Managing Southwestern Corn Borer Populations in Irrigated Kansas Corn

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INTRODUCTION

Southwestern corn borers are severe pests of irrigated corn in south-central and southwestern Kansas. They overwinter as larvae in the crown of the previous year's corn stubble. Larvae pupate by mid- to late May, and adults emerge early in June. Borers complete two generations per year in Kansas. First generation eggs are laid, the eggs hatch, and larvae feed on the growing point of young corn plants. Excessive numbers of larvae feeding then may kill the plant, a condition termed 'dead heart'. However, 1st generation population levels usually are not high enough to cause dead heart.

First generation larvae pupate during late June, and adults emerge from mid-July to mid-August (tasseling-to-dough-stage corn). Second generation eggs are laid then. The eggs hatch and larvae feed in the leaf sheath for about 11 days before boring into the stalk. Many larvae tunneling in the stalk may disrupt the translocation of nutrients, and thus decrease grain yield.

Most of the borers develop to mature larvae and tunnel to the crown of the plant by late August. Large larvae are cannibalistic; so only a single larva usually is found in each corn stalk. By the 1st week of September larvae build overwintering cells, crawl back up within the corn stalk (3-5 in. above soil surface), and girdle the plants. Girdling activity begins in early September and is usually completed by early October. Girdled plants lodge causing heavy ear losses during machine harvest.

Our research on developing management strategies for the southwestern corn borer, initiated during 1974, has centered on cultural control, chemical control, and host-plant resistance.

CULTURAL CONTROL

Early corn harvest is currently recommended to escape southwestern corn borer girdling damage. The initiation and duration of the southwestern corn borer girdling periods were the same during falls of 1976 and 1977 in south-central Kansas. Girdling began about the 1st week in September and was completed by the 2nd week of October (Fig. 1). To escape girdling damage, corn should be harvested by the 1st week of September.

Harvest date depends primarily on grain moisture content acceptable to producers. Commercial dryers usually require a corn-moisture content of 25% or less. Corn that will be stored oxygen-free, acid-treated, or in silos can be harvested at 30%, and earlage (chopped ears and husks) at 35% or higher.

Early harvest may be achieved by harvesting a conventional hybrid at a high moisture content or planting a shorter-season hybrid. Combining high moisture corn and drying at high temperatures damages kernels and reduces corn quality. Damaged grain may continue to degrade as it moves through marketing channels. Studies conducted at Sandyland Experimental Field from 1968 to 1972 indicated that short-season hybrids (106-112 days to relative maturity) reach harvestable moisture earlier than longer-season hybrids (Table 1). However, the yield potential of short-season hybrids was significantly less than that of long-season hybrids. A 110-day hybrid

