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# EFFECT OF PERIOD AND LEVEL OF INFESTATION OF THE FALL ARMYWORM, *SPODOPTERA FRUGIPERDA*, ON IRRIGATED MAIZE YIELD

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ABSTRACT

The effect of period and level of infestation by the fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), on irrigated maize, *Zea mays* L., yield was determined. Two applications of the insecticide chlorpyriphos (336 g[ai]/ha) applied directly to the whorl produced yields equivalent to treatments with three applications. FAW infestation of 100% caused 45% yield reduction. A linear regression model (yield[g/plant] = 87.84 – 0.384 (% plants infested by FAW)) explained 46% of the yield variation. The economic injury level (EIL) was calculated as 2% of the plants infested. This low EIL is due to currently high subsidies provided pesticides in Nicaragua. The impact of pesticide subsidies on EIL's is discussed.

RESUMEN

Se determinó el efecto del período y nivel de infestación del gusano cogollero, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuide), sobre el rendimiento del maíz, *Zea mays* L., de riego. Dos aplicaciones del insecticida chlorpyrifos (336 g ia/ha) aplicados directamente al cogollo resultaron en rendimientos iguales que tratamientos con tres aplicaciones. Una infestación de 100% por el gusano cogollero causó una reducción de rendimiento de un 45%. Un modelo lineal de regresión (rendimiento [g/planta] = 87.84 – 0.384 [% plantas infestadas por *S. frugiperda*]) explicó el 46% de la variación en rendimiento. Se calculó el nivel de daño económico (NDE) como 2% de las plantas infestadas. Se debió este NDE bajo a los subsidios de insecticidas en Nicaragua. Se discute el efecto de subsidios de insecticidas sobre NDE's.

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In Central America, maize (*Zea mays* L.) is traditionally grown during the rainy season (May-December), and two crops can be harvested per year. In an effort to become self-sufficient in maize production, Nicaragua has added a third crop each year, during the dry season, through the introduction of irrigation on the Pacific Plain. Because this new production system is only 3 years old, an integrated pest management (IPM) program for the important insect pests of irrigated maize has not yet been developed. Because we already know the principle pests of irrigated maize, the first step in developing an IPM program is to determine the critical periods of protection and economic injury levels (EIL).

One of the principal pests of maize in Nicaragua is the fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith). FAW is present during all three cropping cycles, but is much more abundant during the second natural rainfall season and in irrigated maize. Pest populations are very high in irrigated maize in the Pacific Plain, where 100% of untreated plants are infested, with up to three 6th-instar larvae per plant.

The current recommendations issued by the Ministry of Agriculture to control FAW in irrigated maize are to apply insecticides 5 times during the vegetative phase every 5 days, three of which are directed solely against FAW (MIDINRA, 1984). Some producers apply insecticides up to 12 times per cropping cycle (personal observation).

Given the current control recommendations and practices used against FAW in irrigated maize and as a first step in developing an IPM program, we carried out a study with 3 objectives: 1) to determine the critical periods of protection from FAW during the vegetative phase, 2) within the periods of infestation which cause yield reduction, to determine the damage function between infestation and yield, and 3) use the damage function to calculate the economic injury level for FAW in irrigated maize.

