Tropical Agricultural Research & Extension 11, 2008

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

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Accepted: 5th September 2008

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 plant yield and density (Harper, 1977). However, in interspecific competition the mean yield of each species is a function of the overall density and the frequency of each component species (Harper, 1977). The study of interspecific competition aids understanding of the ecological combining ability of the interacting species in terms of overall productivity of the system and ordering of the relative competitive abilities of the combining species (Berendse, 1982).

Plants exhibit competitive advantage in the high number of seedlings recruitment, rapid growth of 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-

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dex (H`) for the community averaged 2.08 and 0.96 in the early and the late growing seasons respectively. The result implies that sicklepod dominates the flora of the ecosystem studied in the late season (Whitaker, 1975). Sicklepod has been 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. Erasmo *et al.* (1997) reported that it has rapid germination at a wide range of soil temperature (24-26^{o}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 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^{o}24`N; longitude 3$^{o}$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 peaks 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 1180.6mm 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 'nuissance 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/m^2 in natural habitat. The density of *S. obtusifolia* in natural habitat in the dry forest of Southwestern Nigeria is about 110 plants/m^2. *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 (H_2SO_4) 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 lambdacyalothrin using knapsack sprayer at the rate of 1 litre/ha (50 ml in 15 litres of water) to control *Aphis craccifora* (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^{o}C for 48 h.

The stand yield of each specie 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)

RYa = Ma/Pa
RYb = Mb/Pb - de wit & De Bergh (1965)

where Pa & Pb = mean yield of species `a' and`b' in pure stand.
Ma & Mb = mean yield of species `a' and `b' in mixture.

ii. Relative Yield Total (RYT)

RYTab = RYa + RYb for two species combination involving species a and b
Source: De wit & Van De Bergh (1965)

iii. Relative Replacement Rate (RRR)

$$RRR = \frac{(Ma/Xa)}{(Mb/Xb)}$$

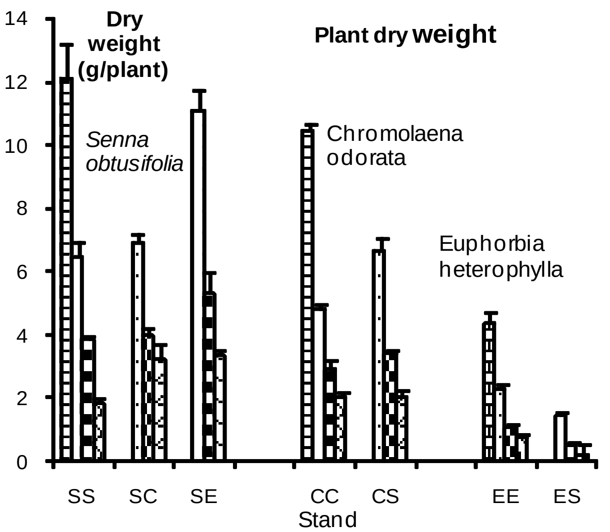
Source: Dekker *et al.*, (1983)
where Ma & Mb = mean yield of species `a' and `b' in mixture.
Xa & Xb are proportion (%) of species a and b respectively, which in this study was 50%.

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).



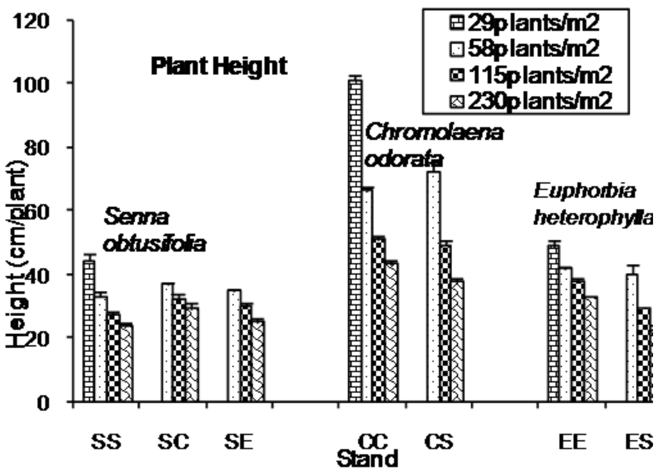


Figure 1. The effect of density on plant dry weight and height of *Senna obtusifolia, Chromolaena odorata and Euphorbia heterophylla grown in monoculture (SS; CC; EE)* and mixture (SC; SE; CS; ES) stands.[Values are means+S.E.]