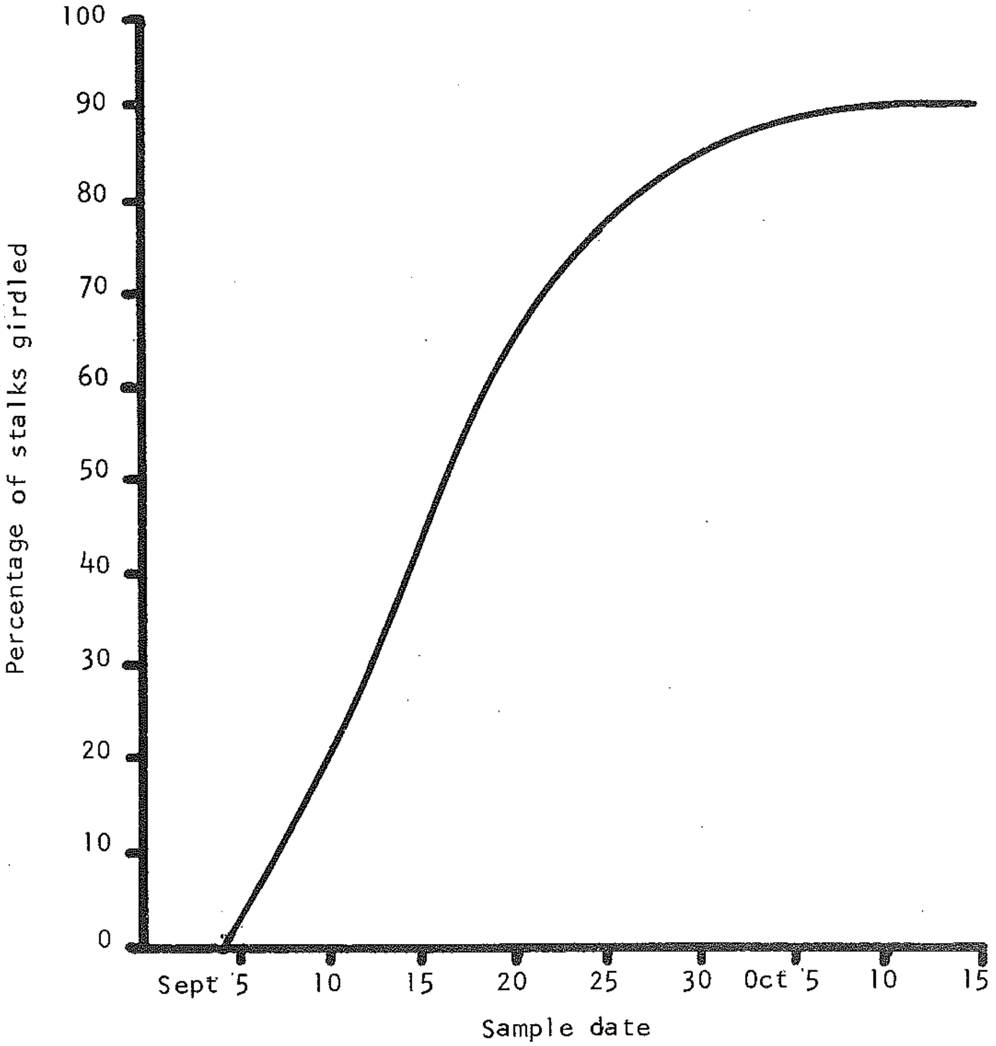

Fig. 1. Model of southwestern corn borer girdling at Sandyland Experimental Field during 1976. (Regression model used: $Y = 7114.36 + 51.1x - 0.09x^2$).

Table 1. Moisture contents (%) of grain of selected corn hybrids for two planting dates and sampled as indicated, Sandyland Experimental Field.

Hybrid	Days to maturity	Date planted: April 10 Moisture % Sept. 4, 75	April 25 Moisture % Sept. 4&5, 75
NC+ 33	106	14.6	18.4
Pioneer 3780	107	13.2	18.2
Pioneer 3722	112	16.2	18.4
Moews 421	117	20.7	25.8
Pioneer 3390	119	19.0	22.8
Moews 520	120	21.5	22.8
Moews 822	120	20.7	23.1
DeKalb 372	125	23.0	25.0
Pioneer 3306	128	19.4	24.6
DeKalb 72A	130	25.2	29.2
Pioneer 3149	137	28.7	33.7

planted April 10 yielded about 18% less than a 135-day hybrid planted the same date. Short-season hybrids will not produce economic returns equal to returns with long-season hybrids harvested at high-moisture content. However, part of the revenue lost may be recovered by eliminating or reducing drying costs.

In general, the entire early-harvest-date strategy depends highly on fall weather. If harvest is delayed by bad weather until late September, corn will not escape southwestern corn borer girdling damage. Then the grower who selected a short-season hybrid will suffer losses from lower yields and southwestern corn borer girdling.

CHEMICAL CONTROL

Efficacy of chemical applications for borer control has been inconsistent. Organochlorine insecticides (e.g., DDT, aldrin, dieldrin, etc.), commonly used to control stem borers, have been banned for agricultural use. Availabel organophosphorus (parathion) and carbamate (Furadan^{TM} and Sevin^{TM}) insecticides are less persistent, so several applications are needed for acceptable control.

