Fertility and Weed Stress Effects on Performance of Maize/Soybean Intercrop

Ray R. Weil* and Mary Ellen McFadden

ABSTRACT

Intercropped corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] may produce more total yield per hectare than either grown separately, ie., land equivalent ratio (LER) >1. Low N fertility, limited moisture, and weed competition have each been reported to result in high land equivalent ratios. Thus it was hypothesized that intercropping advantages were greater under stress conditions. The objectives were to study the effects of soil fertility stress (F_1 = low N-P-K, F_2 = high N-P-K), weed competition stress (W_1 = unweeded, W_2 weeded), and four cropping systems (M_2S, M_1S, M_2, S; where M_2 = high density maize, M_1 = low density maize, and S = soybean at normal density) on the performance of maize and soybean, and on the growth of weeds. 'Cargill 921' maize and 'Union' soybean were planted simultaneously in 1985 and 1986 in alternate rows spaced at 0.5 m on a typic Hapludult in Maryland. Land equivalent ratios and maize equivalent yields were calculated. Dry matter production was determined early in the season, and grain yield plus weed dry matter were determined at final harvest. LER values (mean of 1985 and 1986) ranged from 0.89 ($W_1F_1M_2S$) to 1.18 ($W_2F_1M_1S$). The LER data showed that at high fertility levels, weed stress increased the relative advantage of intercropping. In addition, when plots were weeded, LER increased from 0.96 to 1.13 under fertility stress. Maize equivalent yields were calculated from the relative prices of maize and soybeans. The highest maize equivalent yields in all cropping systems in both years occurred under optimal conditions (W_2F_2).

RESEARCH suggests that a biological advantage to intercropping may result from complementary use of growth resources. Component crops may differ in their use of growth resources over time and space such that when grown together they make more efficient use of light, water, and nutrients than when grown separately. In addition, competition from weeds may be lessened by a combination of crop species occupying two or more niches in the field (Altieri and Liebman, 1986). Willey (1979) hypothesized that intercropping exhibited biological advantages over sole cropping when interspecific competition for growth resources was less than intraspecific competition.

Researchers have reported that the performance of intercropping relative to sole cropping is enhanced by low N fertility (Ahmed and Rao, 1982; Russell and Caldwell, 1989; Hiebsch and McCollum, 1987), limited moisture availability (Natarajan and Willey, 1980 and 1986; Reddy and Willey, 1981), and weed competition (Ayeni et al., 1984). Land equivalent ratio (LER) is the amount of sole-cropped land required to produce the same yields as one unit of intercropped land. Studies of response to N in legume/nonlegume intercrops report LER values generally decrease as N rates increase. Ahmed and Rao (1982) in a maize/soybean intercrop reported LER values from 1.64 at 0 kg N ha^{-1} to 1.42 at 85 kg N ha^{-1}. Russell and Caldwell (1989) studied maize/soybean intercrops with several N application rates and found that maximum LER values were achieved at 0 kg N ha^{-1} at locations where N was limiting to maize growth. Rao and Willey (1980) examined data from 94 experiments on a sorghum [*Sorghum bicolor* (L.) Moench]/pigeonpea [*Cajanus cajan* (L.) Huth] intercrop to find evidence of improved yield stability with intercropping as compared to sole cropping. They reported a decreasing trend in LER with increasing N rates.

Hiebsch and McCollum (1987) noted that legume/nonlegume intercrops may, under low-N regimes, utilize area and time more efficiently than sole crops because of the legume's ability to fix atmospheric N. They reasoned that under high-N regimes N_2 fixation by the legume would decrease, the nonlegume would become more dominant, and interspecific competition for the next-most limiting factor, one limiting to both species, would be intensified. When intercropped species are in direct competition for the same limiting factor, an increase in yield in one component would cause a proportionate decrease in yield of the other. Under these conditions, LER would not likely be significantly greater than 1.0.

