Density of the Lesser Cornstalk Borer, *Elasmopalpus lignosellus* (Zeller) in Peanut Fields: Endemic and Outbreak Population Configurations

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ABSTRACT

The population growth of *Elasmopalpus lignosellus* (Zeller), the lesser cornstalk borer (Insecta: Lepidoptera: Pyralidae), was determined in conventionally tilled Florunner peanut fields in endemic (1983-1985) and outbreak (1986) population configurations. The density of *E. lignosellus* eggs, larvae, and pupae was estimated by weekly soil flotation and by soil sieving. Adult density and abundance was estimated with pheromone traps, emergence cages, and flush samples.

In the endemic years, low levels of eggs, larvae, pupae, and adults occurred throughout the growing season. Adult populations exhibited 1-2 weak peaks per growing season. The outbreak year was characterized by an exponential increase in *E. lignosellus* eggs, larvae, pupae, and adults.

A regression relationship was developed from the 1983-1986 data that relates the weekly mean number of *E. lignosellus* larvae per meter determined by soil sieving to the total rainfall (cm) and the number of hot (≥35 C daily maximum temperature) days in the previous 30 days. This is a predictive tool that can be used to time sampling to predict possible larval population increases before extensive damage occurs.

Key Words: *Elasmopalpus lignosellus*, population ecology, sampling methods, temperature effects.

The lesser cornstalk borer, *Elasmopalpus lignosellus* (Zeller) (Insecta: Lepidoptera: Pyralidae), is a key pest of peanuts grown in the New World and the most economically damaging insect pest of peanuts in the southeastern U.S. (18). Population outbreaks typically occur during periods of hot, dry weather in peanuts grown in sandy soils (3,7,8,9,18). Outbreaks of *E. lignosellus* caused over $43 million in damage to peanuts in Alabama, Georgia, Oklahoma, and Texas in 1980 alone. Yield losses can exceed 70% following severe outbreaks (18). Furthermore, *E. lignosellus* feeding on pods has been linked to seed infections by *Aspergillus flavus* Link ex Fries (R. E. Lynch, personal communication), a fungus which produces aflatoxin that is extremely toxic to mammals, including man and cattle. Accurate prediction of *E. lignosellus* populations is highly desirable, since the damaging larval stage is usually subterranean and extremely difficult to sample.

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Few studies quantitatively document the development of *E. lignosellus* on any crop, and no published studies have examined population growth in both "endemic" and "outbreak" population configurations, as defined by Pedigo *et al.* (14). These data are essential to understanding why *E. lignosellus* outbreaks occur in hot, dry weather. Consequently, studies were initiated in 1982 to determine *E. lignosellus* population growth and development. This paper documents egg, larval, pupal, and adult *E. lignosellus* population growth in endemic (1982-1985) and outbreak (1986) configurations.

Materials and Methods

Experiments were conducted from 1982-1986 at the Alabama Agricultural Experiment Substation in Headland, AL. Florunner peanut seeds were planted in conventionally tilled 91 cm rows in a Dothan fine sandy loam soil. Fields sampled for *E. lignosellus* were ca. 1-2 ha in size. Herbicides and fungicides were applied each year according to extension recommendations.

Insect populations were monitored weekly throughout each growing season. Sampling typically began in early June (ca. 30 days after planting) and ended in early September. Peanut plants were ca. 17 cm tall when sampling began in 1982, were at the V5 plant growth stage in 1983 (1), were V10 in 1984, V8 in 1985, and were at the V14 growth stage in 1986. Weed populations which were also monitored weekly each year, were uniformly low. The only exception to this was yellow nutsedge (*Cyperus esculentus* L.), which was moderately abundant in sampled fields throughout the study.

Egg Sampling: The density of *E. lignosellus* eggs on peanut plants and in the soil was determined weekly from 1984-1986 by soil flotation (19). Our preliminary tests of this technique resulted in a mean of 85% recovery, which is within two standard errors of the mean of 90 ± 3.35% reported by Smith *et al.* (19). In 1984, 10 randomly selected 46 cm long by 30 cm wide by 2.5 cm deep soil samples were collected each week. In 1985 and 1986, each sample was 30 cm long by 30 cm wide by 2.5 cm deep. Each sample was collected from underneath the peanut canopy, with the longitudinal axis of the samples parallel to the rows. Each soil sample was placed in a 3.8 liter plastic bag and was returned to the laboratory for processing within 48 h. Peanut plants growing in each 46 cm section were placed in a 49 liter plastic bag and were also processed. All samples were placed in a walk-in cooler until processed.

