COMPETITIVE ABILITY OF SICKLEPOD (SENNA OBTUSIFOLIA L) IN COMBINATION WITH CHROMOLAENA ODORATA (L) K & R AND EUPHORBIA HETEROPHYLLA L

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ABSTRACT

The natural fallow through which the fertility of tropical soils is restored and the weed pressure is alleviated can no longer be sustained. However, improved bush fallow using fast-growing, deep-rooting and good biomass-accumulating shrubby legumes provides a good alternative. The suitability of Senna obtusifolia in improved fallow management was investigated by studying its competitive ability relative to Chromolaena odorata (siam weed) and Euphorbia heterophylla (poinsettia weed) in replacement series studies at four total densities (29, 58, 115 and 230 plants m⁻²) in pure stands and at three total densities (58, 115 and 230 plants m⁻²) in equiproportion mixture. Replacement series diagrams were drawn and relative competitive ability indices (Relative Yield, RY; Relative Yield Total, RYT; Relative Replacement Rate, RRR) were determined from the plant dry weight (PDW). In the replacement series diagrams of Senna/Chromolaena combination, the curves of the PDW/pot and those of the RY were convex for the two species. The RY values were 0.64±0.12 and 0.59±0.05 for S. obtusifolia and C. odorata respectively. The RYT and RRR, averaged over all densities, were 1.23±0.08 and 1.27±0.17 respectively. However, in the Senna/Euphorbia combination, the curves were convex for S. obtusifolia and concave for E. heterophylla. The RY values were 0.81±0.06 for S. obtusifolia and 0.23±0.05 for E. heterophylla respectively. The RYT and RRR values for the combination were 1.05±0.07 and 11.07±2.40 respectively. The results indicated that though S. obtusifolia and C. odorata attained equilibrium growth with RYT significantly deviated from unity (RYT>1) when grown in mixture, S. obtusifolia exerted greater replacement pressure than C. odorata. Conversely, in the Senna/Euphorbia combination, there was a competitive relationship (RYT>1) in which S. obtusifolia was the aggressor and E. heterophylla the subordinate species. The study showed that while S. obtusifolia exhibited obvious competitive superiority in mixture with E. heterophylla, the superiority was less obvious in mixture with C. odorata.

Key words: Competition, fallow management, helioplastic response, weed control

INTRODUCTION

Competition is an interference relationship between two or more organisms in proximity with common requirements, which are available in supplies that fall below their combined demands (Aldrich, 1984). Plants primarily compete for light, water and nutrients. Competition may be intraspecific when individuals with similar genotypes are involved and interspecific when it involves individuals of two or more species. Intraspecific competition results in linear relationship between the reciprocal of mean individuals (both below- and above-ground) in form of biomass accumulation, height and canopy growth, and high efficiency in water-use and uptake of nutrients (Holt, 1995). Some of these attributes are also sought after in a good fallow plant. Senna obtusifolia (L) Irwin and Barneby (Syn. Cassia obtusifolia L) is a low-growing plant. Though regarded as a weed of agriculture, the plant possesses many attributes that make it a good fallow plant. A cursory observation of the plant on the field reveals that it is fast-growing, deep-rooting and forms a close canopy cover, which are the attributes needed by a fallow plant to recycle nutrients from the 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 sicklepod in Southwestern Nigeria, Awodoyin and Ogunyemi (2003a) reported that in the early growing season the plant constituted 23% of the flora in a community, but accounted for about 81% of the flora in the late growing season. They further reported that the Shannon-Wiener in-
Senna replicated four times. The two studies ran concurrently and to encourage germination of seeds of pots were watered for one week for the soils to consolidate and to encourage germination of seeds of sicklepod at two sites with significantly contrasting soil fertility and pH values were not significantly different.

Competitive ability exhibited by a plant, apart from its genetic make up, is also a function of the neighbour plant. In this report the competitive ability of sicklepod relative to two noxious weeds, Chromolaena odorata (L) K. & R. and Euphorbia heterophylla L in two-species combination replacement series study is discussed.

