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COMPETITION OF SOYBEAN WITH BLACKJACK (*BIDENS PILOSA* L.) AND PIGWEED (*AMARANTHUS HYBRIDUS* L.)

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ABSTRACT

Field studies were conducted to evaluate competitiveness between blackjack or pigweed and soybean using replacement series. Plant height of the three species was not affected by interspecific competition. Branching was reduced in soybean at 75 days after plant emergence (DPE), but increased in the weed species. Soybean, blackjack and pigweed shoot dry weight was reduced in most mixtures. The weed species had higher relative growth rate (RGR) and leaf area index (LAI) than soybean. The highest LAI occurred in monoculture pigweed. Competitive ratio (CR) values showed that pigweed was the most competitive of the three species. Soybean pod number per plant, 1000 seed weight and grain yield per plant were significantly less in mixtures with the two weed species. Pigweed caused more reduction in soybean yield components than blackjack. The number of blackjack seeds per head, seed heads per branch and seeds per plant were significantly reduced in mixtures while seed production by pigweed in mixtures increased by 30 to 253%. It is concluded that both weed species reduce soybean vegetative growth except for height and components of yield.

Key Words: **Interspecific competition, intraspecific competition, mixtures, replacement series, yield components**

RÉSUMÉ

Des études en champs ont été ménées pour évaluer la compétitivité entre le *Biden Pilosa* ou l'*Amaranthus hydridus* L. et le soja en utilisant des séries de substitution. La hauteur des plantes des trois espèces n'était pas affectée par la compétition entre les espèces. La ramification était réduite pour le soja à 75 jours après l'apparition de la plante (DPE), mais augmentaient pour les espèces de mauvaises herbes. Le poid sec des pousses de soja du *Biden pilosa* et de *l'Amaranthus hybridus* était réduit dans la plus part des mélanges. Les espéces de mauvaises herbes avaient un taux de croissance relative (RGR) et un index de surface foliaire (LAI) plus élevés que le soja. L'ISF le plus élevé a eu lieu dans la monoculture de *l'Amaranthus Hybridus*. Les valeurs proportionnelles de compétition (CR ont montrées que l'*Amaranthus hybridus* était la plus compétitive des trois espéces. Le nombre de gousses de soja par plante, le pois de 1000 graines et le rendement en graines par plante étaient significativement moindres dans les mélanges avec les deux espèces de mauvaises herbes. L'*Amaranthus hybridus* a causé plus de réduction dans les composants du rendement du soja que le *Biden pilosa*. Le nombre de graines de *Biden pilosa* par tête et les têtes de graines par branches et les graines par plantes étaient significativement réduit dans les mélanges tandis que la production de graines par *l'Amaranthus hybridus* dans les mélanges a augmenté de 30 à 253 %. Il a donc été conclu que

les deux espèces de mauvaises herbes réduise et la croissance végétative du soja sauf en ce qui concerne la hauteur et les composants du rendement.

***Mots Clés*: Compétition inter-espéces, compétition intra-espèces, mélanges, séries de substitution, composants du rendement**

INTRODUCTION

Pigweed (*Amaranthus hybridus* L.) and blackjack (*Bidens pilosa* L.) are important broadleaf weeds in soybean fields in Zimbabwe (Chivinge and Schweppenhauser, 1994) and elsewhere in tropical and subtropical regions (Hammerton, 1976; Hinson *et al.*, 1982). Blackjack and soybean canopies are of similar height while the pigweed canopy is taller than that of soybean (Chivinge, 1991; Chivinge and Schweppenhauser, 1994). Pigweed grows rapidly (Thomas and Schwerzel, 1968) and has a higher water use efficiency than soybean (Mortensen and Coble, 1989). Competition with weeds result in reduced soybean yield (Vitta *et al.*, 1993).