It is commonly cited that intercropping can be an efficient means of weed control. Steiner (1984) reported that intercropping maize with groundnut (*Arachis hypogaea* L.), mungbean (*Vigna radiata* L.), or sweet potato [*Ipomoea batatas* (L.) Lam.] reduced weed growth, yield losses and time required for weeding. He also observed that in many intercropping systems, only one weeding was required to produce optimum yields instead of the two or three weedings required in sole crops. Moss and Hartwig (1980) reported that intercropping maize and soybean in the same row had a significant effect on lowering the population of common lambsquarter (*Chenopodium album* L.). An intercrop treatment consisting of 56 800 maize plants ha^{-1} with soybean suppressed weeds by 39% as compared to maize cropped alone. By contrast, weed growth was not suppressed by a maize/cowpea [*Vigna unguiculata* (L.) Walp.] intercrop in Nigeria (Ayeni et al., 1984). They concluded that weed growth must be controlled initially to develop a canopy sufficient for weed suppression in intercropped maize/cowpea.

R.R. Weil, Dep. of Agronomy, Univ. of Maryland, College Park, MD 20742; and M.E. McFadden, USDA SCS, P.O. Box 211, Marlinton, WV 24954. Contribution from the Agronomy Dep., Univ. of Maryland Agric. Exp. St., College Park. Scientific Article no. 6095, contribution no. 8260. *Corresponding author.

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Abbreviations: LER, land equivalent ratio; F_1 and F_2, low and high N-P-K, respectively; M_1 and M_2, low and high maize density, respectively; W_1 and W_2, unweeded and weeded, respectively; and S, soybean.

With respect to weed competition, calculations from yield data reported by Ayeni et al. (1984) indicate that LER values fell from 1.43 with full-season weed interference to 1.20 in weed-free plots.

In view of these reports, it was hypothesized that intercropping is more likely to be advantageous under stress conditions than under optimal conditions. If this hypothesis is true, intercropping might be a management strategy more appropriate for resource-poor farmers than for farmers who can afford to provide a near-optimal environment.

This study examined the effects of low fertility status and weed competition on a maize/soybean intercrop. The objectives were: To determine the effects of fertility status and weed competition on yields of a maize/soybean intercrop; to determine the effects of fertility status and maize/soybean intercropping on the production of weed biomass; and to test the hypothesis that intercropping advantages, as measured by LER values and maize equivalent indices, are more likely to occur under stress conditions.

MATERIALS AND METHODS

A field experiment was conducted in 1985 and 1986 at the University of Maryland field station in Beltsville, Maryland, on a Woodstown sandy loam (a fine-loamy, mixed, mesic Typic Hapludult). The particle size distribution was sand, 700 g/kg; silt, 210 g/kg; and clay, 90 g/kg. The soil organic carbon content was 12.8 g/kg, and the soil cation exchange capacity (NaOAc at pH 7.0) was 7.3 $cmol_c$/kg.

The initial soil pH (1:1 in H_2O) was 5.7. Two Megagram per hectare of high calcium lime was applied on 20 Mar. 1985 to raise pH to approximately 6.0. Treatments were arranged in split-split plots. Low (F_1) and high (F_2) fertility treatments were established on 16 by 14 m whole plots. The F_1 treatment received 50-0-0 kg ha^{-1} yr^{-1} of N-P-K, whereas the F_2 treatment received 150-44-83 and 150-88-166 kg ha^{-1} yr^{-1} in 1985 and 1986, respectively. Soil test (Melich I) values for P and K were 6 and 21 mg kg^{-1}, respectively, on the F_1 plots after harvest in 1986. Soil test values for the F_2 plots were 19 and 33 mg kg^{-1}. The sources of N, P and K were prilled ammonium nitrate, granular triple super phosphate, and potassium chloride, respectively. One half of the prilled ammonium nitrate was applied broadcast and disked in just before planting with the remaining half broadcast at the eight to 10 leaf stage of maize. All of the potassium chloride and phosphate was applied broadcast and disked in prior to planting.

Subplots were 16 by 7 m and consisted of two weed-control levels: no weed control (W_1) and full-season weed control (W_2) with 2.8 kg ai ha^{-1} of alachlor [2-chloro-*N*-(2,6-diethylphenyl)-*N*-(methoxymethyl)acetamide] applied pre-emergence and supplemented by hoeing and handpulling.