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	Monoculture Components			Mixture Components			
(plants m^{-2})	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
S.E. – Stand Error
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 (X^2 for *Senna*=0.259; X^2 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 (X^2=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 (X^2=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 (X^2=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 (X^2=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	Relative Yield (RY) (S/C)		Relative Yield (RY) (S/E)		Relative Yield Total (RYT)		Relative Replacement Rate (RRR)	
(plants.m^{-2})	S	C	S	E	(S/C)	(S/E)	(S/C)	(S/E)
58	0.53	0.69	0.85	0.32	1.22	1.17	1.04	7.61
115	0.52	0.58	0.69	0.24	1.10	0.93	1.17	9.92
230	0.87	0.51	0.90	0.14	1.38	1.04	1.61	15.67
Stand mean	0.64	0.59	0.81	0.23	1.23	1.05	1.27	11.07
S.E.	0.12	0.05	0.06	0.05	0.08	0.07	0.17	2.40

(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

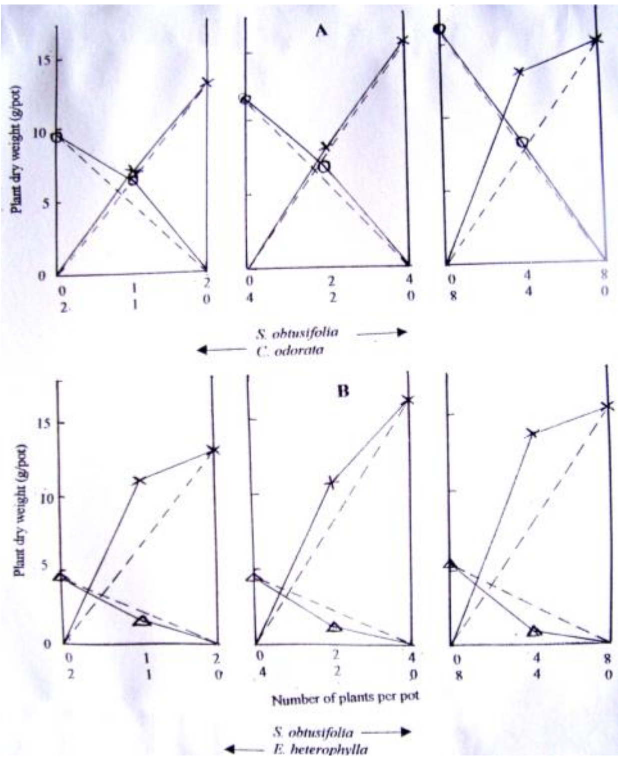


Figure 2. The replacement series diagrams of the plant dry weight per pot in 2-species combination involving A.) *S. obtusifolia* (X) and *C. odorata* (O); and B.) *S. obtusifolia* (X) and *E. heterophylla* (Δ) at 2, 4 and 8 plants per pot (equivalent to 58, 115 and 230 plants per m2). Broken lines represent expected (theoretical) values.

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* over-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

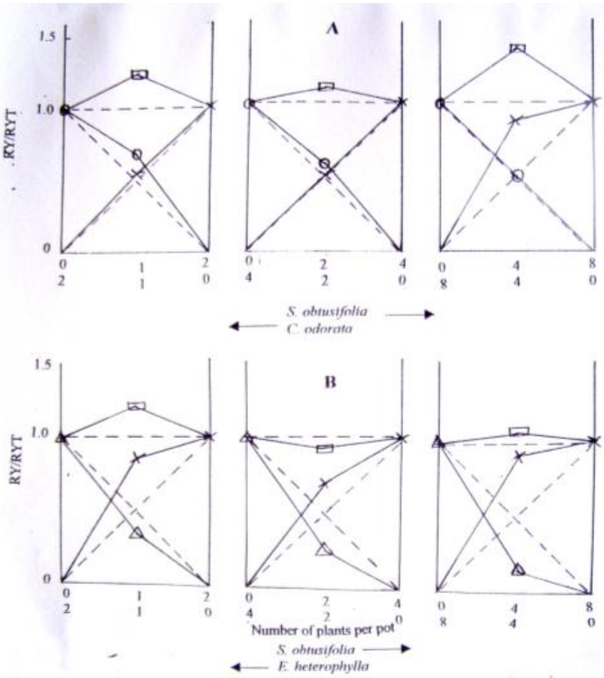


Figure 3. The replacement series diagrams of relative yield (RY) and relative yield total (RYT; -2 species combi nation involving A.) *S. obtusifolia* (X) and *C. odorata* (O); and B.) *S. obtusifolia* (X) and *E. heterophylla* (Δ) at 2, 4 and 8 plants per pot (equivalent to 58, 115 and 230 pla nts per m2). Broken lines represent expected (theoretical) values

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* (aggressor) 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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