In 1984, eggs were not incubated to verify correct identification. In both 1985 and 1986, eggs and larvae collected from soil and plant samples were individually incubated to verify identification, to determine egg viability, and to estimate parasitism.

Larval and Pupal Density: The density of *E. lignosellus* larvae and pupae was determined in 1982-1986 by soil sieving and in 1984-1986

by flotation. The soil sieving technique consisted of sieving in the field 10 randomly selected 91 cm long by ca. 30 cm wide by ca. 2.5 cm deep soil samples each week. The longitudinal axis of each sample was centered over each row. Soil was processed through an 8 or 10 mesh sieve depending upon soil moisture, and the number of larvae and pupae found was recorded.

The density of *E. lignosellus* larvae and pupae was also determined by flotation. Larvae found in the soil were counted and recorded and plant samples were processed for egg density estimation. Living larvae collected in this manner were separately incubated to determine percent parasitism.

Adult Density: Two sampling techniques were used to estimate the density of *E. lignosellus* adults, and one method was employed to estimate adult abundance. Pheromone traps (10,13) were employed from 1982-1986, and both emergence cages and the flushing technique (5,15) were used from 1984-1986. Four traps (Pherocon 1C) baited with a rubber septum containing an *E. lignosellus* sex attractant (courtesy of R. E. Lynch, Coastal Plain Experiment Station, Tifton, GA 31793) were monitored weekly in 1982 and at least twice a week in 1983-1986. Traps were placed on 2.5 cm diameter metal pipes placed within the rows. The sticky surfaces of the traps were ca. 90 cm from the soil line. Septa were replaced weekly, and each trap was changed when a total of ca. 100 moths were caught.

E. lignosellus pupates in the soil, and adults must emerge from the soil to mate and oviposit (20). Emergence cages were constructed to monitor the density of emerging adults. Ten cages per field were used in 1984, six in 1985, and five in 1986. Each 91 cm long by 91 cm wide by 91 cm high cage was randomly placed within a field, and the sides were covered with soil to a depth of ca. 5 cm. The density of newly emerged adult *E. lignosellus* trapped within each cage was determined weekly by lifting the cage, agitating the plants, and counting the adult moths present. Cages were moved to new randomly selected locations weekly, and old locations were flagged to prevent reuse.

Adult *E. lignosellus* population size was also estimated by flushing moths from fields. This technique has been used to determine the absolute density of lepidopteran species in many agricultural habitats (5). In 1984, two, 30 m by 2 row sections of row were sampled weekly; two, 91 m by 2 row sections were sampled in 1985 and 1986. Sampling occurred at or near dawn, since adults are nocturnal and crepuscular in activity (8). Three samplers were required to take a flush sample. Two people (flushers) used a 1 m rod to vigorously agitate the plants within two adjacent rows. An observer recorded the number of moths flying from the disturbed plants. Flight patterns were distinctive, and with little practise *E. lignosellus* adults could be distinguished from other species flushed from the rows. Most adults that were flushed in 1984 and 1985 were collected and identified in situ, and no moths identified as *E. lignosellus* were determined to be another species. In 1986, adult populations were so high for most sample dates that collection of every moth that was flushed was impossible; however, all those collected were determined to be *E. lignosellus*.

Data Analyses: An exponential growth equation was fit to the 1986 egg, larval, pupal, and adult weekly means:

$$N_t = N_0 \bullet EXP(r \bullet t)$$

where N = population size, r = intrinsic rate of increase, and t = time since the first non-zero sample. Nonlinear regression was employed to fit this model to the data (16). Statistical significance of these regressions was determined by a Shapiro-Wilk normality test on the residuals, because an F statistic could validly be calculated (2).

Regression analysis was used to determine if emergence cage estimates of adult population size and pheromone trap counts were related to flush count means. Regression analysis was also employed to determine if larval density estimates from the soil sieving technique were related to estimates from flotation. Stepwise regression (16) was used to determine the relationship between environmental conditions and the weekly mean number of larvae estimated from soil sieving for 1983-1986.

