Weekly Economic Injury Levels for Fall Armyworm (Lepidoptera: Noctuidae) Infestation of Corn in Lowland Ecuador

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ABSTRACT Fall armyworm, *Spodoptera frugiperda* (J. E. Smith), was controlled at weekly intervals in corn on Ecuador's coastal plain to determine the effect of plant stage on yield loss from pest injury. Greatest yield increases due to insecticide treatments occurred when plants were infested in the second week after germination; yields progressively decreased through tasseling. Economic injury levels calculated from a regression of these data increased from 11% to 42% infestation during the first 6 wk following plant emergence. Spray decisions based on economic injury levels linked to crop maturity could result in lower control costs than presently achieved with fixed economic injury levels.

KEY WORDS Insecta, *Spodoptera frugiperda*, corn, economic injury

FALL ARMYWORM, *Spodoptera frugiperda* (J. E. Smith), is a serious pest of corn in Ecuador (Páliz & Mendoza 1983) and in other parts of the Neotropics (Andrews 1980, 1988). Its importance as a field corn pest is greatly reduced at tasseling, when most larvae migrate from the whorl to leaf axils or ears where insect mortality is much higher (Morrill & Greene 1973).

Two other economic pests of corn in Ecuador are the stalk borers *Diatraea saccharalis* (F.) and *D. lineolata* (Walker) (Lepidoptera: Pyralidae) (Páliz & Mendoza 1983). Combined yield losses of 30–60% from fall armyworm and *Diatraea* spp. have been reported by Van Huis (1981). Economic thresholds for fall armyworm have been considered of primary importance for timing chemical control in tropical corn for two reasons. First, observation of foliar damage caused chiefly by fall armyworm is the most commonly used and simplest method for farmers to determine the need for insecticide treatment (Andrews 1980). Second, insecticides directed against fall armyworm in the whorl stage also control larvae of *Diatraea* spp. that have not yet penetrated the stalk (Van Huis 1981, Páliz & Mendoza 1985). We used percentage of plants infested as an index of population density because it is a parameter adaptable to farmer practices and because the number of larvae per plant generally decreases to one in the later instars due to cannibalism (Carvalho & Silveira 1971).

Economic thresholds based on economic injury levels for fall armyworm in the Neotropics vary from 20% (Van Huis 1981) to 30% (Páliz & Mendoza 1985). However, plant response to herbivore damage generally changes with plant development stage (Bottrell 1979, Buntin 1986) so that economic injury levels that change accordingly might provide a more exact guide for management decisions. We measured yield reductions due to fall armyworm damage at weekly intervals. From the yield reductions, we calculated weekly economic injury levels.

Materials and Methods

The experiment was repeated on two separate planting dates (21 January and 10 February) during the rainy season of 1986 at the research station of the Instituto Nacional de Investigaciones Agropecuarios (INIAP) at Pichilingue in Los Rios Province, 7 km SW of Quevedo (1.06° S, altitude 75 m, rainfall 2,079 mm, average temperature 24.3°C). A split-plot design was used with variety as main plots (two levels), insecticide application as subplots (two levels), and three replications. Main plots were eight rows wide and 100 m long. Four rows each of the varieties INIAP 526 (true breeding) and INIAP 550 (hybrid) were included in each plot. Subplots were the center two rows of each main plot, one row randomly assigned to insecticide treatment of infested plants and the other with no treatment. We used yield data from plants without fall armyworm injury to estimate losses that resulted from stalk borer damage. Data from 20 m of row randomly chosen within each plot for periodic insecticide treatment were used to estimate yield from plants free of insect damage.

The plots were located in a 0.5-ha (50 by 100 m) field planted in 90-cm rows with a mechanical seeder calibrated at 50,000/ha. Final plant densities were 36,000 and 48,000 for each planting date. Forty-five kg/ha each of $(NH_4)_2PO_4$ and KCl were incorporated before planting, and two side dressings of 100 kg/ha urea were banded 22 d and 37 d after planting. Herbicide treatments were atra-

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zine 80% wettable powder (Gesaprim; CIBA-GEIGY AG, CH-4002 Basel 7, Switzerland; 2 kg/ha) and alachlor (48 g/liter) (Lasso, Monsanto Agricultural Company, St. Louis; 3 liter/ha) at planting, and atrazine (1 kg/ha) 38 d later.

Weekly observations of all plants within the subplots for fall armyworm began 1 wk after plant emergence and continued for 5 or 6 wk until tasseling (second and first planting dates, respectively). One week after emergence, we marked a plant as infested if it had visible larvae or if the emerging and two most recent leaves had 10 or more scraped areas. Two to 6 wk after emergence, we identified infested plants by presence of larvae at least 1 cm long, or presence of fresh frass in the whorl and perforations in the emerging leaf. In addition, we evaluated 10 untreated plants and 10 treated plants from each subplot for stalk borer damage 72 d after planting by observing the total number of perforations and the number of perforated nodes below the ear.