Interference studies between soybean and velvetleaf (*Abutilon theophrasti*), jimson weed (*Datura stramonium*) and cocklebur (*Xanthium strumarium* L.) have been conducted in temperate countries (Regnier and Stoller, 1989; Akey *et al.*, 1990, 1991) but not much work has been carried out in tropical environments. Worldwide, competition from weeds reduces soybean dry matter (Dekker and Meggitt, 1983a, 1983b; Legere and Schreiber, 1989), yield components (number of pods per plant, number of seeds per plant, number of seed per pod) and finally grain yield (Dominguez and Hume, 1978; Regnier and Stoller, 1989). An effective weed management programme depends not only on knowledge of the population dynamics of the weed but also of crop-weed relationships (Ghersa *et al.*, 1990; Vitta and Leguizamon, 1991).

The objective of the present study was therefore to determine the relative competitiveness of blackjack or pigweed and soybean under tropical conditions.

MATERIALS AND METHODS

The experiment was conducted at the Agricultural Research Trust Farm in Zimbabwe (17° 8' S, 31° 15' E) in 1989/90 and repeated in the 1990/91 rainy season. Soils at the experimental site are clay loams with a pH of 5.6. Soybean (cultivar 'Roan'), blackjack and pigweed were hand-planted in rows 45 cm apart. Plots were irrigated with 25 mm of water soon after planting followed by a similar amount 3 days later to ensure adequate emergence. Fertilizer (Compound D - 8% N; 14% P_2O_5; 7% K_2O; 6.5% S), was applied at 24 kg Narate giving 42 kg P_2O_5, 21 kg K_2O, 20 kg S and 1.2 kg B ha^{-1}. Treatments were of replacement series (de Wit, 1960) for soybean/blackjack and soybean/pigweed species in the proportion of 100/0, 75/25, 50/50, 25/75 and 0/100%. The experiment was arranged as a randomized complete block design with 9 treatments replicated four times.

Plots measured 5.4 x 7 m and contained 12 rows of the plant mixtures. The four edge rows and a 0.5 m section at the end of each plot were excluded from sampling. Seedlings were thinned to one per station, 7.5 cm apart within the row, 14 days after plant emergence (DPE), to a final density of 300, 000 plants ha^{-1}. Weeds which emerged later were hand-pulled when about 14 days old.

Data on plant height, number of branches per plant, leaf area and dry weight for the three plant species were taken from the two outer rows on either side of the plot. Pod height, number of pods per plant, number of seeds per pod and grain yield per plant were taken from the four centre rows at harvest.

Plant height, number of branches per plant and shoot dry weight for the two weed species and soybean were taken at 45, 60, and 75 DPE. Plant height was measured non-destructively from the soil surface to the top of the apical terminal bud on 20 randomly selected plants using the random pair technique (Gomez and Gomez, 1976). Leaf area index (LAI) was calculated according to the method described by Bannister (1976). Shoot dry weight was determined from 10 randomly selected plants of each species per plot cut at the soil surface. Samples were oven-dried at 60°C for 48 or 72 hrs, depending on the bulk of the tissue, to determine their dry weight. Pod height (height above ground of the first pod), number of pods per plant, number of seeds per pod, 1000-seed weight and grain yield per plant were determined from 10 randomly selected soybean plants at harvest. Moisture content of soybean was determined using a moisture metre and corrected to 11% moisture content.

The number of blackjack seed heads per plant, seed heads per branch, and seed per head were determined from 10 randomly selected plants from the four centre rows per plot at seed shed. Total seed number per plant was calculated by multiplying the number of seeds per head by the number of seed heads per plant. For pigweed, the weight of seeds per plant was determined by randomly picking 20 seed heads in the centre four rows at seed shed. Seed heads were sun-dried on a plastic sheet for 20 days, threshed in a plastic bag, winnowed and the weight of seed per plant determined. Data on shoot dry weight were combined over seasons to determine relative growth rate (RGR) calculated according to the method described by Hunt (1982).

Data from the two seasons were combined after Bartlett's tests (Sokal and Rohlf, 1969) showed homogeneity of variances and were analysed using a two-way ANOVA. Means were compared using the least significant difference (LSD) test ($P<0.05$). Competitive ratio (CR) as described by Minjas (1982), the relative mixture response (R_x) method of Jolliffe *et al.* (1984) and relative yield (R_a) of yield components were presented graphically using the method of Roush *et al.* (1989) to determine relative competitiveness of each species.