Sub-subplots were 7 by 4 m and consisted of four cropping systems: (i) intercropped maize at 25 000 plants ha^{-1} and soybean at 200 000 plants ha^{-1} (M_1S); (ii) intercropped maize at 50 000 plants ha^{-1} and soybean at 200 000 plants ha^{-1} (M_2S); (iii) sole cropped maize at 50 000 plants ha^{-1} (M_2); and (iv) sole cropped soybean at 200 000 plants ha^{-1} (S). Seedbed preparation consisted of moldboard plowing, disking, and roller harrowing. Seeding dates were 16 May 1985 and 21 May 1986. Cargill 921 maize and Union soybean, cultivars well adapted to Maryland growing conditions, were planted simultaneously in alternate rows spaced at 0.5 m with a four row plate planter. The desired populations were obtained by overplanting and thinning. To create sole maize plots, the rows of soybean were removed by hoeing just after emergence. For sole soybean plots the maize rows were removed. In 1986, the location of soybean and maize rows was reversed so that the same crop was not grown in the same place as in 1985.

The net harvest plot measured 2.0 by 5.0 m in the center of each sub-subplot. At maize eight to 10 leaf stage (10–12 leaf stage in 1986) maize and soybean whole plants were sampled from an area bordering the net harvest plot. Weeds were also sampled on those dates from 0.1 by 2.0 m strips that were 0.5 m outside the net harvest plot. At maturity, grain was hand-harvested from the entire net harvest plot to obtain yield data. All above-ground weed tissue was also hand-harvested from an area of 1.0 by 5.0 m within the net plot. At harvest, weed species in the net plot were rated visually by two observers on a scale of 0 to 100%: zero equivalent to no infestation and 100 equivalent to complete infestation. Harvesting dates were 29 Sep. 1985 and 20 Sep. 1986 for maize; 5 Oct. 1985 and 11 Oct. 1986 for weeds; and 9 Oct. 1985 and 18 Oct. 1986 for soybean.

Tissue samples were dried for 1 wk at 60 °C in forced air dryers and weighed to determine moisture content and dry matter. The experimental design was a randomized complete block with three replications and 16 sub-subplot treatments. However, for weed dry matter, only the eight unweeded treatments were included in the analysis. Data were analyzed using analysis of variance procedures. Mean separation for factors with more than two levels was by *F*-protected LSD. Large differences in error variance between years required separate analyses of variance for each year.

In addition to dry weight per hectare, the following combined yield parameters were calculated.

Land Equivalent Ratio.

LER was calculated by Willey's (1985) equation:

$$\mathrm{LER} = L_a + L_b = \frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}}$$

where

Y_{ab}, Y_{ba} = yields of intercrop a and intercrop b, respectively.

Y_{aa}, Y_{bb} = corresponding sole crop yields.

L_a, L_b = partial LERs for the two individual crops.

A suggested by Oyejola and Mead (1982), the sole crop yields used in the calculation were the means across three replications of the sole crop given the same fertility and weed treatments as the corresponding intercrops.

Maize Equivalents Yields, Megagram per Hectare.

In order to make comparisons of overall performance of cropping systems involving both maize and soybean yields, soybean yields were converted to maize equivalents yields. The U.S. average prices received by farmers in 1985 and 1986 for maize and soybean (USDA, 1987) were used to compare prices of both crops on an equal weight and moisture content basis. The resulting maize:soybean price ratio was \$0.18:\$0.75 on a dollar per kilogram basis. Thus, one kilogram of dry soybean grain is approximately equivalent to 2.4 kg of dry maize grain in value. Differences in input costs were not considered in this calculation.

RESULTS AND DISCUSSION

Early Season Observations

Early season weed growth responded to applied fertilizer in both years. Weed dry matter production showed a 400% increase in the fertilized plots as compared to the unfertilized plots in 1985 and a 150% increase in 1986 (Table 1). Early season weed population consisted of low-growing broadleaf species such as carpetweed (*Mollugo verticillata* L.), chickweed [*Stellaria media* (L.) Cyrillo], common yellow woodsorrel (*Oxalis stricta* L.) and perennial sowthistle (*Sonchus arvenis* L.).

