Published November, 1995

Influence of Irrigation on Susceptibility of Selected Soybean Genotypes to Soybean Looper

Lavone Lambert and Larry G. Heatherly*

ABSTRACT

Soybean [*Glycine max* (L.) Merr.] is usually grown under water deficit conditions in the southern USA and is often attacked by defoliating insects. Field studies were conducted during a 2-yr period with 'Centennial' (insect susceptible) and D75-10169 (insect resistant) soybean genotypes. Plants were grown either with or without irrigation to determine the influence of water-stressed plants on soybean looper [*Pseudoplusia includens* [(Walker)] oviposition, development, survival, and damage to plants. There were no significant ($P \leq 0.05$) differences in egg deposition on the two plant genotypes, and effect of irrigation on egg deposition was not consistent. At 2 wk after insect release on plants, neither genotype nor irrigation treatment significantly affected number of larvae. Larvae developing on nonirrigated plants of both genotypes were significantly smaller than those developing on irrigated plants. All surviving larvae on Centennial pupated and all larvae on D75-10169 died by 18 d after the onset of oviposition. Defoliation by insects of irrigated plants of both genotypes was more than 50% greater than defoliation of nonirrigated plants. Without insects, seed yields of the two genotypes were similar and were greater from irrigated than from nonirrigated plants. Insect infestation significantly reduced yield of both genotypes, but the decrease in Centennial yield was greater. Yield reduction resulting from insect infestations was greater for irrigated than for nonirrigated plants. These findings show that soybean plants growing under water deficit conditions may allow a delay in initiation of soybean looper control measures, especially since yield potential and resulting profit potential are low.

SOYBEAN LOOPER is a major defoliator of soybean and has become resistant to several insecticides (Leonard et al., 1990). Soybean producers, when faced with damaging insect populations, must make decisions about using an insecticide which may or may not give control on a soybean crop that is growing under yield limiting, water deficit conditions. When drought conditions persist, insecticide costs may not be recouped through the prevention of insect damage and/or increased yield.

There have been no field studies that show the influence of insect susceptible or resistant soybean genotypes, grown under water deficit conditions, on the development of and damage by insects. Additionally, no evaluations have been made to determine the influence of soybean plants growing under water deficit conditions on the expression of insect resistance. It has been shown with greenhouse-grown plants, using laboratory bioassays, that insect susceptible soybean cultivars grown under water deficit conditions reduce the development rate of soybean looper (Lambert and Heatherly, 1991) and Mexican bean beetle (*Epilachna varivestis* Mulsant; McQuate and Conner, 1990).

Resistance in soybean to foliar feeding insects was identified in 1968 (VanDuyn et al., 1971). Since that time, more than 45 advanced breeding lines and three cultivars with insect resistance have been developed (Lambert, 1988). With advances in the development of resistance to insect damage in soybean, it is anticipated that within a few years many recommended cultivars will be resistant to foliar feeding insects.

We conducted field studies with insect susceptible and resistant soybean genotypes to determine effects of irrigation on soybean looper oviposition, development, survival, and damage to plants.

L. Lambert, USDA-ARS Southern Insect Management Lab., P.O. Box 346, Stoneville, MS 38776; and L.G. Heatherly, USDA-ARS Soybean Research Unit, P.O. Box 343, Stoneville, MS 38776. Received 6 May 1994. *Corresponding author (llambert@ag.gov).

Published in Crop Sci. 35:1657–1660 (1995).

MATERIALS AND METHODS

Field studies were conducted at the USDA-ARS Jamie Whitten Delta States Research Center at Stoneville, MS, during 1990 and 1991 on Sharkey clay (very-fine, montmorillonitic, nonacid, thermic, Vertic Haplaquept). Soybean genotypes D75-10169 [MG VII, resistant to foliar feeding insects (Hartwig et al., 1984)] and 'Centennial' [MG VI, susceptible to foliar feeding insects (Hartwig et al., 1976)] were used. Experimental design was a randomized complete block with a split-plot factorial arrangement of treatments in four replicates. Irrigation comprised the main plot and genotype the subplot. Subplots were four 1-m-wide rows 21.5 m long. Main plots were isolated from each other by a 2-m-wide fallow area to provide a nonshrinking buffer zone between irrigation treatments necessary to contain irrigation water on this shrinking soil.

