Growth Dynamics of *Senna obtusifolia* (L.) Irwin and Barneby as Affected By Nitrogen Fertilizer in Soils of Contrasting Fertility in the Nigerian Dry Forest Ecology

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Accepted in January 2004.

Abstract

*The effect of nitrogen fertilizer applied at the rate of 0 (N_0), 50 (N_1) and 100 (N_2) kgN/ha on growth and dry matter accumulation in sicklepod [*Senna obtusifolia *(L.) Irwin and Barneby] was studied in pot culture in sandy loam soil (S_1; pH 3.9) and silty loam soil (S_2; pH 7.2) to understand its growth behaviour in soils of contrasting fertility levels. The studies were completely randomized design. The growth parameters were evaluated at 14-day intervals from 28 to 98 days after sowing (DAS). The potting soil, nitrogen fertilizer and harvest period had significant effects ($P \leq 0.05$) on plant height, leaf area, total plant dry weight and leaf dry weight. The soil x harvest period interaction was significant ($P \leq 0.05$) for all growth parameters, while soil x N interaction was significant for only leaf area and leaf dry weight. The leaf weight ratio (LWR) decreased from 0.62 in S_1 and S_2 plants at 28 DAS to 0.31 in S_1 plants and 0.37 in S_2 plants at 98 DAS. The relative growth rate (RGR) and dry matter production (DMP) were high and more or less stable up to 70 DAS when they abruptly decreased. LWR, DMP and RGR varied significantly with the harvest period of sicklepod. The soil had significant effect on LWR and DMP but had no significant effect on RGR. Nitrogen fertilizer significantly affected DMP, but not LWR and RGR. For all growth parameters, nitrogen influence on plant was in the order of $N_2 > N_1 > N_0$ in the marginal (S_1) soil. However, in the relatively fertile (S_2) soil the order was $N_2 > N_1 > N_0$ at the early growth stage and $N_1 > N_2 > N_0$ at the late growth stage. Factor interactions were not significant on LWR, DMP and RGR. The results suggested that sicklepod has rapid growth and yield performance in both marginal and fertile soils, a quality that may adapt it for use as green manure and fallow plant to restore the productivity of exhausted agricultural fields. The rapidity of establishment is also implicated in its competitive and invasive effects.*

Key words: Dry matter accumulation, growth analysis, nitrogen fertilizer, *Senna obtusifolia*, soil fertility.

Introduction

Though weeds constitute a great threat to agricultural development, their ecological importance in the protection of agroecosystem and in fallow management are well-recognized. The deep-rooting weeds serve as 'nutrient pump' to recycle mineral nutrients leached to subsoil layers back to the topsoil where they are available for crop uptake (Akobundu 1993). The exceptionally fast-growing weeds intercept rain drops to protect the soil against erosion and prevent surface run-off. They also intercept most photosynthetic active radiation (PAR) to suppress the germination of other weed seeds (weed-break) and smother the seedlings of other weed species (Holt 1995). Akobundu, (1993) reported that deep-rooting weeds could be grown as interplant in the rows of tall-growing, shallow-rooting crops like maize and millet to smother other weeds, recycle leached nutrients, reduce frequency of weeding and enhance soil organic matter content. Sicklepod [*Senna obtusifolia* (L.) Irwin and Barneby] which belongs to the family Leguminosae:Caesalpinioideae is one of such weed species.

S. obtusifolia is widely distributed in tropical Africa, occurring on a wide range of soil types and climates. It is a drought-resistant plant of the dry forest and savannas and is capable of survival on poor soils (Dupriez and De-Leener 1989). Patterson, (1993) reported that the plant had maximum growth at day temperatures of 29-34^{o}C and night temperature of 26^{o}C, while day/night temperatures of 28/21^{o}C or lower reduced growth by 50% or more. The plant is probably the only *Senna* shrub with the widest range of uses which include medicament, bee foraging, fodder, coffee substitute, famine food, poultry feed, vegetables, tanning, dyeing, green manuring and fallow management (Yagi *et al.,* 1998; Awodoyin 2000).

S. obtusifolia has been reported as the number one weed problem in the production of peanuts (*Arachis hypogea* L.), soybeans (*Glycine max* (L.) Merril.), cotton (*Gossypium hirsutum* L.) and lima bean (*Phaseolus lunatus* L.) in the United States of America and in grazing land in Queensland, Australia (Teem *et al.* 1980; Willson 1982; Elmore 1989). Notwithstanding, it may be a potential green manure and fallow plant because of its rapid seed germination, prolific growth and restricted flowering/seeding period.

Despite the prevalence of *S. obtusifolia* in the fallow and agroecosystem of West Africa, its biology and ecology are little documented. A good understanding of the biology of weeds is pertinent in the integrated weed management and exploitation of the useful aspects of weeds in environmental protection, food provision and fallow management. It is the thrust of this study to investigate the growth dynamics of *S. obtusifolia* and its response to nitrogen fertilizer application in soils of contrasting fertility levels in the Nigerian dry forest ecology.