Relative mixture response (R_x) was calculated using the equation:

$R_x = (Y_m - Y_x)/ Y_m$, where,

Y_m = yield in monoculture;
Y_x = yield in mixtures.

While competitive Ratio (CR) was obtained from the equation $CR = r_a/d_a * RYT$, where
r_a = relative yield of species (yield in mixtures/yield in monoculture)
b_a = relative yield of species b
d_a = density of species a
RYT = relative yield total ($r_a + r_b$)
a and b are different species in mixtures

A higher R_x shows greater competitiveness. R_a compares the actual performance of each species in the mixtures at each proportion to the expected monoculture performance at that proportion.

RESULTS

Plant height in all species was not affected by interspecific competition (Table 1). At 45 DPE the weed species were taller (57-68 cm) than soybean, with blackjack being taller than pigweed by 11 cm. However, after 70 days pigweed was the tallest species, and at 75 days it was 148 and 175 cm taller than blackjack and soybean, respectively. Soybean (88 cm) and blackjack (115 cm) achieved maximum height by 75 DPE while pigweed continued to elongate up to 75 days.

Numbers of soybean branches were comparable at 45 and 60 DPE in monoculture and in mixtures (Table 2). However, it was reduced by 24.7-37.6% in mixtures at 75 DPE. Blackjack only had more branches in the 50S/50B mixture than in monoculture at 75 DPE. Branching of pigweed in the 25S/75P mixture was 12.5% more than in monoculture at 60 DPE. The 25S/75P mixture had significantly more branches at 75 DPE compared to the 50S/50P and 75S/25P mixtures.

Weed effects on soybean shoot dry weight were inconsistent (Table 3). Soybean shoot dry weight was lowest in mixtures with 25%B at 60 DPE. At 75 DPE, soybean shoot dry weight was 14.8-17.3% less in mixtures with pigweed compared to those in mixtures with blackjack. Shoot dry weight in blackjack was more in mixtures with 50 and 75%S at 60 DPE but less in all mixtures at 75 DPE. Pigweed shoot dry weight was 45.8 to 63.9% more in mixtures at 45 DPE, was the variable affected at 60 DPE; and less in mixtures at 75 DPE.

Monoculture pigweed had the highest RGR but it was similar to that of blackjack in mixtures (Fig.1). Soybean had lower RGR in monoculture and in mixtures with 25 and 75%B (Fig.1). Pigweed had the highest LAI in monoculture and mixtures with 25 and 75%S (Fig.2). Lower LAI in soybean occurred in mixtures with pigweed

TABLE 1. Plant height (cm) of soybean (S), blackjack (B) and pigweed (P) at succesive harvests at 45, 60 and 75 days after plant emergence (DPE)

Species proportion (%)	45 DPE					60 DPE					75 DPE				
S/B/P	S	S/B*	S/P**	B	P	S	S/B	S/P	B	P	S	S/B	S/P	B	P
100S	45	-	-	-	58	52	-	-	-	-	88	-	-	-	-
25/75 -	45	46	68	66	55	56	57	86	72	101	86	89	96	91	109
50/50 -	41	45	71	53	59	58	59	87	66	99	89	89	95	102	113
75/25	40	43	69	59	56	59	58	88	62	117	84	82	95	89	130
100B/P	-	-	-	56	58	-	-	-	62	108	-	-	-	90	122
Average	45	42	45	68	57	52	58	87	65	106	86	88	87	95	119

*, ** = Height of soybean grown in mixtures with blackjack and pigweed, respectively.