Insecticides currently labeled for southwestern corn borer control are Furadan 10G^{TM}, Sevimol 4F^{TM}, and Diazinon 14G^{TM}. Insecticides, NOT CURRENTLY LABELED, that have shown promise are Furadan 4F^{TM}, Ambush 2EC^{TM}, and Pounce 3.2EC^{TM}. Furadan 4F may be available for 1978 in Kansas. Ambush and Pounce are synthetic pyrethroids that are applied at low rates and are very persistent; however, they are probably several years away from registration for use on corn.

In our 1976 and 1977 efficacy trials we applied insecticides by ground and air. Results of selected insecticides from the 1976 trial at the Sandyland Experimental Field under center-pivot irrigation are presented in Table 2. Furadan 10G was applied in treatments 1, 2, and 3 at 1.0 lb AI/a in-furrow at planting (April 23, 1976), and at 2.0 lb AI/a in a 7-in. band (treatment 3) beside the row at cultivation (June 30, 1976). The 2 foliar applications of Furadan 4F, Furadan 10G, and Ambush were applied on July 23 and Aug. 12, which were 7 and 27 days, respectively, after the 1st moth was caught in a light trap. The 3 foliar applications of Sevimol were applied July 23, Aug. 2 and Aug. 12, which were 7, 17, and 27 days, respectively, after the 1st adult was trapped. Foliar applications

Table 2. Results of selected insecticides applied in chemical efficacy trials for southwestern corn borer at Sandyland Experimental Field, 1976.[a]

Trt. No.	Chemical	Form.	Rate (lb AI/a)	No. of applications	(%) Girdled	(%) Infested
1[b]	Furadan	10G	1.0	1	20.0 ab	16.3 ab
	+ Furadan	4F	1.0	2		
2	Furadan	10G	1.0	3	21.3 a	10.0 a
3	Furadan	10G	1.0	1	42.5 bc	45.0 b
	+ Furadan	10G	2.0	1		
4[b]	Ambush	2EC	0.2	2	6.3 a	0.0 a
5	Sevimol	4F	1.0	3	65.0 cd	42.5 b
6	Control	-	-	-	95.0 d	90.0 c

[a] Numbers followed by the same letter in the same column do not differ significantly ($P<0.05$).

[b] This insecticide is not approved for southwestern corn borer control.

of Furadan and Ambush significantly reduced girdling but Sevimol did not. In general, late-season infestation counts were less than late-season girdling counts. The difference was attributed to death of larvae caused primarily by birds. Consequently, girdling counts were considered better late-season estimates of chemical efficacy than infestation counts.

In the insecticide efficacy trials under center-pivot irrigation at Hugoton, Kansas, during 1977 (Table 3), insecticides were applied with ground equipment. Timing of applications was similar to that used during 1976. Insecticides labeled for southwestern corn borer control (Sevimol, Diazinon, and Furadan 10G) did not significantly reduce larval infestations. Plots treated with Furadan 4F and Ambush had significantly lower infestation levels than the control plots. Perhaps foliar applications of Furadan 10G failed in this study because plant-surface moisture was too low to activate the granules.

Table 3. Results of insecticides evaluated for southwestern corn borer at Hugoton, KS, 1977.[a]

		Rate (lb AI/a) and treatment dates (month-day)			
Chemical	Formulation	7-20	7-29	8-30	Infestation (%)
Check	-	-	-	-	60.0 a
Sevimol	4F	1.5	1.5	1.5	46.7 ab
Diazinon	14G	1.0		1.0	43.3 ab
Furadan	10G	1.0		1.0	30.0 abc
Furadan[b]	4F	1.0	1.0	13.3 bc	
Ambush[b]	2EC	0.2	0.2	0.0 c	

[a] Numbers followed by the same letter do not differ significantly ($P<0.05$).

[b] These insecticides are not approved for southwestern corn borer controls.

Aerial efficacy trials were conducted under center-pivot irrigation during 1977 at Great Bend, Kansas. Sevimol plus a sticker (Bond™) was applied by air on July 21, July 28, and Aug. 3, 1977. Plots were sampled for larvae Aug. 17. The Sevimol plus Bond treatment had 25% infested plants compared with 75% for the control.