In subplots designated for insecticide treatment of infested plants, applications were made the week infestation was first detected. Applications were made every 2 wk in plots designated for periodic insecticide treatment. The insecticide chloropyrifos 44.7% emulsifiable concentrate (Lorsban 4E, Dow Chemical USA, Midland, Mich.) was applied directly to the whorl, either mixed with sand (250 ml Lorsban + 100 kg slightly moist sand) at a rate of 1 liter/ha, or (in the first week of the first experiment) as a spray at the same rate. The two unused border rows of each plot were sprayed at 13 d and were treated with sand–insecticide at 20–30 d at the same rates as above. In addition, chloropyrifos or triazphos 50% EC (Hostathion, Hoechst-AG Agricultural Div., D-6230 Frankfurt(80) (Federal Republic of Germany), both at 0.5 liter/ha, were applied at 57 and 71 d with a motorized backpack sprayer to control infestations of grass looper, *Mocis latipes* Guenée (Lepidoptera: Noctuidae). There were 5 wk of treatments in the first experiment but only 3 wk in the second experiment because 1 wk was lost at the beginning when all plants had to be sprayed to reduce a heavy infestation of fall armyworm, and a week was lost at the end because of early tasseling.

At maturity, we randomly harvested 20 plants from each subplot. Ears were individually shelled and their grain was weighed. All individual grain weights were adjusted to 14% moisture. We evaluated yield differences with a split-split plot analysis of variance (Freund et al. 1986, 82–83), designating "variety" as whole plot, "insecticide treatment" as subplot, and "week (of treatment)" as sub-subplot. Plants with no yield (no ears or rotten ears) were eliminated from the analysis. Comparisons between least square means (very close to actual means) for treated and untreated plots on successive weeks were made using the LSMEANS and ESTIMATE statements of the GLM procedure (SAS Institute 1985, 193–197). We conducted oral interviews in May and June 1987 with farmers (n = 24) selected at random within 10 km of the experiment station to obtain information on costs of insecticide use in corn.

Table 1. Yield differences (least square means) of plants infested by fall armyworm within the previous week, with and without insecticide treatment

Planting date	Wk after germination	Difference[a]		SE[c] of estimate	$P^d > 0$
		LS means, g/plant	LS means, %[b]		
21 January	2	28.0	22.6	6.62	0.0001
	3	18.1	16.2	6.50	0.0055
	4	18.6	16.5	6.71	0.0056
	5	21.0	17.7	6.83	0.0022
	6	7.7	6.9	6.56	0.2406
10 February	3	14.8	17.8	5.50	0.0075
	4	12.2	15.2	5.40	0.0239
	5	9.1	13.1	5.63	0.1075

[a] Difference between least square means with and without insecticide (LSmeanI − LSmean0).
[b] 100(1 − LSmean0/LSmeanI).
[c] Standard error of the estimate LSmeanI − LSmean0 for treatment within week.
[d] Probability of H_0 LSmeanI − LSmean0 = 0.

Weekly economic injury levels were calculated from a formula proposed by Norton (1976): $E = C/PDK$, where C is the cost per hectare of an insecticide application ($12.15, SEM = 0.99, n = 25), P is the market price of corn ($100/1,000 kg), D is the loss in yield per hectare at 100% infestation, and K is the reduction in pest attack achieved by control; K was held constant at 0.85, a published value for efficiency of insecticidal control of fall armyworm in corn (Pitre 1986, Young 1986, All et al. 1986, Páliz & Mendoza 1987).

Results and Discussion

There were significant differences in both experiments between both whole-plot (varieties) and subplot (insecticide) treatments. The sub-subplot treatment (treatment week) was significant in the second experiment but not in the first (F = 5.3; df = 2,509; $P < 0.009$, and F = 0.88; df = 4,894; $P > 0.47$, respectively). However, significant differences were observed when comparisons were made between particular treatment weeks for both experiments (Table 1). Application of insecticide to plants recently infested with fall armyworm significantly increased yields through the first 5 wk after germination for the first planting date and through the first 4 wk after germination for the second planting date. Greatest yield reductions (28.0 g/plant, or 22.6% [first planting date]) occurred when plants were infested between the first and second weeks after germination, whereas differences at the last week before tasseling were not significant. Yields for plants infested 3 and 4 wk after germination were intermediate without showing any particular trend.

Table 2. Economic injury levels for fall armyworm

Wk after germination (X)	Economic injury level % Infestation (Y)	
	Actual	Expected[a]
2	14	11
3	21	19
4	23	27
5	26	35
6	50	42

[a] Predicted by the regression $Y = 7.7X - 4$ where Y is percentage of infestation and X is weeks after germination; $r^2 = 0.79$, $P = 0.04$.

Based on the difference between yields in periodically sprayed plots and plants never damaged by fall armyworm or treated with insecticides, stalk borer injury reduced yields an average of 10.8% (range, 0.8–30.1%). Periodic insecticide applications significantly reduced stalk borer damage ($F = 8.13$, $P = 0.005$) but did not eliminate it.

Economic injury levels calculated from Norton's equation were lowest 2 wk after germination (14%) and highest at tasseling (50%) (Table 2). Based on these results, early infestations should be controlled at lower levels than later infestations to achieve the same economic result. Such a practice should result in more economical use of pesticide with no greater risk than from decisions based on an unvarying economic injury level for the entire crop cycle.

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