Plantings were made on 25 May 1990 and 7 June 1991 in a stale seedbed (seedbed prepared in fall; Heatherly and Elmore, 1983) at 33 seed m^{-1} of row with a conventional planter. No fertilizer amendments were required. Planted seed were treated with carboxin (5,6-dihydro-2-methyl-1,4-oxathiin-3-carboxanilide) plus thiram (tetramethylthiuram disulfide) and metalaxyl (*N*-(2,6-dimethylphenyl)-*N*-(methoxyacetyl)alanine methyl ester] for seedling disease control. Vegetation at planting was killed with glyphosate [*N*-(phosphonomethyl) glycine] both years. Cultivation plus pre- and postemergence herbicides were used to maintain all plots weed free. Irrigation water was applied by the furrow method through gated pipe. Watering was begun near beginning of bloom (R1; Fehr and Caviness, 1977) and was continued through beginning seed fill (early September). Irrigation scheduling was determined with tensiometers placed at 30-cm depth, and water was applied when average tensiometer readings were −70 kPa. Both cultivars were irrigated on the same dates in all cases. Weather data (Table 1) were obtained from a National Oceanic and Atmospheric weather station within 1 km of the experimental site.

On 3 Aug. 1990 (Centennial at full bloom stage; D75-10169 at 7 d prior to beginning bloom stage) and 24 Aug. 1991 (both genotypes at beginning podset stage), plastic screen cages 1.8 by 1.8 by 3.64 m high were placed over a portion of two rows of each plot. Twelve pairs (♂ and ♀) of soybean looper adults were released into each cage. Insects used in the test were obtained from the USDA-ARS Southern Insect Management Lab. at Stoneville, MS. They had been reared for more than 10 generations. All insects were held in an environmental control chamber at 25.6 ± 0.5°C and 60 to 70% relative humidity with a 10-h dark–14-h light cycle during larval development and after adult emergence until initiation of oviposition.

Determination of the relative number of eggs deposited on each treatment was made 3 d after the release of insects by counting all eggs on the central leaflets of 10 randomly selected,

Table 1. Average maximum (Max) and minimum (Min) air temperature, rainfall, and pan evaporation at Stoneville, MS.†

	Air temperature				Rainfall and pan evaporation					
	Max		Min		1990			1991		
Period	1990	1991	1990	1991	Rain	Evaporation	Diff.‡	Rain	Evaporation	Diff.‡
	°C				mm					
1-10 June	30	32	20	21	65	68	−3	11	82	−71
11-20 June	35	32	23	23	33	90	−57	22	70	−48
21-30 June	34	32	22	22	2	79	−77	39	64	−25
1-10 July	35	34	24	23	0	81	−81	25	71	−46
11-20 July	30	34	20	22	36	58	−22	11	77	−66
21-31 July	33	32	22	23	39	65	−26	27	67	−40
1-10 Aug.	30	34	20	22	8	57	−49	24	66	−42
11-20 Aug.	33	31	21	20	3	56	−53	0	57	−57
21-31 Aug.	36	30	22	20	0	77	−77	24	50	−26
1-10 Sept.	35	31	22	22	3	64	−61	19	49	−30
11-20 Sept.	32	32	20	19	72	46	26	3	55	−52
21-30 Sept.	29	25	14	11	0	47	−47	49	53	−4

† Temperature and pan evaporation measurements made by National Oceanic and Atmospheric Admin., Mid-South Agric. Weather Service Center, Stoneville, MS.
‡ Diff. = rain − evaporation.