Estimates of *E. lignosellus* population size were converted to number per meter of row for ease in comparison. The only exception to this was the adult male pheromone trap counts, which were analysed as number per trap per night. Egg and larval sampling means determined from soil sieving, and adult sampling means from the emergence cages were converted to the number per meter of row by calculating the percent of a row-meter that the length represented and by dividing the mean by the decimal percent.

Results

Egg Density: E. lignosellus egg density varied among years (Fig. 1). Density in 1984 was high early in the season, and declined as the season progressed. In 1985, eggs from a carabid beetle were found to be extremely similar to *E. lignosellus* eggs, so the observed population fluctuations in 1984 may not truly reflect *E. lignosellus* egg density. In 1985, *E. lignosellus* egg density was uniformly low throughout the season, with no apparent large peaks. Egg density in 1986 contrasted strikingly with the 1985 data. *E. lignosellus* egg density increased exponentially from 7 July 1986 to 20 August 1986, and decreased exponentially from 20 August 1986 until sampling ceased on 2 September 1986 (Table 1). The rate of population increase, as measured by the intrinsic rate of increase "r", was statistically equivalent to the rate of population decline. Peak egg density occurred on 20 August 1986 at 7.66 eggs/m.

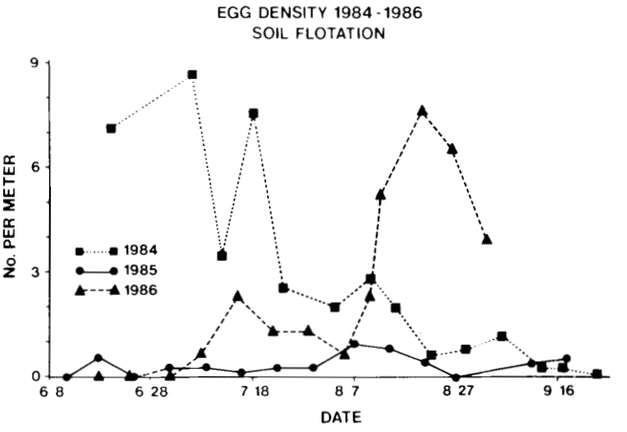

Fig. 1. Density of *E. lignosellus* eggs in 1984-1986 as determined by soil flotation. Each point is a mean of 10 observations.

Egg viability was 100% throughout study, and no infertile eggs were found. Parasitization of eggs in the study was 0.0%, suggesting that egg parasites cannot easily find *E. lignosellus* eggs or that there were very few egg parasites.

Larval and Pupal Density: E. lignosellus larval density was very low from 1983-1985 (Fig. 2a), with a maximum population size of less than 3 larvae/m in these endemic years. In 1986, which was an outbreak year, the larval population increased exponentially from 25 June 1986 until 5 August 1986 (Table 1).

Larval density calculated from the soil flotation method produced similar but not identical results (Fig. 2b). Populations were low in endemic years and high in the outbreak year, but larval population fluctuations were more pronounced with the flotation technique. The larval population increased exponentially from 15 July 1986 to 20 August 1986 (Table 1). However, the rate of increase from the flotation technique was more than three SEs less than the rate of increase calculated from the soil sieving data.

The larval population determined by soil sieving was linearly related to the population estimate from flotation in two of the three years tested ($p \leq 0.03$) (Table 2).

