Density (plant/m^2)	Height (cm/plant)	Stem diameter (cm/plant)	Height at1st branch (cm/plant)	Number of primary branches
200 (D1)	156.9±0.5	0.83±0.03	99.05±3.14	7.7±0.40
133 (D2)	138.2±1.24	0.89±0.03	76.75±1.58	8.8±0.55
100 (D3)	132.6±0.83	1.00±0.03	25.80±2.39	11.7±0.98
80 (D4)	128.0±0.93	1.08±0.02	7.05±0.03	11.9±1.13
66 (D5)	124.7±1.24	1.15±0.03	5.35±0.22	14.7±1.40
0 (D6) (control)	-	-	-	-
LSD(.001)	3.86	0.11	2.41	8.16
C.V. (%)	1.39	5.53	9.37	10.78

The stem diameter growth was inversely related to the density with D1 plants (200 plants/m^2) having the lowest value (0.89 cm) and D5 plants (66 plants/m^2) having the highest value (1.15 cm). The differences among means of the test densities were significant (P<0.001).

The D5 plants produced the highest number of branches (approx. 15) and at a low height (5 cm). The high-density (D1) plants commenced branching way up the main stem at about 100 cm height and the number of branches were few (Table 2). The differences among the densities with regard to the mean height at first branching and the mean number of primary branches were highly significant (P<0.001).

Shoot dry matter yield

The shoot dry matter yield per plant at 200 plants/m^2 (D1) and 133 plants/m^2 (D2) were similar but significantly (P<0.001) lower than those of the plants at other test densities (Table 3). The shoot dry matter yield per m^2 for D2, D3, D4 and D5 plots were statistically similar but significantly (P<0.001) lower than the yield of high-density (D1) plot (Table 3).

Table 3: Effect of density on dry matter accumulation of *S. obtusifolia* and the dry weight of associated weeds at 14 weeks after sowing. (Values are means±S.E.)

Density (plant/m^2)	Shoot Dry weight(g/plant)	Shoot biomass/ unit area (kg/m^2)	Dry weight of associated weeds (logXg/m^2)
200 (D1)	28.27±1.09	5.65±0.22	0.79±0.01
133 (D2)	33.79±1.03	4.49±0.14	1.06±0.005
100 (D3)	49.16±2.10	4.92±0.21	1.27±0.07
80 (D4)	61.63±2.30	4.93±0.18	1.56±0.07
66 (D5)	73.46±5.16	4.85±0.34	1.59±0.07
0 (D6) (control)	-	-	2.77±0.01
LSD(0.001)	10.94	0.95	0.21
C.V. (%)	10.92	9.44	6.99
n	20	20	12

Weed biomass and weed spectrum

The weed biomass on all plots planted with *S. obtusifolia*, irrespective of density, was significantly (P<0.001) lower than weed biomass on control plots (Table 3). With respect to weed biomass, the D2 and D3 plots were not significantly different, so also for the D4 and D5 plots. However, the weed biomass on D1 plot was significantly (P<0.001) lower than the weed biomass on all other plots (Table 3). A clear floor was observed on all plots under *S. obtusifolia* regardless of the stocking density.

The weed species encountered on the various plots indicated that 'species richness' (S) increased with decreasing stocking density (Table 4). The species common to all plots irrespective of density were *Amaranthus spinosus, Commelina benghalensis, Fluerya aestuans, Physallis angulata* and *Sida acuta*. *Chromolaena odorata, Euphorbia heterophylla, Lantana camara* and *Acalypha segetalis* were recorded on low-density plots but absent on high-density plots.

Table 4: Percentage frequency of weed species encountered on the plots of *Senna obtusifolia* stocked

Weed species	Stocking Density (plant.m^{-2}) 200 (D1)	133 (D2)	100 (D3)	80 (D4)	66 (D5)	Remarks
1. *Acalypha segetalis*	0	0	33.3	25.0	16.7	*
2. *Amaranthus spinosus*	33.3	16.7	16.7	41.7	41.7	
3. *Calopogonium mucunoides*	0	8.3	0	0	8.3	
4. *Chromolaena odorata*	0	0	25.0	58.3	41.7	*
5. *Commelina benghalensis*	25.0	33.3	8.3	0	16.7	
6. *Euphorbia heterophylla*	0	0	8.3	16.7	25.0	*
7. *Fluerya aestuans*	58.3	50.0	33.3	66.7	66.7	
8. *Lantana camara*	0	0	0	8.3	16.7	*
9. *Peperomia pellucida*	0	33.3	0	0	0	
10. *Physallis angulata*	8.3	8.3	16.7	33.3	25.0	
11. *Sida acuta*	16.7	8.3	33.3	33.3	41.7	
Species richness (S)	5	7	8	8	10	

* - effectively controlled by *S. obtusifolia* at high densities.