fully expanded leaves from plants in each plot. Relative number of larvae among treatments was determined 10 and 12 d (1990) and 9 and 13 d (1991) after the release of insects. These determinations were made by the same procedure used to determine egg deposition, except counts were made on whole leaves. Relative leaf area and percentage defoliation (Table 2) were determined 12 (1990) and 13 (1991) d after insect release. Percentage defoliation was determined by measuring, with an area meter, the area of the central leaflet of trifoliolates from which larval number had been determined and the area of a paper pattern of the leaflets' intact area and calculating the difference between the two. Area of undamaged leaflets was represented by the paper patterns. Relative larval weights among treatments were determined 10 and 12 d after insect release in 1990 and 9 and 13 d after release in 1991. These determinations were made by randomly collecting and weighing 10 larvae from plants in each treatment in each replication.

Plants were harvested for seed yield and weight on 30 Oct. 1990 and 10 Nov. 1991. Yield was determined by hand harvesting two 1-m row sections from the two interior rows of each plot inside and outside the caged areas. All 1-m sections harvested were bordered on each end by at least 1 m of row. Two 100-seed samples were randomly taken from the harvested seed to determine individual seed weight. Both seed yield and seed weight were corrected to 130 g kg^{-1} moisture content. All data were analyzed by analysis of variance procedures (SAS Institute, 1990) to evaluate the significance of treatment effects and their interactions. Where significant interactions occurred, mean separation was achieved with an $LSD_{0.05}$ value calculated with either the whole unit or subunit error terms or an adjusted error term made up of main unit and subunit errors (Cochran and Cox, 1957). Error mean squares were pooled whenever they were not significantly different. Where pooled errors were used and a significant interaction occurred, only one LSD value is presented for determining differences between or among interaction means.

RESULTS AND DISCUSSION

From 11 June through 10 July 1990, higher average maximum temperature and greater pan evaporation (Table 1) occurred than for the same period in 1991. From 11 July through 10 Aug., average maximum temperature and pan evaporation were greater in 1991. From 11 Aug. through 10 Sept. 1990, the weather was hotter with less rainfall and greater pan evaporation than in 1991. In both years, rainfall was well below pan evaporation amounts and plant stress occurred during July and August. The effect of this stress was evidenced in both years by smaller leaves (Table 2) and lower seed yield (Table 3) and in 1990, by larger seed (Table 4) from nonirrigated plants.

Because of the different weather patterns of the two years, irrigation was started and continued dissimilarly. In 1990, irrigation was applied on 9 and 17 July, 2, 14, 23, and 30 Aug., and 7 Sept. (both genotypes at early seed fill stage). In 1991, irrigation was applied on 25 July, 6 and 19 Aug., and 4 Sept. (Centennial at Stage R5;

Table 2. Area and percentage defoliation by soybean looper of center leaflet of 10 randomly selected leaves of Centennial and D75-10169 soybean grown under nonirrigated and irrigated conditions at Stoneville, MS, in 1990 and 1991.

Irrigation treatment	Leaf area			Defoliation		
	Centennial	D75-10169	Mean	Centennial	D75-10169	Mean
	cm²			%		
			15 Aug. 1990†			
Nonirrigated	57.4	62.6	60.0	34.0	6.4	20.2
Irrigated	63.4	73.2	68.3	50.6	11.1	30.8
Mean	60.4	67.9		42.3	8.7	
			6 Sept. 1991‡			
Nonirrigated	47.7	48.0	47.9	18.4	4.0	11.2
Irrigated	57.0	57.6	57.3	26.0	8.4	17.2
Mean	52.3	52.8		22.2	6.2	

† Significant irrigation treatment and genotype effect for both leaf area and defoliation.
‡ Significant irrigation treatment effect for leaf area and defoliation; significant genotype effect for defoliation.

Table 3. Seed yield and weight of seed of soybean-looper-infested and noninfested Centennial and D75-10169 soybean grown under nonirrigated and irrigated conditions at Stoneville, MS, in 1990 and 1991.