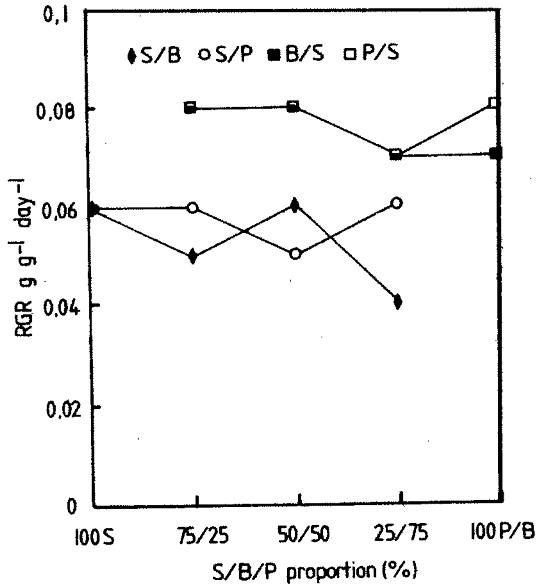

Figure 1. Relative growth rate (RGR) of soybean (S), blackjack (B) and pigweed (P) grown in mixtures 45-60 days after emergence.

TABLE 2. The number of branches in soybean (S), blackjack (B) and pigweed (P) grown in mixtures at successive harvests (DPE)

Crop/weed proportions (%)	No. of branches plant^{-1}		
	45 DPE	60 DPE	75 DPE
Soybean			
100S	4.4	5.7	8.5
755/25B	4.5	6.0	6.3
50S/50B	4.6	5.4	6.4
25S/75B	4.7	5.6	5.7
75S/25B	3.7	5.2	5.4
50S/50B	4.0	5.2	5.6
25S/75B	3.6	5.2	5.3
LSD (0.05)	NS	NS	1.8
Blackjack			
75S/25B	12.3	14.1	19.4
50S/50B	12.5	14.2	20.5
25S/75B	11.0	12.9	17.1
100B	12.8	14.0	18.7
LSD (0.05)	NS	NS	1.8
Pigweed			
75S/25P	4.4	23.0	23.0
50S/50P	4.5	22.7	23.1
25S/75P	4.6	27.9	28.4
100P	4.7	24.8	25.5
LSD (0.05)	NS	2.4	3.2

DPE = days after plant emergence
NS = Not significant

compared to those of blackjack, while blackjack generally had the lowest LAI (Fig. 2).

Soybean was more competitive in mixtures with blackjack at 45 and 75 DPE but lower values were obtained in mixtures with pigweed at 60 DPE (Table 4). Pigweed generally had higher CR values than blackjack at 45 and 75 DPE, but the reverse obtained at 60 DPE.

TABLE 3. Shoot dry weight of soybean (S), blackjack (B) and pigweed (P) at successive harvests (DPE)

Crop/weed proportion (%)	Weight (g plant⁻¹)		
	45 DPE	60 DPE	75 DPE
Soybean			
100S	9.18	19.88	28.67
75S/25B	9.93	19.88	32.39
50S/50B	9.28	9.90	34.60
25S/75B	8.72	17.53	26.97
75S/25P	7.43	18.40	24.44
50S/50P	8.75	19.89	24.40
25S/75P	7.53	20.56	23.69
LSD (0.05)	NS	2.96	6.05
Blackjack			
75S/25B	7.70	29.79	44.09
50S/50B	8.16	25.70	50.46
25S/75B	6.89	18.49	66.70
100B	7.24	21.32	70.40
LSD (0.05)	NS	3.76	1.61
Pigweed			
75S/25P	12.38	45.91	131.26
50S/50P	12.04	35.30	162.58
25S/75P	13.54	39.40	158.59
100P	8.26	39.92	180.01
LSD (0.05)	1.83	5.71	7.74

DPE = days after plant emergence.
NS = Not significant

Soybean pod height and number of seeds per pod were not affected by competition from pigweed (P) or blackjack (B) (Table 5). Competition from pigweed significantly reduced the number of soybean pod number per plant in mixtures by 38.8 to 40.7%, but the presence of blackjack did not affect pod number (Table 5). Relative pod number for soybean in mixtures with 25%P performed below monoculture expectation, and its value was much lower than that with blackjack, but those in mixtures with blackjack were above (Fig.3).