MATERIALS AND METHODS

The two replacement series studies (Senna versus Chromolaena and Senna versus Euphorbia) were carried out separately in pots in the crop garden, Department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria. Ibadan (latitude 7°24‘N; longitude 3°54’E; altitude 234 m above sea level) is located in the rainforest-savanna transition zone of Southwestern Nigeria. 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). An eight-month wet season (March-October) and a four-month dry season (November-February) characterize the area. The rainfall pattern is bimodal with maxima in June and September and a dry spell in late July/August. The mean annual rainfall and number of rainy days over a five-year period (1994-1998) were 1180.6 mm and 114 days respectively (Awodoyin and Ogunyemi, 2005a).

The two studies were conducted in plastic pots filled with topsoil collected from the crop garden. Each pot (20 cm top diameter and 22 cm depth) was filled with 4.0 kg (dry weight) topsoil to 90% capacity. The soil is sandy clay loam in texture, acidic (pH = 5.7), and had low organic matter (3.21%) and low nitrogen (0.23%) contents. The pots were arranged on iron-net table outdoors in the crop garden. The pots were watered for one week for the soils to consolidate and to encourage germination of seeds of ‘nuisance weeds’ that were hand-removed. The seven treatments were randomly allocated to pots and replicated four times. The two studies ran concurrently for 14 weeks between 11 June and 20 September 1998.

Interactions were monitored at four total densities (1, 2, 4, 8 plants per pot) in pure stands, and at three total densities (2, 4, 8 plants per pot) in equiproportion (1:1) mixtures to have seven treatments. The study followed the ‘replacement series’ of de Wit (1960). The stocking rates 1, 2, 4 and 8 plants per pot respectively are equivalent to 29, 58, 115 and 230 plants/m² in natural habitat. The density of S. obtusifolia in natural habitat in the dry forest of Southwestern Nigeria is about 110 plants/m². C. odorata and E. heterophylla were selected because of their weed status and their high degrees of noxiousness in crop production (Olaoye and Egunjobi, 1974; Bridges et al., 1992).

Seeds of sicklepod used for the study were collected from the wild at dark brown pod stage. The seeds were acid-scarified in tetraoxosulphate (VI) acid (H₂SO₄) for 10 minutes to have uniform seed germination and seedling vigour. The seeds of C. odorata and E. heterophylla were collected from bush fallow in the University and used to establish nursery for the two plants.

In each experiment the positions to take the two plant species were made equidistant in the pots at the required total densities. The species were made to alternate with each other in mixed stands. The seedlings of C. odorata and E. heterophylla were transplanted into their positions in the pot at two-leaf stage. Two weeks after transplanting, acid-scarified seeds of sicklepod were sown into pots at required numbers.

The pots were adequately watered two times a week. Watering was withheld if there was rainfall within 72 h. Excess water from the irrigation or rainfall drained off from the perforated base of the pots.

Two weeks after introducing seeds of sicklepod, the pots were given a basal fertilizer dressing of N.P.K 20-10-10 at 25 kgN/ha. Each pot took 0.25 g of the fertilizer. This amount of fertilizer also supplied 12.50 kgP/ha. and 12.50 kgK/ha. The plants were sprayed weekly with lambdacyhalothrin using knapsack sprayer at the rate of 1 litre/ha (50 ml in 15 litres of water) to control Aphis craccifera (cowpea aphid) that infested C. odorata so as to exercise its full competitive ability.

At the end of the trials, plant height were measured with a meter rule. The contents of each pot, was emptied into a bucket of water to dislodge the soil and collect the whole plants. The plants were separated into individuals and measurements were taken on plant dry weight (PDW) after drying in the oven at 80°C for 48 h.