Irrigation treatment	Insect infestation	Seed yield: Centennial	Seed yield: D75-10169	Weight of seed: Centennial	Weight of seed: D75-10169
		g m^{-2}		mg seed^{-2}	
		1990†			
Nonirrigated	Without	163.1	154.4	96	107
Irrigated	Without	271.2	249.7	93	92
Mean		217.2 a	202.0 a	95 b	99 bc
Nonirrigated	With	50.0	92.6	123	112
Irrigated	With	76.3	172.6	108	99
Mean		63.2 c	132.6 b	116 a	105 b
		1991‡			
Nonirrigated	Without	58.2 c	59.3 c	92	87
Irrigated	Without	169.3 a	149.5 a	94	89
Nonirrigated	With	20.7 d	60.9 c	90	90
Irrigated	With	31.8 d	96.3 b	92	86
Mean				92	88

† For seed yield and weight of seed, irrigation treatment effect and genotype × insect infestation interaction are significant. Genotype × insect infestation means followed by the same letter are not significantly different ($LSD_{0.05}$ = 40.9 for yield; $LSD_{0.05}$ = 6 for weight of seed).
‡ For seed yield, irrigation treatment × genotype × insect infestation interaction is significant at $P \leq 0.05$. Means followed by the same letter are not significantly different ($LSD_{0.05}$ = 21.1). For weight of seed, genotype effect significant at $P \leq 0.05$.

D75-10169 5 d prior to Stage R5). Centennial reached R1 on 24 and 29 July in 1990 and 1991, respectively, and D75-10169 reached R1 on 10 and 12 Aug. in 1990 and 1991, respectively.

Under the no-choice conditions imposed in the experiment, neither irrigation treatment nor genotype significantly affected number of eggs deposited in 1990 (Table 4). In 1991, significantly more eggs were deposited on leaves of plants growing under irrigated conditions, but again genotype had no effect on egg deposition. Thus, no trend was evident in this study about the effect of soil water supply on egg deposition by soybean looper on leaves of resistant and susceptible soybean genotypes.

Number of larvae per 10 leaves (Table 4) was higher in 1990 than in 1991. Number of larvae was not significantly different between irrigated and nonirrigated plants or between genotypes at 10 and 12 d after insects were released into cages in 1990. In 1991, number of larvae at 9 d after release was higher on D75-10169 leaves and on leaves of plants grown without irrigation; however, absolute differences were small. At 13 d after insect release in 1991, neither irrigation treatment nor genotype significantly affected number of larvae. Increase in number of larvae between the two sample dates was greater on Centennial than on D75-10169. Eighteen days after insect release, all surviving larvae on Centennial had pupated and all larvae on D75-10169 had disappeared (data not shown). No pupae were found on plants or in leaf litter of D75-10169. It appears that larvae died before reaching pupation on both irrigated and nonirrigated D75-10169 plants.

Weights of larvae from Centennial plants (Table 4) in 1990 were higher than from plants of D75-10169 in both nonirrigated and irrigated environments at both 9 and 13 d after release of insects, while irrigation had a significant effect on larvae weight only at 13 d after

Table 4. Eggs of soybean looper deposited per center leaflet, and number and weight of larvae per whole leaf of 10 randomly selected trifoliolates of Centennial (Cent) and D75-10169 (D75) soybean grown under nonirrigated and irrigated conditions at Stoneville, MS, in 1990 and 1991.

Irrigation treatment	Number of eggs, 3 d: Cent	D75	Mean	Number of larvae, 10, 9† d: Cent	D75	Mean	Number of larvae, 12, 13† d: Cent	D75	Mean	Larval weight, 10, 9† d: Cent	D75	Mean	Larval weight, 12, 13† d: Cent	D75	Mean
										mg					
							1990‡								
Nonirrigated	6.3	5.7	6.0	7.1	8.7	7.9	8.8	7.4	8.1	7.2	3.3	5.2	32.8 b	10.9 c	21.8
Irrigated	4.2	5.0	4.6	7.3	10.2	8.8	11.0	10.1	10.6	8.7	4.5	6.6	47.4 a	13.6 c	30.5
Mean	5.3	5.4		7.2	9.4		9.9	8.8		7.9	3.9		40.1	12.2	
							1991§								
Nonirrigated	1.9	1.9	1.9	1.1	1.6	1.4	2.4	1.7	2.1	12.3	7.5	9.9	67.2	38.9	53.0
Irrigated	3.3	2.2	2.8	0.8	1.0	0.9	1.9	1.8	1.9	18.5	10.3	14.4	80.3	48.4	64.3
Mean	2.6	2.1		0.9	1.3		2.2	1.8		15.4	8.9		73.8	43.6	