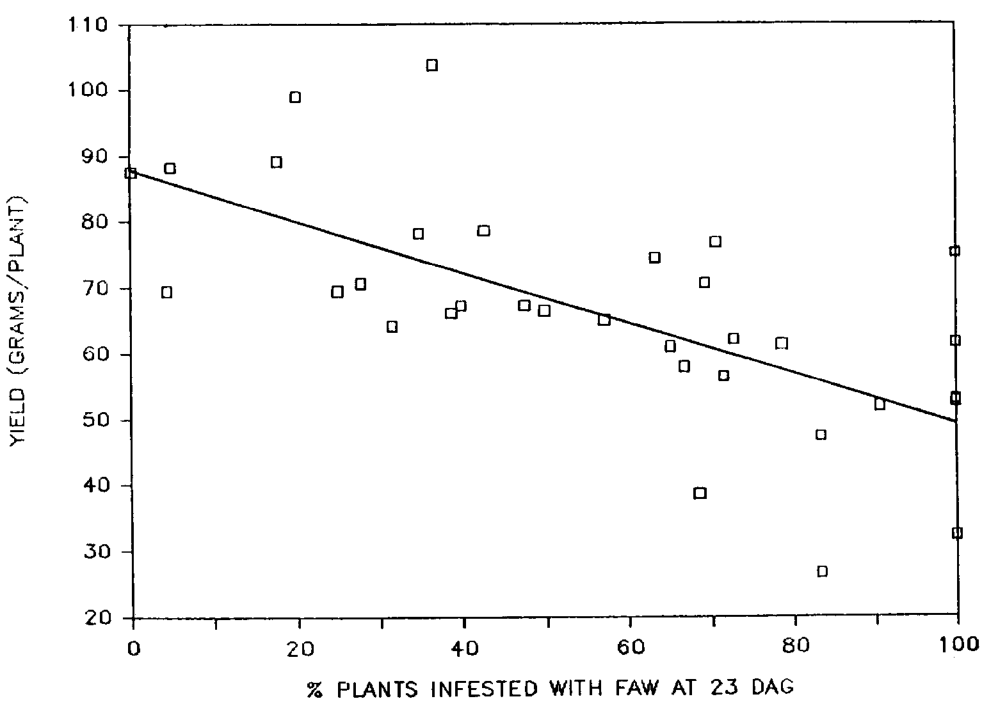


Fig. 1. Effect of FAW infestation at 23 DAG on Yield.

## Materials and Methods

Open-pollinated maize variety NB-6 was planted at the National Center for Basic Grain Research in Managua, Nicaragua, in March, 1987, with 7 plants/m and 80 cm between rows. Due to the naturally occurring 100% infestation level of FAW in maize, we created the treatments by applying insecticide to individual plants. Chlorpyrifos (480 E) was mixed with sawdust and applied by hand directly into whorls (336 g[ai]/ha), a commonly used practice against FAW in Central America.

A randomized complete block design with 20 treatments and 8 blocks was used. Treatments were combinations of 3 periods and 4 levels of infestation. The three periods were: 5-17, 17-31, and 31-45 days after germination (DAG), corresponding to seedling and early whorl, mid-whorl, and late whorl to tassel. The four levels of infestation were 100%, 70%, 40%, and 0% of the plants infested with FAW larvae (Fig. 1). Infestation by FAW was determined at 10, 23, 30, and 39 DAG, using the center row of each plot, by visually examining the whorl for FAW larvae, feeding damage, or frass.

At 115 DAG the central row of each plot was harvested, and total number, number broken, and number of lodged plants were counted. Mean yield of commercial grain at 15% humidity per plant was calculated for each plot.

To determine the effects of periods of infestation on yield, the 7 treatments that had 100% infestation during the periods were analyzed with an analysis of variance (ANOVA). Differences among treatments were determined with Tukey's multiple comparison test (Steel & Torrie 1980). Regression models were used to determine the relation between FAW infestation and yield. Stepwise regression was used to determine which date of infestation was the best predictor of yield.

## Results and Discussion

There was a significant effect of infestation period on yield (ANOVA, $F = 3.53$, d.f. = 6,38, $P < .01$). Treatments that were infested with FAW for 2 or 3 periods had a significantly lower yield than treatments that were not infested, or were infested during one of the periods (Table 1).

Using treatments that had infestation in two or three of the periods, a stepwise regression analysis indicated that, of the 4 infestation dates, 23 DAG was the best predictor of yield. Linear and quadratic regression models were compared, with the linear model explaining a greater percentage of the variance in yield. The estimated regression model is: $Y = 87.84 - 0.384(PI)$, with $r^2 = 0.458$, where $Y =$ yield (g/plant) and $PI =$ % plants infested (Table 2).