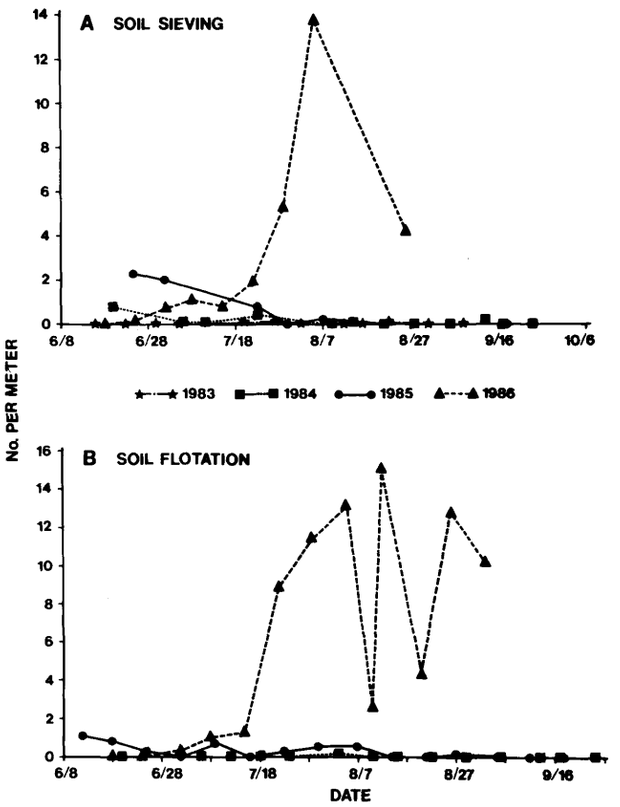

Fig. 2. Density of *E. lignosellus* larvae in 1983-1986. A = soil sieving, and B = soil flotation. Each point is a mean of 10 observations.

Table 1. Fit of exponential growth equation to lesser cornstalk borer 1986 seasonal density means[a].

Stage	Sampling Method	No.[b]	N_o[c] ± SE	r[c] ± SE
Egg	Flotation	8	0.75 ± 0.083	0.073 ± 0.0185
Egg	Flotation	4	8.01 ± 0.569	-0.053 ± 0.0093
Larvae	Flotation	7	1.18 ± 0.736	0.048 ± 0.0127
Pupae	Flotation	6	0.00003 ± 0.00007	0.244 ± 0.0482
Larvae	Soil Sieve	7	0.02 ± 0.009	0.133 ± 0.0092
Adults	Flushing	9	0.05 ± 0.030	0.051 ± 0.0099
Adults	Emerg. Cages	5	0.15 ± 0.064	0.093 ± 0.0127

[a] $N_t = N_o * EXP(r*t)$, where N=population size (no./m), r=the intrinsic rate of increase, and t=time in days since the first non-zero sample.

[b] No. of sample dates used in the analysis.

[c] Parameters estimated using nonlinear regression. All regressions are significant, as measured by a normality test on the residuals ($p<0.01$).

Slopes for the two significant regressions, however, were vastly different, with a slope of 7.80 ± 1.45 (mean ± SE) in 1984 and 0.58 ± 0.20 in 1986. An analysis over all years did produce a significant regression (Table 2), but because of the among year variability a single equation converting soil sieve means to flotation means is not recommended.

Table 2. Regression statistics for the relationship of lesser cornstalk borer larvae found using soil sieves to the number calculated from the flotation technique[a].

Dataset	No.[b]	Slope ± SE	Intercept ± SE	Prob.[c]	r^2
1984	11	7.80 ± 1.45	0.09 ± 0.04	<0.01	0.76
1985	5	0.23 ± 0.72	0.15 ± 0.26	0.77	0.03
1986	8	0.58 ± 0.20	-0.05 ± 1.68	0.03	0.58
1984-1986	24	0.57 ± 0.08	0.09 ± 0.38	<0.01	0.69

[a] Y=m*X + b, where Y=soil sieve mean and X=flotation mean.

[b] Number of sample dates used in the analysis.

[c] Probability of a greater F statistic.

No parasites of *E. lignosellus* larvae were recovered from larvae reared until adulthood from weekly soil flotation samples collected in 1984-1986.

No *E. lignosellus* pupae were found with the soil sieve technique in 1983 and 1984 (Fig. 3a). In 1985, pupae were found on only two sample dates whereas in 1986 pupae were found on six dates. Pupal density estimated from soil flotation was similar to the soil sieve means (Fig. 3b). No *E. lignosellus* pupae were found in 1984 with the soil flotation technique. In contrast to the soil sieve results, no pupae were also found in 1985. In