† First number for 1990; second number for 1991.
‡ No significant ($P \leq 0.05$) differences for number of eggs or for number of larvae on either sampling date; significant genotype effect for larval weight on first sampling date; significant irrigation treatment × genotype interaction for larval weight on second sampling date ($LSD_{0.05}$ = 5.9).
§ Significant ($P \leq 0.05$) irrigation treatment effect for number of eggs; significant irrigation treatment effect and genotype effect for number of larvae on first sampling date; no significant differences for number of larvae on second sampling date; significant irrigation treatment effect and genotype effect for larval weight on both sampling dates.

release on Centennial plants. In 1991, weight of larvae was greater from Centennial plants and from irrigated plants at both 9 and 13 d after release. Larval development in both nonirrigated and irrigated treatments and on both genotypes was faster (greater larvae weight at first sampling) in 1991 than in 1990, but this was more than offset by the fewer larvae in 1991. The slower rate of development of larvae on nonirrigated plants than on irrigated ones demonstrates that water deficit conditions make soybean less suitable for insects and supports findings previously reported (Lambert and Heatherly, 1991) from greenhouse-laboratory bioassays. Under natural conditions with insect susceptible soybean where insect infestations are low or moderate, water deficit may allow a longer period of time in which natural controls can operate, which may delay or eliminate the need for control measures. Additionally, when insecticides are used, they should result in better control since small larvae require smaller amounts of insecticide to be lethal than do large larvae. The low yield and resulting low net return from nonirrigated soybean in this region (Heatherly and Spurlock, 1993) dictates that all inputs be minimal, and these results indicate that insect control inputs may be minimally required for nonirrigated soybean.

On 15 Aug. 1990 (12 d after insect release) and 6 Sept. 1991 (13 d after insect release), defoliation of nonirrigated and irrigated Centennial was greater than defoliation of D75-10169 (Table 2). Both irrigated and nonirrigated Centennial plants were 100% defoliated by 14 and 18 d after insect release in 1990 and 1991, respectively. Defoliation levels of D75-10169 never exceeded 31% on irrigated plants and 17% on nonirrigated plants either year, at which time larval populations disappeared. These low levels of defoliation of D75-10169 would not have required treatment for control, especially in the nonirrigated treatment. The significant and 53% greater defoliation of irrigated plants in both years was apparently due to drought stress imposed by water deficit conditions on the nonirrigated plants.

Seed yields (Table 3) of Centennial and D75-10169 averaged across irrigation treatments were similar when insects were not present, while average seed yield of D75-10169 was greater than that of Centennial with insects present in 1990. Irrigation significantly increased yield of both genotypes in the insect-infested and noninfested environments. Insect infestation significantly reduced yield in both nonirrigated and irrigated environments, but the decrease was less in D75-10169 than in Centennial. In 1991, yields of Centennial and D75-10169 were again similar in the nonirrigated and irrigated treatments without insects. Insect infestation significantly reduced yields of nonirrigated and irrigated Centennial but significantly reduced yields of D75-10169 only in the irrigated treatment.