The stand yield of each species in mixture relative to its stand yield in monoculture was plotted in a replacement series graph for each experiment. The
competition between the two species was assessed in each experiment by calculating the following indices:

i. Relative Yield (RY)

\[
\text{RY}_a = \frac{M_a}{P_a} \\
\text{RY}_b = \frac{M_b}{P_b} 
\]

-de wit & De Bergh (1965)

where \( P_a \) & \( P_b \) = mean yield of species ‘a’ and ‘b’ in pure stand.
\( M_a \) & \( M_b \) = mean yield of species ‘a’ and ‘b’ in mixture.

ii. Relative Yield Total (RYT)

\[
\text{RYT}_{ab} = \text{RY}_a + \text{RY}_b 
\]

-for two species combination involving species a and b
Source: De wit & Van De Bergh (1965)

iii. Relative Replacement Rate (RRR)

\[
\text{RRR} = \frac{(M_a/X_a)}{(M_b/X_b)} 
\]

-Dekker et al., (1983)

where \( M_a \) & \( M_b \) = mean yield of species ‘a’ and ‘b’ in mixture.
\( X_a \) & \( X_b \) are proportion (% of species a and b respectively, which in this study was 50%.

ANOVA was used to compare the combining species with regards to the yield and the competition indices in each study. Mean comparisons were made by calculating the LSD at 5% level of probability.

Chi square test was employed to compare the observed and expected values of the various indices for each species in the two studies. The expected values were estimated based on the assumption that the combining species have equal competitive abilities and are therefore growing in mixture stands as they are in their respective pure stands. The observed RYT and RRR indices were compared to unity and the observed RY compared to 0.5, which are the expected values (Martin and Field, 1986).

RESULTS

Plant dry weight (PDW) and Plant height

At all test densities, the PDW per plant of \( S. \) obtusifolia in mixture with Euphorbia was significantly \((P<0.05)\) greater than the mixture stand with Chromolaena that was in turn greater than the monoculture stands (Figure 1). While the PDW per plant of \( C. \) odorata in mixture with Senna was significantly \((P<0.05)\) greater than its monoculture stand, the PDW per plant of \( E. \) heterophylla in mixture with Senna was significantly \((P<0.05)\) lower than its monoculture stands. As density increased the PDW in all the species and stands decreased. \( S. \) obtusifolia plants grew significantly \((P<0.05)\) taller when grown in mixture than in monoculture. At all test densities, the \( S. \) obtusifolia plants were taller when in mixture with Chromolaena than in mixture with Euphorbia, though the differences were not significant (Fig 1). The monoculture stands and mixture stands of \( C. \) odorata were not significantly different with regard to plant height. The monoculture stands of \( E. \) heterophylla significantly \((P<0.05)\) grew taller than the mixture stands. The mean PDW and mean height of the three plants, either in monoculture or mixture, were reduced by increasing density (Fig 1).

Figure 1. The effect of density on plant dry weight and height of \( Senna \) obtusifolia, Chromolaena odorata and \( Euphorbia \) heterophylla grown in monoculture \((SS; CC; EE)\) and mixture \((SC; SE; CS; ES)\) stands.[Values are means+S.E.]
Replacement Series

Plant Dry Weight (PDW)

The replacement series diagrams of the PDW per pot of the Senna/Chromolaena combination at the three combining densities showed that the observed yield of the two species were greater than or nearly similar to the expected yield (Fig 2). The curves for the two species were convex. The mixture yield per plant of S. obtusifolia and C. odorata were 4.73±1.12 g and 4.04±1.38 g respectively while their mean monoculture yields were 4.08±1.34 g and 3.25±0.82 g respectively (Table 1).

However, in the combination of Senna/ Euphorbia, the replacement series diagrams showed that the observed yields for S. obtusifolia were greater than the expected (convex curves) while those of E. heterophylla were lower than the expected (concave curves) at all total densities (Fig 2). The mixture yield per plant of S. obtusifolia and E. heterophylla were 6.61±0.37 g and 0.74±0.37 g respectively while their respective monoculture yields were 4.08±1.34 g and 1.39±0.47 g (Table 1). Comparison of the mixture yield per plant to the monoculture yield in the two combining species (SE:SS; ES:EE) revealed that neither in the S. obtusifolia nor in the E. heterophylla were the differences between their respective means significant. However, the differences between the means of the mixture yield per plant of the two species (SE:ES) were significant (P<0.05) at all total densities.