The three efficacy trials previously discussed provide substantial insight to proper use of currently labeled and prospective insecticides. Furadan 10G applied in areas with adequate plant-surface moisture may provide adequate control. Its performance in extreme southwestern Kansas is questionable. Furadan 4F seems efficacious in south-central and southwestern Kansas. Sevimol should be applied with a sticker to prevent it from washing off, especially under sprinkler-irrigation systems. Diazinon 14G has not performed adequately in Kansas trials. Ambush (synthetic pyrethroid) has performed well in all efficacy trials but is probably several years away from registration. Results of efficacy trials at Sandyland Experimental Field during 1977 suggest that a single, well-timed application of Ambush may provide adequate borer control.

Proper timing of insecticide applications is a major problem. They must be applied when young larvae will contact them before they bore into stalks. Moth flights, and thus egg laying, at Sandyland Experimental Field varied widely between 1976 and 1977 (Fig. 2). Adults were first collected July 15, 1976, with peak catch Aug. 1. During 1977 peak catch was July 14, 18 days earlier than in 1976. Moth flights vary not only from year to year in the same location, but from location to location the same year. Peak moth flights usually are 1 to 2 weeks later in southwestern Kansas than in south-central Kansas. But they may start at the same time. Consequently, timing insecticide applications with light traps is virtually impossible.

Sampling for second generation eggs as a way to time insecticide applications can be used with small plots but not over broad areas. Many

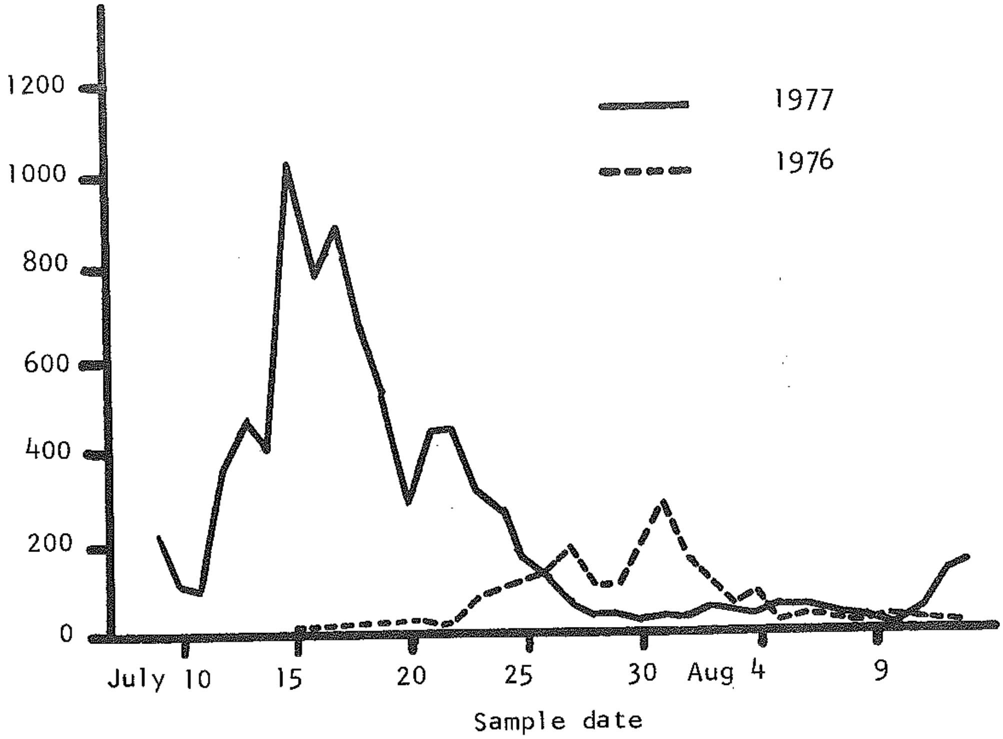

Fig. 2. Dates 1st generation southwestern corn borer adults were collected in light traps at St. John, Kansas, during 1976 and 1977.

corn plants must be sampled daily to detect the beginning of the second generation. Little or no lead time could be given aerial applicators nor can the technique be used to predict peak oviposition or duration of the oviposition period.