A fertility × cropping system interaction occurred for weed growth in 1985 and 1986. At F_1, cropping systems did not affect weed growth (Table 1); however, at F_2, the greatest weed growth was found in M_1S in 1985 and in sole soybean in 1986. In both years, weed growth was least in M_2S. We expected that narrowing row spacing from 1 m in the sole crop plots to 0.5 m in the intercrop plots would decrease early season weed growth, but this was not observed. The population density of maize seemed to be the principal controlling factor of early season weed growth.

Cropping systems differed for maize dry matter production in both years because of maize population differences (Table 1). Maize dry matter at the early sampling was proportional to maize density. In both years, similar early season soybean dry weights were observed for all cropping systems. These results suggest the following: (i) early soybean growth was not depressed by maize competition, and (ii) weeds, instead of soybeans, tended to fill in for the lower maize population during the first 5 wk after sowing. Moss and Hartwig (1980) reported similar results with a stand of common lambsquarter (*Chenopodium album* L.) in a maize/soybean intercrop. However, in a cereal/legume mixture, the legume was severely depressed by cereal competition soon after planting (Natarajan and Willey, 1980).

Early season soybean dry matter was reduced 12% by the presence of weeds in 1985, but was unaffected by weeds in 1986. Early soybean dry matter was nearly 100% greater in 1986 than in 1985, though the early production of maize and weed dry matter did not differ between the 2 yr. The data on plant dry matter and field observations from both years indicated no significant herbicide injury to either crop.

Table 1. Aboveground dry matter of maize, soybean, and weeds in early season, 1985 and 1986, as influenced by cropping system, weeding, and soil fertility levels.

Cropping systems within weed-fertility levels	1985			1986		
	Maize	Soybean	Weed	Maize	Soybean	Weed
	Mg ha^{-1}					
W_1F_1‡						
M_2S	0.40	0.29	0.10	0.36	0.50	0.18
M_1S	0.24	0.26	0.13	0.13	0.52	0.19
M_2	0.34	–	0.10	0.26	–	0.18
S	–	0.32	0.15	–	0.55	0.18
W_2F_1						
M_2S	0.41	0.31	–	0.22	0.66	–
M_1S	0.23	0.33	–	0.18	0.49	–
M_2	0.28	–	–	0.16	–	–
S	–	0.31	–	–	0.56	–
W_1F_2						
M_2S	0.55	0.28	0.41	0.64	0.68	0.25
M_1S	0.31	0.28	0.96	0.29	0.65	0.46
M_2	0.44	–	0.45	0.54	–	0.38
S	–	0.31	0.57	–	0.68	0.70
W_2F_2						
M_2S	0.47	0.35	–	0.53	0.69	–
M_1S	0.22	0.28	–	0.46	0.67	–
M_2	0.51	–	–	0.58	–	–
S	–	0.38	–	–	0.62	–
SE	0.04	0.02	0.06	0.09	0.05	0.08
Source of variation	*F* value					
Fertility (F)	13.8**	<1.0	32.2**	33.2**	<1.0	11.7**
Weeding (W)	<1.0	6.1*	<1.0	<1.0	<1.0	
F × W	<1.0	<1.0		<1.0	<1.0	
Cropping system (C)	33.7**	2.8	9.5**	4.2*	<1.0	2.8
F × C	3.6*	1.1	7.6**	<1.0	<1.0	2.8†
W × C	<1.0	<1.0		1.9	1.2	
F × W × C	2.8†	2.5†		<1.0	<1.0	

†,*,** Significant at the 0.10, 0.05 and 0.01 levels of probability, respectively.
‡ M_2S = intercropping with 50 000 maize plants/ha; M_1S = intercropping with 25 000 maize plants/ha; M_2 = sole crop maize with 50 000 plants/ha; S = sole crop soybean; W_1 = unweeded; W_2 = weeded; F_1 = low fertility; F_2 = high fertility.

Results at Harvest

At harvest, major weed species included horsenettle (*Solanum carolinense* L.), fall panicum (*Panicum dichotomiflorum* Michx.) and common ragweed (*Ambrosia artemisiifolia* L.). These species accounted for 70 to 80% of all weeds present in both years. Small populations of redroot pigweed (*Amaranthus retroflexus* L.) and common lambsquarter were also present.