Competition from pigweed and blackjack did not affect soybean 1000-seed weight though plants

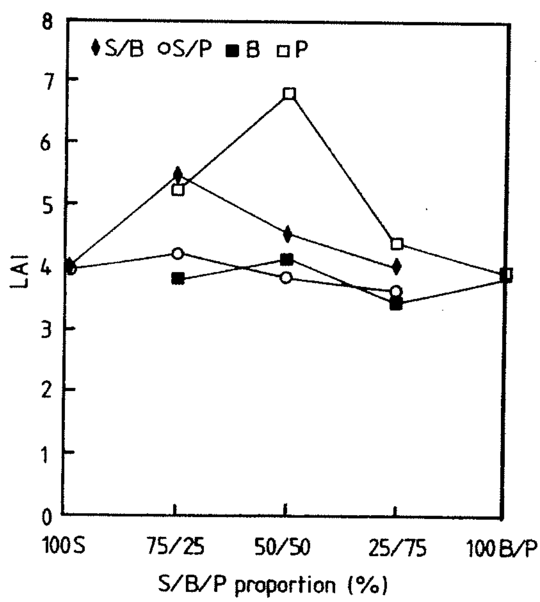

Figure 2. Leaf area index (LAI) of soybean (S), blackjack (B) and pigweed (P) at 60 days after plant emergence.

TABLE 4. Shoot dry weight competitive ratio (CR) of soybean (S), blackjack (B) and pigweed (P) grown in varying proportions and harvested 45, 60, 75 days after emergence (DPE)

Species proportion (%)	45 DPE			60 DPE			75 DPE		
	S	B	P	S	B	P	S	B	P
75S/25B	2.18	2.10	-	1.61	3.48	-	3.16	0.98	-
50S/50B	1.91	2.39	-	1.83	2.67	-	2.24	1.15	-
25S/75B	1.90	1.9	-	1.77	1.73	-	2.02	1.86	-
75S/25P	1.25	-	4.28	1.60	-	3.04	1.84	-	1.36
50S/50P	2.01	-	3.31	2.01	-	1.97	1.65	-	1.85
25S/75B	1.23	-	4.92	2.09	-	1.97	1.61	-	1.81

in mixtures with pigweed had less weight compared to those in monoculture (Table 5). Relative 1000-seed weight was above monoculture expectation and values were close to unity (Fig. 4). Grain yield per plant for soybean (Table 5) significantly declined by 41.5% in mixtures with 75%B and by 35.9 - 64.4% in mixtures with 50 and 75%P. Relative grain yield per plant showed that the performance of soybean in mixtures was above monoculture expectation though plants in mixtures with pigweed performed better at lower soybean densities (Fig. 5).

The number of blackjack seeds per head and seed heads per branch were not affected by competition from soybean, but the number of seed heads per plant and seeds per plant were significantly reduced by 21.6 to 25% and 18.3 to 20.7%, respectively (Table 6). Relative seed

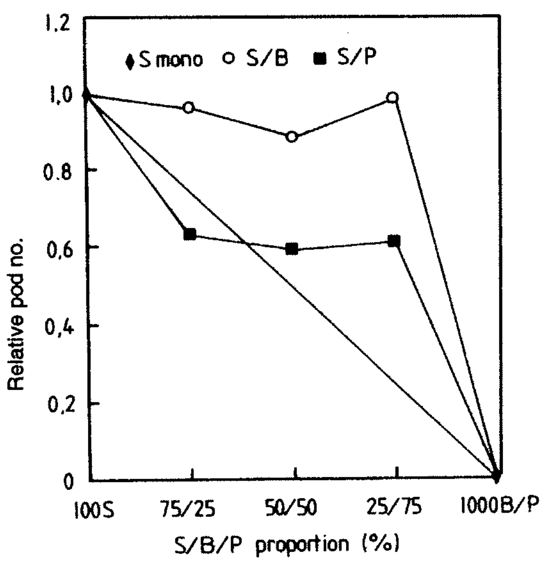

Figure 3. Relative pod number plant⁻¹ of soybean (S) grown in mixtures with blackjack (B) and pigweed (P)

TABLE 5. Yield performance of soybean (S) grown with blackjack (B) and pigweed (P) in various proportions.