Relationship between density and growth parameters/weed biomass

There were high correlations (r) of density to all the growth parameters and shoot yield of *S. obtusifolia*, and weed biomass, except shoot dry matter yield per unit area (Table 5). The correlation of the density with each of the growth parameters, dry matter accumulation and weed biomass was not significant.

Stem diameter per plant, number of primary branches per plant, shoot dry weight per plant and weed biomass per m^2 were strongly negatively correlated with the stocking density of *S. obtusifolia*. On the other hand, height per plant, height at first branching and shoot dry matter yield per unit area were positively correlated with the stocking density (Table 5).

Table 5: The regression equations for the relationship between density and growth parameters of *Senna obtusifolia*, and dry weight of weeds

Growth parameters	n	Intercept a	S.E of a	Regression coefficient b	S.E. of b	r	r^2	t_{cal}
Plant height	100	108.6	1.66	0.24	0.009	+0.99	0.98	-0.04ns
Stem diameter	100	1.258	0.038	-0.002	0.001	-0.90	0.81	-0.50ns
No. of primary branches	100	16.42	1.65	-0.047	0.007	-0.89	0.80	-0.02ns
Ht. at 1st branch	100	-45.94	2.17	0.77	0.02	+0.96	0.91	-0.02ns
Shoot dry weight/plant	100	86.65	5.09	-0.32	0.03	-0.91	0.82	-0.03ns
Shoot biomass/m^2	100	4.39	0.42	0.005	0.003	+0.41	0.37	-0.01ns
Associated Weed dry weight	72	2.43	0.05	-0.01	0.003	-0.93	0.87	-0.27ns

ns - not significant
Model: $Y = a + bX$,
where Y - parameter value; X - density
a – intercept; b - regression coefficient
r^2 - coefficient of determination; r - correlation coefficient

Discussion

At high-density (D1), *S. obtusifolia* grew tallest. At this density, the plants were crowding for space thereby casting shade on each other. The resultant reduced light intensity could explain the greatest height of the plants as they rapidly grew to avoid shade, that is they became etiolated, a mechanism described as the helioplastic response of shade intolerant plants (heliophytes) to light stress (Daubenmire, 1974). The result may imply that *S. obtusifolia* is an obligate heliophyte. Ogunyemi (1976) reported that *Ulex gallii* in response to light stress exhibited etiolation of the shoot which probably aids its successful establishment in closed *Calluna* scrub of British heath communities. Odeleye (1998) reported that soybean varieties grown under reduced light intensities grew taller than control plants. With the imposition of reduced light, much of the assimilate allocated to the growth was probably exploited in cell elongation with the resultant enhanced height growth at the expense of growth in stem diameter. This may account for the strong negative correlation (r = -0.90) between stocking density and stem diameter.

Due to less shading, hence less competition for light in the above ground, D5 (low density) plants grew short, had highest number of branches and produced the first branch at a low height. Kasperbauer (1971) reported that high light intensities result in suppression of the elongation of internodes, thereby resulting in the production of short plants. The inverse relationship between stocking density and number of branches in this study was similar to the report by Smith and Jordan (1994) that the first effect of crowding in *S. obtusifolia* was on the number of branches that increased with increasing distance among neighbours. The fewer number of branches in D1 plants than plants in other test densities may be due to delay in branch production resulting from intense competition for space and light. While D5 plants produced the first branch at about 5 cm height, the D1 plants delayed branching until they attained 100 cm height. The low number of branches obtained in D1 plants may also be explained by self-pruning phenomenon, a condition whereby plants drop the lower branches that could not photosynthesize due to interception of insolation by the overhead dense canopy. This helioplastic response to shade resulting from crowding had been exploited in the cropping of fibre plants like *Crotalaria juncea* (sunnhemp) to obtain long fibres (Anon., 1979).