Table 1. Total plant dry weight (g) per plant of S. obtusifolia, C. odorata and E. heterophylla in 2-species combinations at various densities

| Density (plants.m⁻²) | Monoculture Components | Mixture Components |
|-----------------------|------------------------|--------------------|
|                       | SS CC EE SC CS SE ES   |
| 58                    | 6.50 4.80 2.30 6.92 6.68 11.11 1.46 |
| 115                   | 3.87 2.92 1.11 4.00 3.40 5.36 0.54 |
| 230                   | 1.88 2.02 0.76 3.27 2.03 3.37 0.22 |
| Stand mean            | 4.08 3.25 1.39 4.73 4.04 6.61 0.74 |
| S.E.                  | 1.34 0.82 0.47 1.12 1.38 0.37 0.37 |

SS - Senna monoculture stand
CC - Chromolaena monoculture stand
EE - Euphorbia monoculture stand
SC - Senna in mixture with Chromolaena
SE - Senna in mixture with Euphorbia
CS - Chromolaena in mixture with Senna
ES - Euphorbia in mixture with Senna

Relative Competitive Ability

Experiment 1 – Senna/Chromolaena mixture

The RY values for S. obtusifolia ranged from 0.52 in 115 plants.m⁻² to 0.87 in 230 plants.m⁻² with an average of 0.64±0.12. The RY values for C. odorata ranged from 0.51 in 230 plants.m⁻² to 0.69 in 58 plants.m⁻² with an average value of 0.59±0.05 (Table 2). The differences between the two species at all total densities were not significant. The observed RY deviated from the expected 0.5 in the two species (X² for Senna=0.259; X² for Chromolaena=0.072). With the observed RY consistently greater than the expected in the two species, their replacement series curves were convex at all test densities, though the convexity was less obvious in C. odorata (Figure 3A).

The RYT values ranged from 1.10 to 1.38 with a mean value of 1.23±0.08. The observed mean RYT deviated significantly from the expected unity (X²≈0.073). The RRR exerted by S. obtusifolia on C. odorata in the two-species mixture ranged from 1.04 to 1.61 with a mean value of 1.27±0.17, which did not deviate from the expected unity (X²≈0.053).

Experiment 2: Senna/Euphorbia mixture

In this combination RY values for S. obtusifolia ranged from 0.69 in 115 plants.m⁻² to 0.90 in 230 plants.m⁻² with an average of 0.81±0.06, which deviated significantly from the expected 0.5 (X²≈0.072). The RY values for E. heterophylla ranged from 0.14 in 230 plants.m⁻² to 0.32 in 58 plants.m⁻² with an average of 0.23±0.05, which also deviated from the expected (X²≈0.106). The differences between the

Table 2. The relative competitive ability indices of S. obtusifolia, C. odorata and E. heterophylla in 2-species combinations at various densities

| Density (plants.m⁻²) | (S/C) | (S/E) | (S/C) | (S/E) |
|-----------------------|-------|-------|-------|-------|
| 58                    | 0.53  | 0.69  | 0.85  | 0.32  |
| 115                   | 0.52  | 0.58  | 0.69  | 0.24  |
| 230                   | 0.87  | 0.51  | 0.90  | 0.14  |
| Stand mean            | 0.64  | 0.59  | 0.81  | 0.23  |
| S.E.                  | 0.12  | 0.05  | 0.06  | 0.05  |

(S/C) - Senna/Chromolaena 2-species combination
(S/E) - Senna/Euphorbia 2-species combination
S.E. – Standard Error

S - Senna component in mixture stand
C - Chromolaena component in mixture stand
E - Euphorbia component in mixture stand
two species at all total densities were significant (P<0.05).