Materials and Methods

The study was conducted using two types of potting soils namely 100% gutter sand (S_1) and a 1:4 mixture of gutter sand/forest topsoil (S_2), representing marginal and relatively fertile soils respectively. S_1 and S_2 potting soils were loam sand and silty loam respectively (Table 1). S_1 was acidic (pH=3.9) and S_2 was neutral (pH=7.2) in reaction and fairly rich in essential nutrients. The study was conducted in two trials that ran concurrently for 98 days between 17th July and 30th October 1998 in the crop garden behind Department of Crop Protection and Environmental Biology, University of Ibadan, Ibadan (7^{o}24`N; 3$^{o}$54`; altitude 234 m above sea level).

Three nitrogen levels, 0 (N_0), 50 (N_1) and 100 (N_2) kgN/ha designated as control, low and high N levels respectively, were evaluated as treatments in each soil type. A total of 72 plastic pots (4-L capacity, 20 cm top diameter and 22 cm deep) were used for each trial. Each pot was filled to 90% capacity with about 4.0 kg air-dried soil. In each trial, the 72 pots were randomly arranged into three units with 24 pots each. The three nitrogen treatments were randomly allocated to the three units. The pots were arranged outdoor on iron-net table to ensure air-pruning of the roots. The pots were watered daily for two weeks to ensure soil compaction.

Table 1. Some properties of the two experimental soils.

	Gutter sand (S_1)	Gutter sand/forest topsoil (S_2)
pH (H_2O)	3.9±0.04*	7.2±0.05
Organic carbon (%)	0.49±0.04	3.07±0.06
Total N (%)	0.06±0.01	0.35±0.01
Available P (mg/kg soil)	4.57±0.29	18.73±0.48
Exch. K (cmol/kg)	0.14±0.01	0.67±0.02
Sand (%)	80.4±0.50	42.0±0.39
Silt (%)	10.2±0.35	48.0±0.43
Clay (%)	9.4±0.63	10.0±0.34
Textural class	Loam sand	Silty loam

* (Values shown are mean ± S.E.; n=3).

The seeds of *S. obtusifolia* which were acid-scarified by soaking in concentrated H_2SO_4 for 10 min. were sown in the soil in each pot. At 14 days after sowing (DAS), the seedlings were thinned to four per pot, an equivalence of 115 plants/m^2 that was encountered in natural habitat (Awodoyin 2000). At this time, each pot received 0.25 g of N.P.K 20-10-10 that is equivalent to 2.5 kgN/ha, 12.5 kgP/ha and 12.5 kgK/ha as basal dressing. At 28 DAS and subsequently at 14-day intervals, nitrogen treatments were given as ammonium sulphate (26% N). The control, low and high treatments respectively received 0 g, 0.38 g and 0.77 g of ammonium sulphate fertilizer per pot, applied in five equal splits. Each pot was given 500 ml water two times a week. The excess water drained off from the perforated base of the pots. Watering was withheld if there was rainfall within 72 hours.

Data Collection and Analyses

Prior to the application of each split of N fertilizer at 28, 42, 56, 70, 84 and 98 DAS, four pots were randomly selected from each treatment unit to have a total of 16 plants that were assessed for plant height, leaf area and dry matter. These primary data were used for growth analysis to determine leaf weight ratio (LWR), dry matter production (DMP) and relative growth rate (RGR) according to the procedures of Kvet *et al.*, (1971) and Hunt, (1982).

Leaf area per plant was estimated from the regression equation:

$Yp = 3.94Mp - 45.96$ ($R^2 = 0.92$)
where Yp = leaf area and Mp = pooled lamina length of the six leaflets in each leaf.

The regression equation was derived from a preliminary analysis of different models for rapid estimation of leaf area using graphically calculated leaf area and measured leaflet length, leaflet width and their products for 120 fully-expanded leaflets (20 leaves). The values were also pooled and regressed with the calculated leaf area (Table 2). For the dry matter estimation, contents in each pot were emptied and the root mass washed under water to remove the soil. The plant samples were oven-dried at 80°C for 48 h. and weighed separately as leaf and total dry matter. Analysis of variance followed by Least Significant Difference (LSD) test at 5% level of probability were employed to compare and separate the means at the various periods respectively.

Table 2. Regression equations for nondestructive rapid estimation of leaf area in *S. obtusifolia*.