The results indicate that there is no one period that is more critical in causing yield reduction, although there is a non-significant tendency for infestation during later periods to cause greater yield loss (Table 2).

The results demonstrate that the entire vegetative phase of irrigated maize does not have to be protected from FAW to produce maximum yield. Two applications of chlorpyriphos produced yields that were not different from the treatment with three applications (Table 2). The effect of infestation by FAW on yield of irrigated maize appears cumulative during the vegetative phase, but maize plants are able to compensate for damage inflicted during any one period. Thus, the current insecticide recommendations could be reduced from current levels of 3-8 applications from seedling until tassel stage, to 2 during mid- to late-whorl stage, without reducing yield.

The shape of the damage function is different from the function obtained in similar experiments under natural rainfall where the regression model was curvilinear and yield did not decrease until 40% of the plants were infested (Hruska et al. 1987). Damage functions may be very specific to environmental conditions.

TABLE 1. EXPERIMENTAL TREATMENTS; PERIOD AND LEVEL OF INFESTATION BY *S. FRUGIPERDA*.

| Treatment | Period and Level of Infestation[1] Days After Germination 5–17 | 17–31 | 31–45 |
|---|---|---|---|
| 1. | ------100%------ | | |
| 2. | ------ 70%------ | | |
| 3. | ------ 40%------ | | |
| 4. | | ------100%------ | |
| 5. | | ------ 70%------ | |
| 6. | | ------ 40%------ | |
| 7. | | | ------100%------ |
| 8. | | | ------ 70%------ |
| 9. | | | ------ 40%------ |
| 10. | ------100%------ | ------100%------ | |
| 11. | ------ 70%------ | ------ 70%------ | |
| 12. | ------ 40%------ | ------ 40%------ | |
| 13. | | ------100%------ | ------100%------ |
| 14. | | ------ 70%------ | ------ 70%------ |
| 15. | | ------ 40%------ | ------ 40%------ |
| 16. | ------100%------ | ------100%------ | ------100%------ |
| 17. | ------ 70%------ | ------ 70%------ | ------ 70%------ |
| 18. | ------ 40%------ | ------ 40%------ | ------ 40%------ |
| 19. | | | |
| 20. | ------100%------ | ------100%------ | ------100%------ |

[1]Lines indicate infestation by FAW and numbers the percentage of plants infested.

TABLE 2. EFFECT OF PERIOD OF INFESTATION ON YIELD.

| Treatment | Period of Infestation (Days After Germination) 5–17 | 17–31 | 31–45 | Yield[1] (g/plant) (S.D.) | |
|---|---|---|---|---|---|
| 1. | ---------- | | | 69.76 (11.82) | A |
| 2. | | ---------- | | 64.95 (19.66) | A |
| 3. | | | | 59.11 (27.83) | A |
| 4. | | | ----------- | 58.73 (13.84) | A |
| 5. | ---------- | ---------- | | 51.72 (8.82) | B |
| 6. | | ---------- | ----------- | 41.12 (10.51) | B |
| 7. | ---------- | ---------- | ----------- | 38.67 (16.77) | B |

[1]Means followed by the same letter do not differ significantly according to Tukey's test (P>.05).

Yield was reduced by 45% when 100% of the plants were infested. This yield reduction is more severe than studies conducted under natural rainfall, where 100% infestation caused between 15-30% yield reduction (Obando 1976, Van Huis 1981, Hruska et al. 1987).

The difference in the shape of the yield/infestation function and the greater reduction in yield in irrigated maize may be due to greater water loss in plants under irrigated maize than under natural rainfall. Irrigated maize grown in the hot dry season with typically strong winds would undergo high rates of evapotranspiration. Equal amounts of defoliation would be expected to produce greater water loss in the dry season than under natural rainfall.