In 1990, average weight of seeds (Table 3) from nonirrigated plants of both genotypes was significantly greater than average weight of seeds from irrigated plants of both genotypes regardless of insect infestation treatment. Where growing conditions reduce the number of seeds reaching maturity, a common response of soybean is to produce larger seeds (Reicosky and Heatherly, 1990). Centennial with vs. without insects produced heavier seeds, while insect infestation did not significantly affect weight of seeds of D75-10169. Measured differences in seed weight in 1990 are apparently the result of water deficit and/or insect-induced stress. In 1991, the differences in seed weight between irrigation treatments and insect infestation treatments were not significant. Seed of Centennial were slightly heavier than those of D75-10169.

Findings of this study show that when control decisions for soybean looper are being made, the water supply available to plants should be considered. Under low to moderate insect infestations such as those likely to occur in some years under natural conditions, it may be possible to delay the initiation of control measures for insect susceptible soybean growing under water deficit conditions. This finding is especially important when coupled with that of Heatherly and Spurlock (1993) showing that nonirrigated soybean in the region is only marginally profitable. These findings should be confirmed under natural infestation conditions where damage to insect resistant genotypes should be minimal vs. that sustained under the stringent conditions imposed in this study.

ACKNOWLEDGMENTS

The technical assistance of Walter Solomon and Larry Ginn is gratefully acknowledged. The authors thank the MAFES Delta Branch Experiment Station, Stoneville, MS, for providing land on which this study was conducted.

REFERENCES

Cochran, W.G., and G.M. Cox (ed.). 1957. Factorial experiments with main effects confounded: Split-plot designs. p. 293–306. *In* Experimental designs. 2nd ed. John Wiley & Sons, New York.

Fehr, W.R., and C.E. Caviness. 1977. Stages of soybean development. Iowa Agric. Exp. Stn. Spec. Rep. 80.

Hartwig, E.E., C.J. Edwards, and T.C. Kilen. 1975. Centennial: A new soybean variety. Mississippi Agric. For. Exp. Stn. Info. Sheet 1274.

Hartwig, E.E., S.G. Turnipseed, and T.C. Kilen. 1984. Registration of soybean germplasm line D75-10169. Crop. Sci. 24:214–215.

Heatherly, L.G., and C.D. Elmore. 1983. Response of soybean (*Glycine max*) to planting in untilled, weedy seedbed on clay soil. Weed Sci. 31:93–99.

Heatherly, L.G., and S.R. Spurlock. 1993. Timing of furrow irrigation termination for determinate soybean on clay soil. Agron. J. 85: 1103–1108.

Lambert, L. 1988. Host plant resistance in soybean to *Heliothis* spp. p. 13–20. *In* G.A. Herzog, et al. (ed.) Theory and tactics of *Heliothis* population management: III – Emerging control tactics and techniques. Southern Coop. Series. Bull. 337. Agric. Exp. Stn., Oklahoma State Univ., Stillwater.

Lambert, L., and L.G. Heatherly. 1991. Soil water potential: Effects on soybean looper feeding on soybean leaves. Crop Sci. 31:1625–1628.

Leonard, B.R., D.J. Boethel, A.N. Sparks, Jr., M.B. Layton, J.S. Mink, A.M. Pavloff, E. Burris, and J.B. Graves. 1990. Variations in response of soybean looper (Lepidoptera: Noctuidae) to selected insecticides in Louisiana. J. Econ. Entomol. 83:27–34.

McQuate, G.T., and E.F Conner. 1990. Insect response to plant deficits: II. Effects of water deficits in soybean plants on the growth and survival of Mexican bean beetle larvae. Ecol. Entomol. 15: 433–445.

Reicosky, D.C., and L.G. Heatherly. 1990. Soybean. p. 639–674. *In*. B.A. Stewart and D.R. Nielsen (ed.) Irrigation of agricultural crops. Agron. Monogr. 30. ASA, CSSA, and SSSA, Madison, WI.

SAS Institute. 1990. SAS/STAT user's guide. Ver. 6. 4th ed. Vol. 1. SAS Inst., Cary, NC.

VanDuyn, J.W., S.G. Turnipseed, and J.D. Maxwell. 1971. Resistance in soybeans to the Mexican bean beetle: I. Sources of resistance. Crop Sci. 11:572–573.