Regression	n	Regression equations	R^2
Area vs leaflet length	120	y = 3.5962x – 6.1582	0.904
Area vs leaflet breadth	120	y = 6.0161x – 5.2164	0.9276
Area vs (leaflet length x breadth)	120	y = 0.7646x + 0.6576	0.982
Area vs (pooled length of 6 leaflets)	20	y = 3.9395x – 45.962	0.9244
Area vs (pooled breadth of 6 leaflets)	20	y = 5.7908x – 28.149	0.9834
Area vs (pooled length x breadth)	20	y = 0.7986x + 1.5617	0.9949

Results

In the eroded gutter sand (S_1) and at all periods of assessment, plant performance followed the trend $N_2 > N_1 > N_0$. The differences among the N treatments were highly significant ($P \leq 0.05$) with regards to plant height, leaf area, plant dry weight at 42 DAS and throughout the duration of the study (Figs. 1 & 2).

In the mixed soil (S_2) the N treatments followed the trend $N_2 > N_1 > N_0$ with regards to all growth parameters considered up to 56 DAS, though the differences among the treatments were not significant. However, as from 70 DAS the differences among the treatments were significant ($P \leq 0.05$) and were in the order $N_1 > N_2 > N_0$.

The potting soils had highly significant effect ($P \leq 0.01$) on the performance of the plant with regard s to plant height, leaf area, leaf dry weight, and total plant dry weight (Table 3). The plants grown in mixed soil (S_2) were better than those grown in gutter sand (S_1). Also, irrespective of the potting soil at the N levels, the growth parameters of the plant increased significantly ($P \leq 0.05$) with progressive harvest time (Figs. 1 and 2), those S_1 plants were better than S_2 plants in their rate of increase. In all the parameters (soil, harvest period and N level), the main treatments were significantly different. The potting soil x harvest period interaction was highly significant ($P \leq 0.05$) for all the parameters (Table 3).

The growth and dry matter accumulation followed the sigmoidal curve (Figs. 1, 2a and b) ideally exhibited by all biological systems. Three growth phases that can be identified in the curves were the lag phase that fell within 0 – 56 DAS, the exponential phase that fell within 56 – 76 DAS and the declining phase (when increasing rate had decreased) that started from 70 DAS and continued till 98 DAS.

Table 3. Effects of soil type, nitrogen level and harvest period on growth and leaf weight ratio of *S. obtusifolia*.

Treatments	Plant height (cm)	Leaf area ($x10^2$ cm^2)	Leaf dry weight (g)	Total plant dry weight (g)	LWR
Experimental soils (A)					
S_1(gutter sand)	26.30	2.27	1.18	3.69	3.78
S_2 (gutter sand/forest topsoil)	36.94	4.23	2.78	7.04	4.37
LSD $_{0.05}$	1.54	0.23	0.24	0.59	0.19
Harvest period (B)					
28DAS	12.43	1.17	0.60	0.95	6.27
42DAS	21.35	2.23	0.89	2.00	4.48
56DAS	25.48	2.88	1.27	3.55	3.45
70DAS	35.07	3.79	2.45	6.89	3.33
84DAS	44.56	4.43	3.15	8.73	3.50
98DAS	50.85	4.99	3.53	10.08	3.41
LSD $_{0.05}$	2.68	0.56	0.41	1.02	0.32
Nitrogen levels (C)					
N_0 (Control)	29.24	2.77	1.59	4.42	3.97
N_1 (50kgN/ha)	32.49	3.48	2.19	5.88	4.13
N_2 (100kgN/ha)	33.15	3.49	2.16	5.80	4.12
LSD $_{0.05}$	1.89	0.39	0.29	0.72	ns
LSD $_{0.05}$					
A x B	3.78	0.79	0.58	1.45	ns
A x C	ns	0.56	0.41	Ns	ns
B x C	ns	ns	Ns	Ns	ns

DAS – Days after sowing
LWR- Leaf weight ratio
ns – not significant

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In the two soils, the leaf weight ratio (LWR) was highest at 28 DAS (S_1=0.624; S_2=0.623) but decreased steadily up till termination of the study at 98 DAS when the values were low (S_1=0.313; S_2 =0.367) (Fig. 2c). Dry matter allocation into the leaf was high up to 42 DAS with LWR values of 0.461 and 0.477 for S_1 and S_2 soils, respectively. Although the effect of nitrogen application was not significant, the harvest periods and the soil type significantly ($P \leq 0.05$) influenced LWR (Table 3). The soil x harvest period, soil x N and harvest period x N interactions on LWR were also not significant. In both the S_1 and S_2 plants, LWR did not follow any consistent trend among the application.

Table 4. Effects of soil types, nitrogen levels and harvest period on mean dry matter production and relative growth rate of *S. obtusifolia*.