Using the estimated damage function, the economic injury level (EIL) was calculated to be 2% of the plants infested. This is far lower than any other calculated EIL for FAW in maize, where published values vary between 20 and 50% (Sarmiento & Casanova 1975, Young & Gross 1975, Obando 1976, Van Huis 1981, Young & Gross, unpublished).

EIL's change any time there is a change in the damage function, value of the crop, cost of control, or efficacy of control changes (Hruska & Rosset 1987). An examination of the EIL calcualtion revealed that the low value was due to the relatively low cost of pesticides.

In Nicaragua, as in many developing countries pesticides are heavily subsidized by the government (Repetto 1985). Nicaraguan farmers pay between 3-5% of the world market cost for agricultural inputs. At the same time that pesticide prices are low, crop prices are relatively high, due to a shortage of basic grains in the country. The relation between the cost of insecticide and the value of maize is 0.52 (price of 3.78 liter of chlorpyrifos to the producer/value of 45.4 kg of maize), whereas in the United States the realtionship is 13.45 (Hruska & Gladstone 1987).

If we use world prices for insecticides and maize the EIL is 20% of the plants infested, similar to values reported in the literature (Sarmiento & Casanova 1975, Obando 1976, Van Huis 1981).

The *raison d'etre* of the EIL is to eliminate uneconomical pesticide applications. The decision criterion is set at maximizing profit for the individual farmer. What maximizes individual profit, however, may not maximize social profit.

Pesticide subsidies are a double-edged sword. On the one hand they make agricultural inputs readily available to farmers with limited resources, while on the other hand they may encourage unnecessary pesticide use. The classical EIL calculation may not provide a useful decision rule for farmers and countries with subsidized pesticides. A new decision rule is necessary, one that estimates and incorporates the values of "externalities" in the calculation. Hruska & Gladstone (1987) suggest a method to calculate a revised EIL and set pesticide subsidy levels to meet the goals of society.

## Acknowledgments

We thank the Instituto Superior de Ciencias Agropecuarias and the Ministerio de Desarrollo Agropeucario y Reforma Agraria for support of this work with material resourses. This research was supported in part by a grant from the Norwegian Ministry of Development Cooperation.

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# EVALUATION OF RICE CULTIVARS FOR ANTIBIOSIS AND TOLERANCE RESISTANCE TO FALL ARMYWORM (LEPIDOPTERA: NOCTUIDAE)

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## ABSTRACT

The effects of antibiosis on the growth of fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), larvae by rice, *Oryza sativa* L., seedlings at different plant stages and the tolerance of seedlings to artificial defoliation at the 7-leaf stage were evaluated in five plant introductions (PI) and the check cultivar 'Mars'. FAW larvae fed 5-leaf stage foliage had significantly lower larval, pupal, and adult weights than larvae fed 3-leaf stage foliage. The effects of antibiosis on the growth of FAW were evident in PIs 160842, 160827, 346833, and 346839, but not in PI 160823 or Mars. PIs 160842, 160827, and 160823 exhibited higher tolerance in plant regrowth after defoliation than PI 346833, 346839, or Mars. PIs 160842 and 160827 exhibited both the antibiosis and tolerance resistance.

## RESUMEN

Se evaluó en cinco plantas introducidas (PI) y en la variedad testigo 'Mars', el efecto de antibiosis en el crecimiento de larvas del gusano cogollero, *Spodoptera frugiperda* (J. E. Smith), en plantas de semillero de diferentes etapas de crecimiento del arroz, *Oriza sativa* L., y de la tolerancia de las plantas a la defoliación artificial en la etapa de 7-hojas. Larvas, pupas, y adultos del gusano cogollero alimentadas con follaje de la etapa de 5-hojas, tuvieron significativamente un peso menor que las larvas que se alimentaron con follaje de la etapa de 3-hojas. El efecto de antibiosis en el crecimiento