Studies were initiated in 1976 to establish a predictive phenological model for southwestern corn borer development. Because insects are cold blooded (poikilothermic), development of many species depends principally on temperature. A thermal-unit accumulation system (Table 4) was developed to determine developmental rates of southwestern corn borers. Approximately

Table 4. Means ($\bar{x}$) and standard errors (S.E.) of the cumulative thermal units required for development of the southwestern corn borer.

Stage	$\bar{x}$		S.E.
Egg	190	±	6.8
Larval stadia			
1st	361	±	15.3
2nd	533	±	10.9
3rd	713	±	7.9
4th	902	±	11.3
5th	1153	±	21.7
Pupal	1321	±	9.2

1,321 thermal units were required for corn borer development from egg-to-adult. Daily thermal units were calculated by averaging maximum and minimum daily temperatures and subtracting the threshold temperature (50F) for southwestern corn borer development. When minimum daily temperature was less than 50F but the maximum exceeded 50F, we used 50F as the minimum temperature to avoid negative thermal units. First-generation development rates during 1976 and 1977 agreed with predictions from the accumulation system. A mathematical model was developed to predict adult emergence with a k^{th}-order distributed-delay technique.

Predicted moth emergence and light-trap catch during 1976 are compared in Fig. 3. At first glance, predicted moth emergence did not agree with observed emergence. Moth flight emergence dates for initiation, peak,

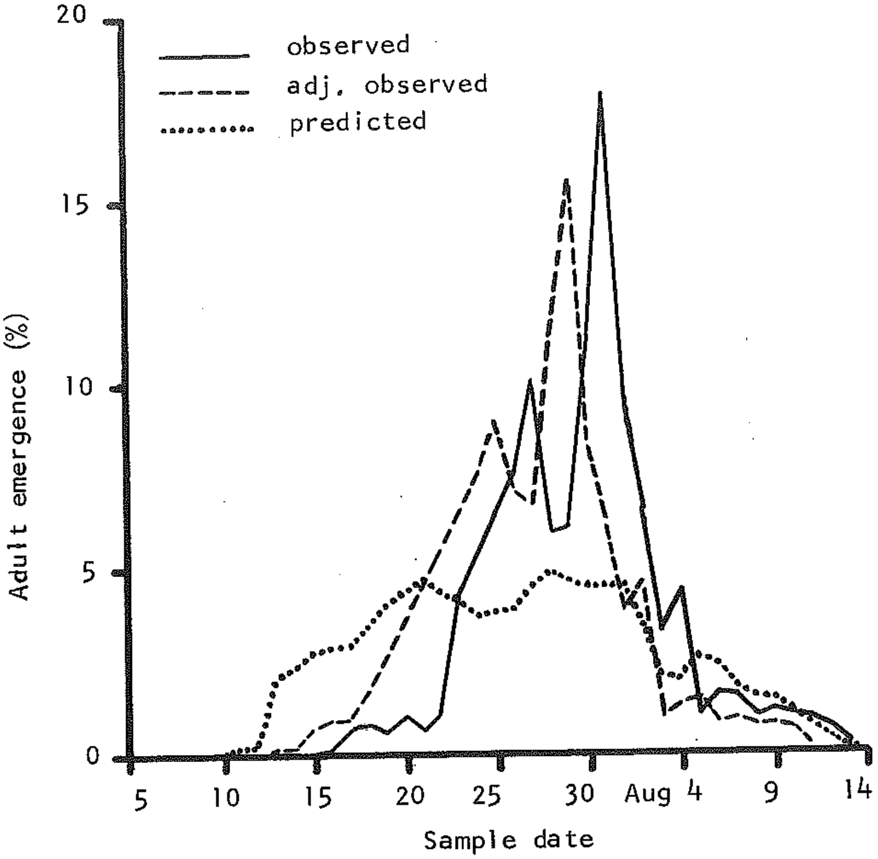

Fig. 3. Predicted, observed, and adjusted observed values of adult southwestern corn borer emergence.

and termination, based on the predictive model, were July 10, July 28, and Aug. 13, respectively. Emergence dates for the same events, indicated by light-trap catches, were several days later. Also, peaks for predicted moth emergence were substantially less than those observed. However, proper timing of insecticide applications depends on accurately predicting when moth flights start, peak, and terminate. The relative magnitude of the predictive and observed values is not important.