In 1986, during the first month after sowing and the last month before harvest,rainfall was only 25% of that in 1985 (Fig. 1). Wilting symptoms suggested that competition for moisture among maize plants and between maize and weeds was more severe in 1986 than in 1985. In 1985 and 1986, there were significant fertility × cropping system interactions for weed dry matter (Table 2). Weed response to fertility was re-

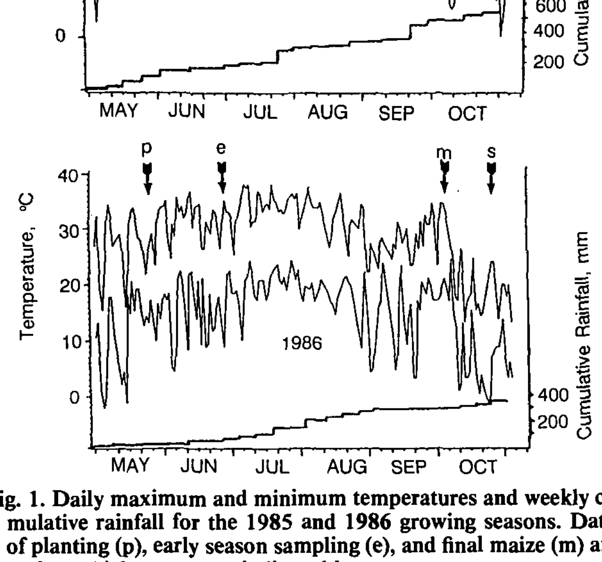

Fig. 1. Daily maximum and minimum temperatures and weekly cumulative rainfall for the 1985 and 1986 growing seasons. Dates of planting (p), early season sampling (e), and final maize (m) and soybean (s) harvests are indicated by arrows.

Table 2. Dry weight yield of maize grain, soybean grain, and weeds at final harvest, 1985 and 1986, as influenced by cropping system, weeding, and soil fertility levels.

Cropping systems at different weed-fertility levels	1985			1986		
	Maize grain	Soybean grain	Weed whole plants	Maize grain	Soybean grain	Weed whole plants
	Mg ha^{-1}					
At W_1F_1‡						
M_2S	2.46	0.74	0.39	1.96	0.54	0.28
M_1S	2.15	1.00	0.22	2.78	0.79	0.30
M_2	4.08	–	0.50	4.45	–	0.33
S	–	1.85	0.77	–	1.59	1.32
At W_2F_1						
M_2S	3.37	0.82	–	2.89	0.56	–
M_1S	2.81	1.01	–	3.38	0.71	–
M_2	4.47	–	–	3.68	–	–
S	–	2.13	–	–	2.09	–
At W_1F_2						
M_2S	2.64	0.74	0.60	6.15	0.49	0.19
M_1S	2.25	0.80	1.09	4.73	0.76	1.10
M_2	4.05	–	0.81	7.12	–	0.45
S	–	1.39	1.93	–	1.99	2.59
At W_2F_2						
M_2S	3.37	0.99	–	6.56	0.52	–
M_1S	3.63	1.33	–	5.76	0.97	–
M_2	7.75	–	–	7.98	–	–
S	–	2.61	–	–	2.83	–
SE	0.48	0.09	0.17	0.45	0.14	0.20
Source of variation	*F* value					
Fertility (F)	6.7*	1.1	5.8	30.8*	2.2	13.4**
Weeding (W)	21.5**	61.0**		3.8	61.7**	
F × W	5.2*	29.2**		<1.0	10.8**	
Cropping system (C)	29.0**	203.9**	10.1**	15.8**	151.9**	29.1*
F × C	2.7†	<1.0	3.6*	4.2*	5.3*	4.7*
W × C	1.8	12.6**		<1.0	6.9**	
F × W × C	3.5*	4.8*		1.4	<1.0	

†,*,** Significant at the 0.10, 0.05 and 0.01 levels of probability, respectively.
‡ M_2S = intercropping with 50 000 maize plants/ha; M_1S = intercropping with 25 000 maize plants/ha; M_2 = sole crop maize with 50 000 plants/ha; S = sole crop soybean; W_1 = unweeded; W_2 = weeded; F_1 = low fertility; F_2 = high fertility.

duced by increasing maize density in both cases. Sole soybean allowed the greatest weed production with approximately two and four times that allowed by other cropping sytems in 1985 and 1986, respectively.