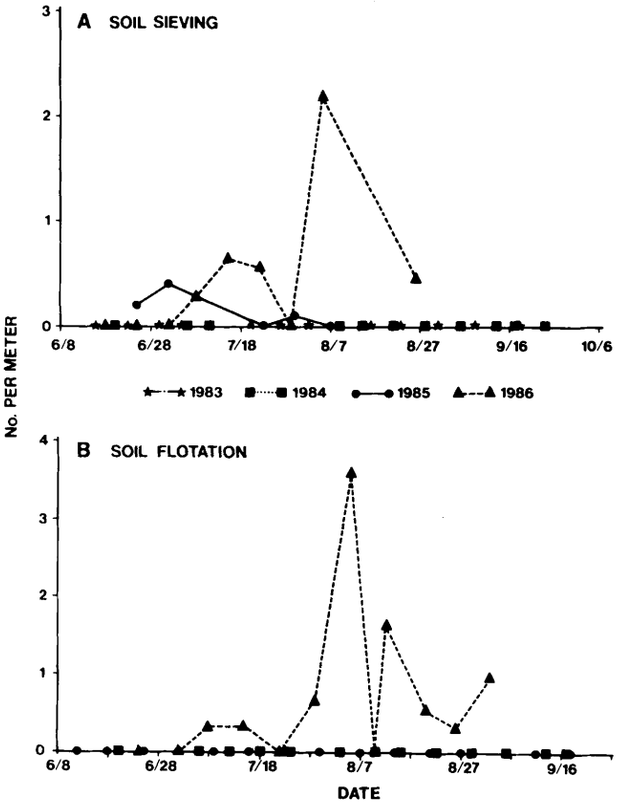

Fig. 3. Density of *E. lignosellus* pupae in 1983-1986. A = soil sieving, and B = soil flotation. Each point is a mean of 10 observations.

1986, the *E. lignosellus* population calculated from soil flotation increased exponentially from 2 July 1986 until 5 August 1986 (Table 1). The rate of pupal population growth was much greater than the rate of egg or larval growth from soil flotation.

Adult Abundance and Density: E. lignosellus adult male abundance, as measured by pheromone traps, was extremely variable from 1982-1986 (Fig. 4a). Abundance in 1982 and 1983 was variable and low, with a peak population size of 17.5 moths per trap per night occurring on 13 July 1982 and 4.3 moths per trap per night on 22 August 1983. Two peaks occurred in adult male abundance in 1984. Both of these adult abundance estimates were more than two SEs greater than those immediately preceding and following. In 1985, the largest population of male moths occurred on 14 June. Thus, at least one population peak occurred in each of the endemic years. No discernible peaks occurred during the outbreak year of 1986. Instead, male moth populations appeared to fluctuate wildly from date to date. This was particularly apparent in August, when the trap means were 6.4, 11.3, 3.2, 4.7, 11.2, 4.1, 2.5, 14.5, 3.4, 13.3, and 9.2 moths per trap per night, respectively.