The strong negative relationship (r = -0.91) between the shoot biomass per plant and density indicates an intense intraspecific competition above-ground for CO_2 and light, and below-ground for soil nutrients and water (Hill 1977). The competition was probably caused by the imposed high density that resulted in crowding for limited space by the plants. It might further be explained that the low dry matter yield per plant in D1 plots was a result of reduced light intensities. Schopfer (1990) reported that there was a general and more rapid export of organic materials at the expense of storage in plants grown under reduced light intensity.

The low shoot dry matter yield per plant at the high density plots (D1) was compensated for by the higher number of plants per unit area. Therefore, the shoot dry matter yield per m^2 for D1 plants was significantly ($P<0.001$) greater than those for other test-density plants. The low (r = 0.41) correlation coefficient between density and shoot dry matter yield/m^2 may suggest that though the dry matter yield may be increasing with increasing density, the trend was not quite strong.

The statistical similarities among the mean shoot dry matter yield/m^2 in D2, D3, D4 and D5 plots may indicate that the density does not seriously affect the productivity of *S. obtusifolia*. Smith and Jordan (1994) reported that stands of *S. obtusifolia* at low densities of between 5 and 51 plants/m^2 formed closed canopies with similar amount of leaf area and biomass.

The observed rapid dry matter accumulation in *S. obtusifolia* is characteristic of most tropical green manure legumes. The amounts of accumulated dry matter and nitrogen are quite important for succeeding crops. Lathwell (1990) reported that under favourable conditions in the tropics, dry matter accumulates rapidly in leguminous green manures, and in a few weeks large amount of both dry matter and nitrogen are present.

The high reductional effect of increasing density on weed biomass as revealed by the strong negative correlation coefficient value (r = -0.93) may indicate that S. *obtusifolia* could serve as 'smother plant', effectively suppressing the growth of weed seedlings when grown at a density range of 66-200 plants/m^2, though best at 200 plants/m^2.

The increasing species richness with decreasing density may be explained by the increasing light intensities permeating the canopy to reach the soil surface. The weeds that are common to all plots were either shade tolerant (Sciophyte) as with *C. benghalensis* or exhibited some degree of plasticity in their adaptation to prevailing light intensities. For example, *A. spinosus* and *P. angulata* were spindly, a result of etiolation of their shoot. *Chormolaena odorata, Euphorbia heterophylla, Lantana camara* and *Acalypha segetalis* that are obligatorily heliophytes occurred on only low density plots due to improvement in insolation reaching the soil surface. Also, *Calopogonium mucunoides* was able to thrive on the plots by climbing the stem of *S. obtusifolia* to receive light above the dense canopy.

The green manure legumes are preferred to the grain legumes in fallow management as sources of dry matter and nitrogen for any succeeding crop since much of the accumulated dry matter in the latter are in the grain that is exported as harvests. For example, soybean [*Glycine max* (L.) Merril.] produced 10.0 Mg/ha total dry matter of which 2.5 Mg/ha was grain (Lathwell, 1990) while cowpea [*Vigna unguiculata* (L.) Walp.] produced about 3.5 Mg/ha of total dry matter with about 1.8 Mg/ha as grain (Mughogho *et al.* 1982).

Conclusion

In the present study, the closeness among neighbours of *S. obtusifolia* at density range 66-200 plants/m^2 resulted in dense canopy that aided effective weed smothering. This suggests that *S. obtusifolia* is a good bush fallow plant. The similarities of the test densities as regard biomass production indicates that dense spacing for rapid canopy closure to prevent germination of weed seeds in the soil seed bank and smother seedlings of other weeds may not reduce the herbage yield for green manuring and mulching. Stocking at high density has the added advantage of producing straight and clear-stemmed plants in the situation that the stems are needed for matting and fence construction. The fact that the percent frequency of *C. odorata* and *E. hirta* decreased with increasing density of *S. obtusifolia* may suggest that the weeds, especially the former, were effectively controlled, more so that the field was under the fallow of *C. odorata* prior to the study.

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