Close examination of light-trap catches and egg counts during 1977 indicated inconsistencies in the data. Peak oviposition was 2 to 3 days before peak female moth flight. Primary peaks in the male moth population flight preceded peaks of the female population flight 2 to 3 days. Classification of the female reproductive parts showed that females collected in the traps were 4 to 5 days old. Adjusting the female trap catch by that factor caused primary peaks in female emergence to precede male emergence by 2 to 3 days. Development rates, however, for males and females were the same and field surveys indicated a 1:1 sex ratio in the field. Therefore, males collected in the light traps were 2 to 3 days old. Adjusting 1976 light-trap samples for male and female age-class bias made the predicted and the observed adult emergence curves agree relatively well (Fig. 3). Observed moth flight initiation, peak, and termination were July 12, July 20, and Aug. 14, respectively. The phenological model provides a way to predict moth flights, and thus, to properly time insecticide applications. We plan to test this technique further during 1978.

HOST-PLANT RESISTANCE

Commercial corn hybrids currently available offer little or no resistance to southwestern corn borer damage. Corn-breeding research in Kansas has been directed toward developing genotypes resistant to second-generation borers.

During 1977 we evaluated resistant genotypes identified by USDA researchers at Mississippi State University under artificial infestation at Manhattan, Kansas, and natural infestation at the Sandyland Experimental

Field. Results of the natural infestation nursery are presented in Table 5. The resistant-by-resistant cross reduced borer tunneling 44.2%. The resistant-by-susceptible cross and composite populations I and II did not significantly reduce tunnel length per plant. Composites I and II are synthetic populations being developed in Mississippi. The resistant-by-resistant cross had significantly fewer tunnels per plant than the controls. No significant differences in mean tunnel length per tunnel were observed which indicates that the mechanism of resistance was probably antibiosis. Reductions in tunneling resulted from larvae dying. Girdling was not significantly reduced.

Table 5. Mean number of tunnels, tunnel length per tunnel, tunnel length per plant, and reduction in tunneling, St. John, KS. 1977.

Treatment	No. tunnels/ plant	Tunnel length/ tunnel (cm)	Tunnel length/ plant (cm)	Tunneling reduction (%)
Res. x Res.	2.6 a	12.1 a	32.1 a	44.2
Res. x Susc.	3.7 b	12.4 a	46.7 ab	18.7
Composite I	3.7 b	11.3 a	41.6 ab	26.0
Composite II	4.1 b	14.0 a	57.9 b	0
Control	5.0 c	11.9 a	59.7 b	-
Control	4.9 c	10.9 a	53.8 b	-

[a] Numbers followed by the same letter in the same column do not differ significantly ($P<0.05$).

In 1977, we evaluated 300 progeny sources from crosses between the resistant sources and Kansas adapted lines at Manhattan and St. John. Selections were made under artificial infestation (Manhattan) and natural infestation (St. John). Tunnel lengths ranged from less than 5 cm (about 2 inches) to more than 100 cm (about 40 inches) in each stalk. Pollinations were made on all plants evaluated, and plants with less than 15-cm (6 inches) tunneling per stalk were selected for further study.

From 9,843 plants evaluated at Manhattan and St. John, we selected 273 superior plants. Eighteen selections had penetration holes but no measurable tunneling. Selections at St. John were for plants not girdled as well as plants with limited tunneling.

The best selections from both locations are in a winter nursery in the fourth generation of inbreeding and will be tested during 1978. In addition to further screening for resistance to southwestern corn borer, all selections will be evaluated for hybrid-yield potential. Best selections will be continued in efforts to develop resistant, high-performing, inbred lines, which should be accomplished by the sixth to eighth inbred generation.