The replacement series diagrams of the plant dry weight per plant for the two species revealed that in mixture stands while *S. obtusifolia* yielded the expected and had convex curves, *E. heterophylla* under-yielded the expected and had concave curves at all total densities (Figure 3B). The RYT values ranged from 0.93 to 1.17 with a mean value of 1.05±0.07, which did not deviate from the expected unity ($X^2=0.202$). The RRR values ranged from 7.61 to 15.67 with a mean of 11.07±2.40, which deviated from the expected unity ($X^2=91.58$).

**DISCUSSION**

The greater dry matter accumulation by *S. obtusifolia* and *C. odorata* in mixture than their respective monoculture indicates that intraspecific competition within population of each species was more intense than interspecific competition between them. However, in *E. heterophylla* the intra-specific competition was less intense than the inter-specific competition. The greater yield of *S. obtusifolia* when in association with *E. heterophylla* than its yield when in association with *C. odorata* might indicate that *S. obtusifolia* exerted greater suppressive effect when in association with *E. heterophylla* than when in association with *C. odorata*.

The greatest dry matter yield recorded for *S. obtusifolia* in the mixture stands of *S. obtusifolia/E. heterophylla* may be explained by the difference in their rooting system. *E. heterophylla* has weak root system, so *S. obtusifolia* took the advantage of the least resistance below ground to produce profuse root mass. In *S. obtusifolia* the strong tap root system grew extensively to mop up the nutrients at the lower soil horizon and the profuse lateral root system ramified the upper soil horizon to absorb the nutrients.

The observed relative yield (RY) for *S. obtusifolia* and *C. odorata* that were significantly greater than the expected 0.5 value indicates that the mixture stands over-yielded the average yield of monoculture stands. This and the RYT that is greater than one for the species combination suggest that the relationship between *S. obtusifolia* and *C. odorata* is “mutually stimulatory”, suggesting that they have functional niche differentiation or synergistic relationship (Bebawi and Naylor, 1981). It is also probable that one species is exploiting resources of the environment other than the pool of resources being
shared as a result of different rooting depth. Isichei and Awodoyin (1990) suggested that the relationship between *Tephrosia bracteolata* and *Andropogon tectorum* in mixture was mutually stimulatory as a result of different rooting depth and abilities of the two species to fix atmospheric nitrogen in their root nodules and rhizosphere. The results further indicated that in a mixture involving *S. obtusifolia* and *C. odorata*, *S. obtusifolia* yield component per pot accounted for 116% of its monoculture yield at a particular density, while *C. odorata* component accounted for 109% of its monoculture stand.

In *S. obtusifolia/E. heterophylla* combination, the RYT values that approximated unity indicates that there was intense competition between their populations. The RY curves for *S. obtusifolia* at all test densities were convex and those of *E. heterophylla* were concave. These, according to Harper (1977), suggest a competitive relationship between the two species wherein *S. obtusifolia* (assessor) preempted most of the environment and outcompeted *E. heterophylla* (subordinate). The RY value for *S. obtusifolia* indicates that it produced 131% of its corresponding monoculture yield while *E. heterophylla* produced only 73% of its corresponding monoculture yield. The RRR values for *S. obtusifolia* versus *C. odorata* and *S. obtusifolia* versus *E. heterophylla* that were greater than unity indicate that over time, the population of *S. obtusifolia* will become dominant as the two weed species are excluded from the assemblage. However, while the exclusion of *C. odorata* will be slow and gradual, that of *E. heterophylla* will be rapid. Awodoyin and Ogunyemi (2005b) reported that when sicklepod was grown at total densities ranging between 66 plants m⁻² and 200 plants m⁻², it effectively controlled other weeds, though weed biomass on 200 plants m⁻² plots was significantly lower than other plots.

**CONCLUSION**

It can be inferred that the magnitude of competitive ability of a species is determined by the combining species and the total density. While *S. obtusifolia* exhibited quite obvious competitive superiority in mixture with *E. heterophylla*, it exhibited less obvious competitive superiority when grown in mixture with *C. odorata*. *S. obtusifolia* is a potential sown fallow plant to suppress the growth of noxious weeds.

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