Crop/weed proportion (%)	Pod height (cm)	Seeds pod⁻¹	Pods plant⁻¹	Weight of 1000 seeds	Grain yield plant⁻¹ (g)
100S	14.0	2.2	54	239.90	28.80
75S/25B	14.9	2.3	52	238.20	25.62
50S/50B	14.2	2.1	48	236.30	20.91
25S/75B	13.9	2.3	53	257.10	16.25
75S/25P	15.6	2.1	34	198.60	22.06
50S/50P	14.9	2.6	32	216.70	17.81
25S/75P	14.8	2.3	33	196.00	14.91
LSD (0.05)	NS	NS	20	NS	8.30

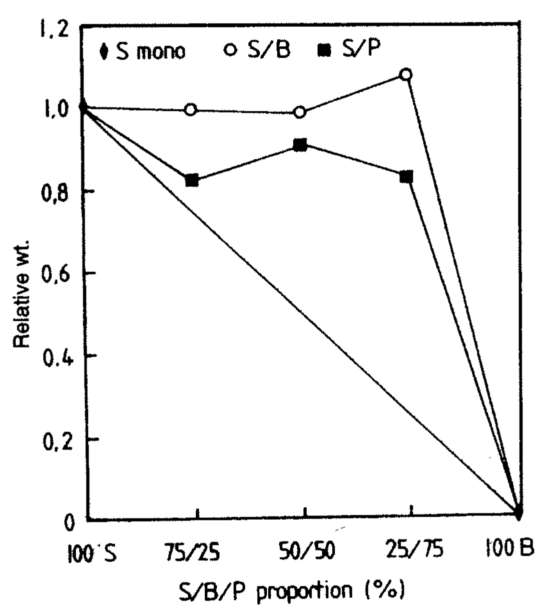

Figure 4. Relative weight of seda of soybean (S) grown in mixtures with blackjack (B) and pigweed

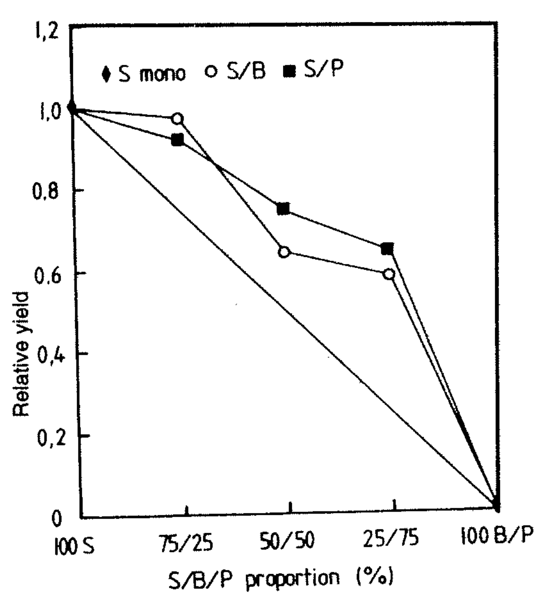

Figure 5. Relative grain yield plant⁻¹ of soybean (S) grown in mixtures with blackjack (B) and pigweed (P)

number per head was fairly close to unity in mixtures and well above monoculture expectations (Fig. 6). Seed yield per plant in pigweed (Table 6) was significantly higher by 140.9 to 252.9% in mixtures, while relative seed yield showed that values were above unity and sharply increased as the density of soybean increased (Fig. 7).

Relative mixture response of soybean, using pod number per plant, was consistently higher in mixtures with pigweed compared with that in