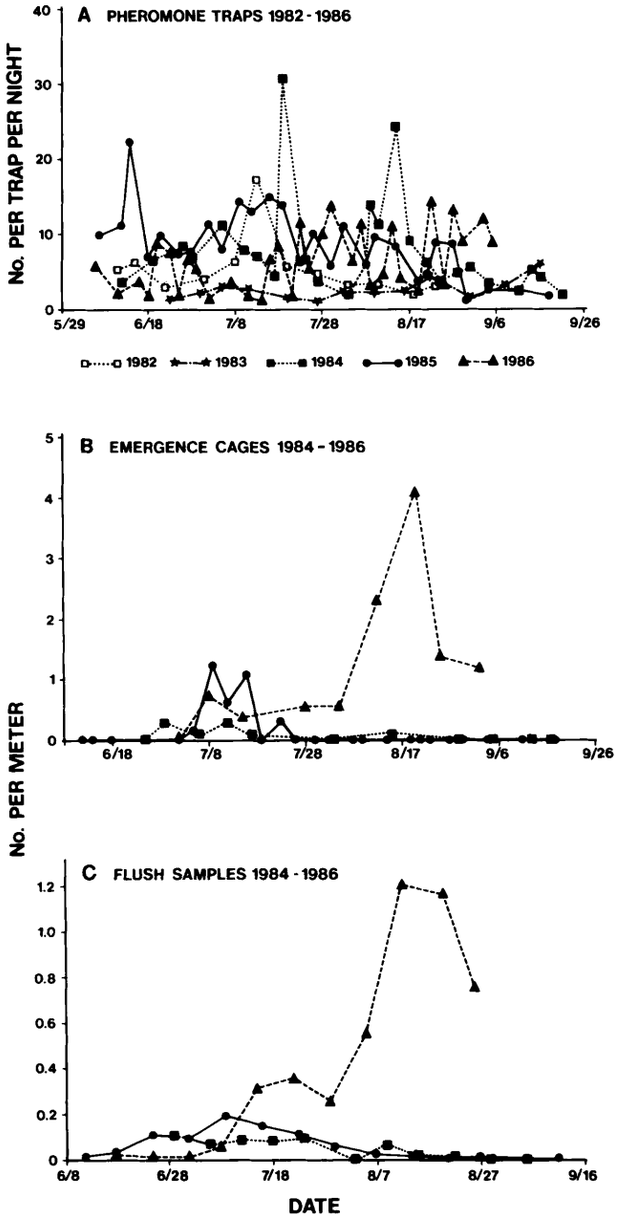

Fig.4. Density and abundance of *E. lignosellus* adults in 1982-1986. A = male abundance from pheromone traps, B = adult density from emergence cages, and C= adult density from flush samples. Most pheromone trap means were calculated from counts from four traps; a few are from three traps and were caused by excessive wind knocking down a trap. Ten emergence cages were used in 1984, six in 1985, and five in 1986. 120 m of row were flush sampled each week in 1984, and 364 m were flushed in 1985-1986.

Adult *E. lignosellus* density as determined by emergence cages varied among years (Fig. 4b). Very few adults were found in emergence cages in 1984, with a peak population size of only 0.27 adults per meter occurring on both 29 June 1984 and 12 July 1984. The emerging adult population peaked at 1.2 moths/m on 9 July 1985. In neither year did the population grow exponentially. In 1986, the newly emerged adult *E. lignosellus* population increased exponentially from 15 July 1986 until 20 August 1986, when a peak population of 4.1 moths/m occurred (Table 1). After this date, moth populations declined to less than 1.4 moths/m.

Adult *E. lignosellus* population trends calculated from flush samples were very similar to emergence cage trends (Fig. 4c). Few adults were flushed in the endemic population years of 1984-1985, and the population grew exponentially in 1986 (Table 1). The intrinsic rate of increase was similar for both flush and emergence cage regressions, as indicated by overlapping means ± 3 SEs. A peak population size of 1.2 moths/m occurred on 12 August 1986.

The mean number of male moths per pheromone trap per night was linearly related to the number of moths per meter calculated from flush samples in only one of three years (Table 3). Large differences in regression slopes among years suggest that no simple relationship existed between trap and flush counts. Also, there was no linear or curvilinear relationship relating trap counts to flush counts over all years (Table 3).

Table 3. Regression statistics for the relationship of adult male lesser cornstalk borers caught per trap per night to the number of moths per meter as determined by the flush technique [a].

Dataset	No.[b]	Slope ± SE	Intercept ± SE	Prob.[c]	r^2
1984	10	4.11 ± 11.26	8.14 ± 2.54	0.72	0.02
1985	13	40.56 ± 13.88	5.82 ± 1.19	0.01	0.44
1986	11	0.94 ± 2.17	3.20 ± 1.19	0.67	0.02
1984-1986	34	-2.21 ± 2.99	7.30 ± 1.01	0.47	0.02

[a]Y=m•X + b, where Y=trap count mean and X=flush count mean.

[b]Number of sample dates used in the analysis.

[c]Probability of a greater F statistic.

The mean number of newly emerging moths was linearly related to the number of moths per meter found with flush samples in two of the three years tested

($p \leq 0.01$) (Table 4). Further, the mean number of emerging adults was linearly related to the flush sample population estimates when data were pooled over all years ($p < 0.01$). (Table 4). However, an examination of the regression slopes within year indicates that the use of the pooled slope to calculate the mean number of emerging adults per date may over- or underestimate population size.

Table 4. Regression statistics for the relationship of adult lesser cornstalk borers caught in emergence cages to the number of moths per meter as determined by the flush technique[a].

Dataset	No.[b]	Slope ± SE	Intercept ± SE	Prob.[c]	r^2
1984	8	0.08 ± 0.20	0.08 ± 0.05	0.69	0.03
1985	13	5.83 ± 1.20	-0.17 ± 0.10	<0.01	0.68
1986	6	2.84 ± 0.66	0.06 ± 0.42	0.01	0.83
1984-1986	27	2.51 ± 0.34	0.01 ± 0.11	<0.01	0.69

[a]Y=m•X + b, where Y=emergence cage mean and X=flush count mean.

[b]Number of sample dates used in the analysis.

[c]Probability of a greater F statistic.