Cropping system had a significant effect on maize grain yield in both years (Table 2). Sole cropped maize yields were 79% higher than intercropped maize in 1985 and 36% higher than intercropped maize in1986. Yield response to fertilizer by weeded maize was greater in M_2 than in M_1S in 1985. Weeded maize grown in M_2S did not respond to fertilizer. These results agree with those of Ahmed and Rao (1982) in their work with a maize/soybean intercrop. By contrast, in 1986, the response to fertilizer by maize was greater in M_2S than in the other cropping systems. Fertilizer increased unweeded maize yield by 213% in M_2S in 1986.

A significant three-way interaction for maize grain in 1985 indicated that the response to weed control by cropping systems was not consistent at different fertility levels. At F_1, maize in M_2S responded to weed control with a 36% increase in yield, while maize in M_2 had little response. At F_2, the opposite occurred, with a 91% increase for maize in M_2 compared to only a 28% increase for maize in M_2S.

Table 3. Land equivalency ratios (LER) and maize equivalent yields in 1985 and 1986 for four cropping systems within four fertility × weeding combinations.

Cropping systems at different weed-fertility levels	1985 combined yield		1986 combined yield	
	LER	Maize equivalent yield	LER	Maize equivalent yield
		Mg ha^{-1}		Mg ha^{-1}
At W_1F_1‡				
M_2S	1.00	4.23	0.78	3.25
M_1S	1.07	4.57	1.13	4.69
M_2	–	4.08	–	4.45
S	–	4.44	–	3.80
Mean	1.04ns	4.33	0.96ns	4.05
At W_2F_1				
M_2S	1.14	5.34	1.05	4.24
M_1S	1.11	5.25	1.25	5.07
M_2	–	4.47	–	3.68
S	–	5.10	–	5.02
Mean	1.12ns	5.04	1.15ns	4.50
At W_1F_2				
M_2S	1.18	4.42	1.11	7.33
M_1S	1.13	4.18	1.05	6.55
M_2	–	4.05	–	7.12
S	–	3.35	–	4.77
Mean	1.16ns	4.00	1.08ns	6.44
At W_2F_2				
M_2S	0.82	5.77	1.01	7.81
M_1S	0.98	6.82	1.06	8.08
M_2	–	7.75	–	7.98
S	–	6.27	–	6.80
Mean	0.90ns	6.65	1.04ns	7.67
SE	0.07	0.50	0.10	0.51
Source of variation	*F* value			
Fertility (F)	<1.0	6.6	<1.0	117.9**
Weeding (W)	2.0	45.7**	1.2	10.7**
F × W	8.2*	15.2**	2.9	2.2
Cropping system (C)	<1.0	<1.0	3.6†	2.7†
F × C	<1.0	1.9	3.8†	4.7**
W × C	<1.0	<1.0	<1.0	1.6
F × W × C	2.7†	1.6	<1.0	<1.0

†,*,** Significant at the 0.10, 0.05 and 0.01 levels of probability, respectively. NS = nonsignificant.
‡ M_2S = intercropping with 50 000 maize plants/ha; M_1S = intercropping with 25 000 maize plants/ha; M_2 = sole crop maize with 50 000 plants/ha; S = sole crop soybean; W_1 = unweeded; W_2 = weeded; F_1 = low fertility; F_2 = high fertility.

Soybean yields were reduced significantly when intercropped with maize in both years (Table 2). Soybean yield reduction was greater in 1986 than in 1985, and greater in both years for the intercrop with high maize density. The mean yield of weeded soybean increased by 29% in response to applied fertilizer. Maize was more responsive to fertilizer than soybean. The mean yield of weeded M_2 increased by 72% in response to applied fertilizer.