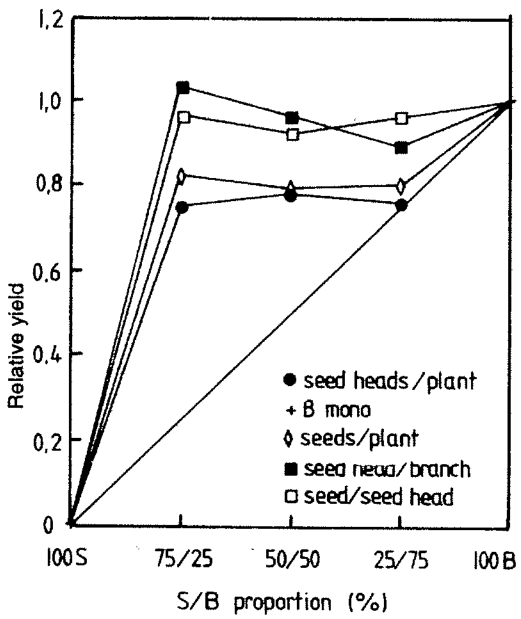

Figure 6. Relative yield components of blackjack (B) grown in mixtures with soybeans

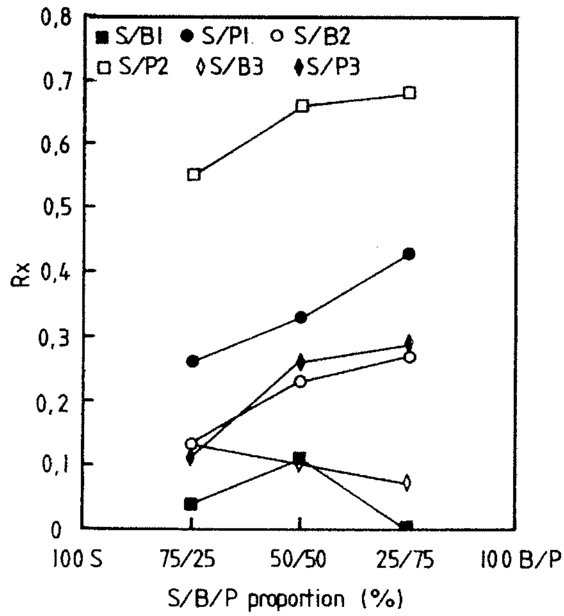

Figure 8. The relative mixture response(Rx) of soybean(S) grown with pigweed (P), blackjack (B) (1,2,3=pod number, pod weight, seed weight, respectively

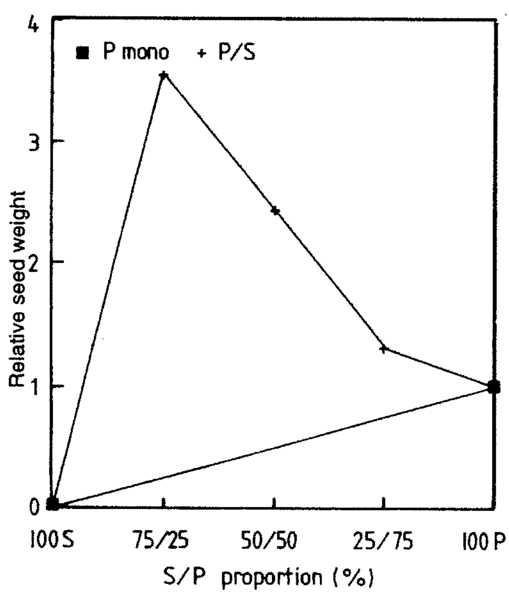

Figure 7. Relative seed weight of pigweed (P) grown in mixtures with soybean (S)