Relating Larval Density to Weather: Stepwise regression analysis results indicate that the weekly mean number of *E. lignosellus* larvae determined by soil sieving from 1983-1986 was related to two environmental variables (N = 35 sample dates, $p \leq 0.02$, $r^2 = 0.52$):

$$Z = -3.1886 + 0.2794 \bullet X + 0.1754 \bullet Y$$

where Z = larval population size (no./m), X = number of days in the previous 30 where the daily maximum temperature was ≥ 35 C, and Y = total rainfall (cm) during the previous 30 days. Thus, when little rainfall occurred and it was very hot during the day more lesser cornstalk borer larvae were found in sieve samples.

Discussion

Both endemic and outbreak population configurations occurred in 1982-1986. In the endemic configuration, low population levels of eggs, larvae, pupae, and adults occurred throughout the growing season. Adult populations exhibited 1-2 peaks per growing season, as measured by pheromone traps, emergence cages, or by flushing. Discrete generations in endemic years have been reported in sorghum (6) and peanuts (8). The outbreak configuration was characterized by an exponential increase in *E. lignosellus* eggs, larvae, pupae, and adults with time. No discernible peaks occurred until abiotic factors became unfavorable for continued population development.

Exponential growth is a continuous growth function that assumes a stable age distribution and no discrete generations (21). Lack of discrete generations implies continuous immigration, overlapping generations caused by individual variability in development rates, or other unknown processes. The emergence cage means in 1986 were routinely greater than the flush sample weekly means, indicating that immigration contributed little to the population outbreak. Thus, population overlap was apparently caused by variability in individual development times (17), or by unknown factors.

The *E. lignosellus* population outbreak in 1986 was probably caused by favorable environmental conditions, i.e. drought combined with unusually hot weather. There were 26 days in July 1986 that had a daily maximum temperature of ≥ 35 C, which was twice that recorded for any month during the 1982-1985 growing seasons. Also, the 15 June to 15 August period was drier in 1986 than similar periods in 1982-1985. Hot and dry conditions are favorable for *E. lignosellus* population development because of a) increased daily oviposition rate, b) increased egg, larval, and pupal development rates resulting from higher daily soil temperatures and lower soil moisture, and c) decreased egg and larval mortality (11,12). In the southeastern U.S., isolated *E. lignosellus* population outbreaks in endemic years are spatially and temporally separated, probably because of the spatially and temporally hetergeneous nature of rainfall. Further, suitable hosts for *E. lignosellus* are themselves spatially and temporally distributed. Thus, *E. lignosellus* management cannot be viewed as if this insect only attacks peanuts, but must be viewed in the context of infested peanut fields in a suitable crop mosaic of corn, small grains, peanuts, and sorghum, with population growth and extinction governed by abiotic conditions (12). This makes area-wide prediction of outbreaks in peanuts possible only if area-wide abiotic conditions prevail. Such events do occur (ex: 1986). Prediction of isolated outbreaks in endemic years must be done on a field to field basis. The regression relationship that relates the mean number of *E. lignosellus* larvae per meter calculated by soil sieving to the total rainfall (cm) and the number of hot (≤ 35 C daily maximum temperature) days in the previous 30 days will enable such predictions to be made. This predictive tool can be used to time sampling to detect larval population increases before extensive damage occurs. Thus, soil sieving for larvae, combined with daily records of total rainfall and the number of hot days should aid in forecasting outbreaks.

Egg and larval parasitization rates in this study were 0%, even in the outbreak population year. Funderburk *et al.* (4) reported that parasitism of *E. lignosellus* larvae collected from peanuts fields in northern Florida was < 4%. Egg viability in this study was 100%, even after the eggs were submerged in a 1.0% sodium hypochlorite solution and a magnesium sulfate solution. This suggests that very few unfertilized eggs are laid by *E. lignosellus,* or that infertile eggs are rapidly destroyed by bacteria, fungi, etc.

Based on our 1984-1986 analyses, no means from one *E. lignosellus* larval or adult sampling technique can be used to calculate the means from another sampling technique. The slopes of the significant regressions varied markedly among years, indicating that attempted sampling technique conversions could significantly over- or underestimate actual means. Pheromone traps inadequately estimated adult population trends as determined by flushing, and no overall regression could be calculated relating pheromone trap means to flush means. Funderburk *et al.* (5) found that *E. lignosellus*

adults were linearly related to those found from flushing in 1982. However, only one year's regression results were reported.

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