	DMP	RGR
Experimental soils (A)		
S_1 (gutter sand)	1.16	3.18
S_2 (gutter sand/forest topsoil)	2.49	3.45
LSD $_{0.05}$	0.41	Ns
Harvest period (B)		
28-42DAS	1.06	5.37
42-56DAS	1.55	4.13
56-70DAS	3.34	4.60
70-84DAS	1.84	1.51
84-98DAS	1.35	0.94
LSD $_{0.05}$	0.65	0.77
Nitrogen levels (C)		
N_0 (Control)	1.32	2.91
N_1 (50kgN/ha)	2.09	3.48
N_2 (100kgN/ha)	2.08	3.54
LSD $_{0.05}$	0.51	Ns
LSD $_{0.05}$ (**Interactions**)		
A x B	ns	Ns
A x C	ns	Ns
B x C	ns	Ns

DAS – Days after sowing
DMP – Dry matter Production
RGR – Relative Growth Rate
ns – not significant

In the two soils, DMP increased progressively with plant age up to 70 DAS and decreased thereafter (Fig. 3). The S_2 soil gave significantly ($P \leq 0.05$) higher DMP than the S_1 soil (Table 4). Nitrogen application had a significant ($P \leq 0.05$) effect on the DMP. In S_1 the effect of N application on DMP apparently followed the trend $N_2>N_1>N_0$. All the factor interactions were not significant (Table 4).

In the two potting soils, RGR was almost constant up to 70 DAS and decreased sharply thereafter (Fig. 3a). Only harvest period had significant ($P < 0.001$) effect on RGR. The soil and N treatments, and all factor interactions had no significant effects. Although N application had no significant effect on RGR, the trend at the later growth stages was in the order $N_2 > N_1 > N_0$ for S_1 soil and $N_1 > N_2 > N_0$ for S_2 soil.

Discussion

Senna obtusifolia responded positively to increasing rate of N fertilizer applicataion in marginal soil (S_1). In the more fertile soil (S_2), addition of low rate of N fertilizer (N_1) benefited the plants more than the high rate (N_2). The N_0 plants grown in mixed soil (S_2) grew and accumulated dry matter as much as N_2 plants grown in S_1 soils. This suggests adequate supply of N in the fertile soil (S_2). Since N is highly mobile in the soil, most of it could have been leached out of the gutter sand. As expected, S_1 being loam sand with low organic carbon content had a high rate of N loss while S_2, silty loam with high organic carbon content had a relatively low rate of loss. Organic matter is known to make N available to plants gradually over a long period for absorption by the plant (Sanford 1981). Working on soils in the Nigerian derived and guinea savannas, Isichei, (1979) obtained a high correlation (r = 0.98 at 0 - 15 cm; r = 0.89 at 30 - 40 cm depth) between percent organic carbon and nitrogen. The higher nutrient status, especially N and P, in S_2 compared to S_1 may explain the observed significant differences in their effects on growth and dry matter production.

The leaf weight ratio (LWR) is a function of the strategic allocation of net primary production between leaf and other parts of the plants. The decreasing LWR with plant age may be due to translocation of photosynthates from leaves to other plant parts. The influence of leaf senescence resulting partly from self-shading is also strongly indicated. Leaf senescence is aggravated by the withdrawal of most nutrients to the flower primordia that form active sinks in the late growth stage of annuals. The consequence of this is the reduction of assimilate production leading to a decrease in both RGR and DMP. The increase in height and other plant growth parameters with age in this study agreed with previous reports of Rashmi *et al.,* (1995) on *Cassia tora* (*S. obtusifolia*) and other selected weeds. From their findings, RGR of *C. tora* increased up to age 3 months (90 days). However, in the current study RGR was high and more or less stable up to 70 DAS but decreased thereafter. Under greenhouse conditions, Erasmos *et al.,* (1997) reported that the relative growth of *S. obtusifolia* decreased quickly until 63 days after emergence (DAE) and thereafter maintained a low and constant rate until 161 DAE.

The DMP is essentially an expression of the fraction of the assimilate that goes into structural plant development (Kvet *et al.,* 1971). In the current study, DMP increased up to 70 DAS and decreased thereafter in the two soil types.

This trend may explain the exponential phase of plant growth exhibited up to 70 DAS and the subsequent declining phase. The observed growth phase may explain that allocation of assimilates favoured structural formation up to 70 DAS, but beyond it favoured respiration and other catabolic activities including the displacement of leaves for maximum reception of solar radiation for photosynthesis and floral initiation. The declining DMP may be due to a reduction in photosynthetic production as ageing leaves lost their assimilatory ability while the assimilatory power of the young leaves were still low. In very early studies, Briggs *et al.*, (1920) reported that the assimilatory power of the young leaves for some time after their appearance is negligibly small.

It is evident in the study that *S. obtusifolia* has rapid growth and biomass accumulation in both marginal and fertile soils. If the plant can be well managed to avoid seeding and hence infestation of soil seed bank it could be used in green manuring and fallow establishment. The rapidity of its establishment is implicated in its superior competitive ability with some crops and may also have invasive effect on natural ecosystem.

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