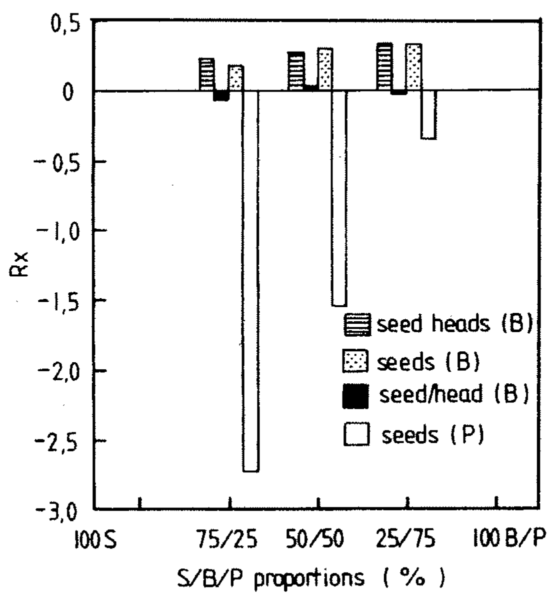

Figure 9. The relative mixture response (Rx) of blackjack (B) and pigweed

blackjack (Fig. 8). Higher R_x occurred with increase in the density of pigweed. In mixtures with blackjack, soybean R_x was less with increase in the weed density. Soybean R_x, using pod weight, was higher in mixtures with pigweed than that with blackjack and was also higher as the density of the weed species increased (Fig. 8). Relative mixture response, using seed weight, was low with increase in blackjack density but the reverse occurred in mixtures with pigweed (Fig. 9).

TABLE 6. Yield components and seed yield of blackjack (B) and pigweed (P) grown with soybean (S)

Crop/weed proportions %)	Seeds head^{-1}	Seed heads branch^{-1}	Seed heads plant^{-1}	Seeds plant^{-1}	Seed weight plant(g)
75S/25B/P	47	16.2	153	7472	8.11
50S/50B/P	45	15.1	160	7250	5.53
25S/25B/P	47	14.0	155	7275	2.98
100B/P	49	5.7	204	9144	2.30
LSD (0.05)	NS	NS	8	927	2.00

DISCUSSION

The high competitive ratio for pigweed showed that it was the most competitive among the three species. High competitiveness and high RGR as shown by pigweed in this study is an indicator of competition superiority over soybean as reported by Roush and Radosevich (1985). Pigweed accounted for the reduced branching in soybean.

Soybean reach maximum vegetative production at about 60 DPE hence it was more competitive at that stage. This also explains why it had highest CR values at that stage. Blackjack was also more competitive at about 60 DPE because it reaches maximum vegetative growth around that time after which most of its resources are chanelled to reproductive growth hence less competition later.

Pigweed being up to 2 m tall with a deep root system might have exploited consumable resources of light, water and nutrients to the disadvantage of soybean. Shading from pigweed may have reduced light quality and consequently reduced flowering and promoted pod abortion in soybean, as reported by Smith (1982) and Heindl and Brun (1983), resulting in reduced number of pods per plant and grain yield. Similar results have been reported with mixtures of soybean and upright starbur (Chivinge and Mudzana, 1989; Mutsvairo, 1992) and velvetleaf (Regnier and Schrieber, 1989).

The low R_x values for mixtures with pigweed indicate that pigweed is more competitive than blackjack. As most soybean R_x values were above monoculture expectation in mixtures with both weed species, it implies that competitiveness of soybean depended on its proportion in the mixtures.

Blackjack and soybean attain maximum vegetative growth at about 60 DPE hence their niches overlapped and the weed was outcompeted. This accounted for the reduction in blackjack seed heads per branch and seeds per plant. Reduction in weed seed number has been reported in black nightshade (*Solanum ptycanthum*) (Quakenbush and Anderson, 1981) and upright starbur (Chivinge and Mudzana, 1989; Mutsvairo, 1992) when both weed species were competing with soybean. Increase in seed production by pigweed as the density of soybean increased indicates that intraspecific competition in pigweed was less as its proportion became lower. Pigweed plants were over 2 m, and planting them at populations of 300,000 plants ha^{-1} led to intensified intraspecific competition which adversely affected seed production. However, reducing pigweed populations to 75 000 plants ha^{-1} (25%) reduced intraspecific competition hence the observed highest seed yield in mixtures with 75%S.

Agronomic implications of the study are that if the proportion of pigweed in the mixture is over 25%, soybean yield will be reduced. In addition, fewer pigweed plants in a soybean crop enhance pigweed seed production hence the need to remove the weed during the early vegetative stages. Enhanced seed production by pigweed increases the seed bank leading to higher weed densities in the following seasons and consequently more weeding would be needed. Soybean will suppress seed production by blackjack as long as the proportion of the weed is under 75% and both plant species emerge at the same time. Consequently, delaying removal of blackjack to just before its flowering may not cause much reduction in soybean yields.

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