A three-way interaction for soybean grain in 1985 indicated that the response to weed control by cropping systems was not consistent at different fertility levels (Table 2). At F_1, solecrop soybean showed a 15% increase in yield in response to weeding as compared to 11 and 1% for soybean in M_2S and M_1S, respectively. At F_2, solecrop soybean showed an 88% increase in yield in response to weeding as compared to only 34 and 66% for soybean in M_2S and M_1S, respectively.

Alternatively, the results indicated that if weeding were not possible, the relative yield reductions would be less in intercropping as compared to sole cropping. In 1985, the effect of weed interference significantly affected soybean dry matter production at the early season sampling date (Table 1). By the end of the season (Table 2), soybean yields in weedy plots were significantly lower when fertilized (W_1F_2) as compared to when unfertilized (W_1F_1). Apparently, fertilizer stimulated weeds to compete more effectively with soybean for light and moisture.

In 1986, the fertility × weeding interaction for soybean grain yield was again significant, indicating that the response to weeding was not consistent over fertilizer treatments. At F_1, weeding increased soybean yields by 15%. Sole cropped soybean responded most to weeding with an increase of 0.50 Mg ha^{-1}. At F_2, weeding increased soybean yields by 33%. Again, sole cropped soybean had the greatest response to weeding with an increased yield of 0.84 Mg ha^{-1}.

Land Equivalent Ratio

The most frequently used index of biological advantage is LER, which places the component crops on a relative and directly comparable basis (Willey, 1979). It is defined as the relative land area that would be required for sole crops to produce the yields achieved in intercropping. A value greater than 1.0 indicates an overall advantage of intercropping.

The highest LER in 1985 was 1.16 and occurred at W_1F_2. This value was significantly different than 0.90, the LER obtained at W_2F_2. At F_2, weed stress increased the LER by 0.26. However, at F_1, the LER decreased from 1.12 to 1.04 when plots were left unweeded. Viewed in terms of fertility stress, at W_1, fertility stress decreased the LER by 0.12. At W_2, fertility stress increased the LER by 0.22. In 1986, LER values were higher for M_1S than for M_2S, and this difference was greater under low fertility conditions.

These data suggest that at high fertility levels, intercropping was more efficient relative to sole cropping when the plots were left unweeded. In addition, when weeding was practiced, intercropping was more efficient relative to sole cropping at low fertility levels.

Maize Equivalent Yield

Yield data were weighted by a crop market value index. Maize equivalent yields of maize and soybean in 1985 were largely determined by weeding and applied fertilizer (Table 3). The fertility × weeding interaction in 1985 showed that the yield response to increasing fertilizer was not consistent over the weed treatments. When the plots were weeded, applied fertilizer increased maize equivalent yields averaged over cropping systems from 5.04 to 6.65 Mg ha^{-1}. But when left unweeded, increasing fertilizer did not increase maize equivalent yield, presumably because of intensified weed competition. Weeding did not affect maize equivalent yield responses to fertility in the intercrops; however, for both sole crops, maize equivalent yield responded positively only when weeded.

Maize equivalent yields in 1986 were also largely determined by the main effects of fertility and weeding. There was also a highly significant fertility × cropping system interaction. Applied fertilizer increased maize equivalent yields for the intercrops more than for the sole crops.

CONCLUSIONS

In view of reports of increased LER under low-N fertility, limited moisture, and weed competition, it was hypothesized that the advantages to intercropping relative to sole cropping are greater under stress conditions. Land equivalent ratio and equivalent yields were calculated in order to measure the performance of intercropping as compared to sole cropping. Land equivalent ratio data showed that at high fertility levels, weed stress increased the relative advantage of intercropping. In addition, when plots were weeded, intercropping was more efficient relative to sole cropping under fertility stress. These data give only limited support to the original hypothesis. Either weed or fertility stress improved land-use efficiency of the intercrop relative to the sole crop, but both stress conditions combined did not. With respect to maize equivalent yields, the highest yields in all cropping systems in both years occurred under optimal conditions (W_2F_2). Overall, these values indicated that in 1985, weed stress was greater than fertility stress and in 1986 the reverse was true. This research revealed not only the importance of stress, but also the interaction of different stress conditions, in evaluating the advantages to intercropping.

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