Seasonal Abundance and Overwintering Mortality In Populations of Lepidopterous Leafminers of Pecan[1]

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ABSTRACT Seasonal monitoring of four leafminers on pecan foliage, *Stigmella juglandifoliella* (Clemens), *Cameraria caryaefoliella* (Clemens), *Phyllonorycter caryaealbella* (Chambers), and *Coptodisca lucifluella* (Clemens), indicated that larval densities of all four species were highest in late summer and fall. *Stigmella juglandifoliella, C. caryaefoliella, P. caryaealbella* and *C. lucifluella* appear to have at least 5, 4, 4 and 4 significant increases in larval density per year, respectively. First emergence of *C. caryaefoliella* and *P. caryaealbella* adults occurs from mid- to late March. Larval mortality caused by hymenopterous parasitoids ranged from 14-61%. Overwintering mortality of *C. caryaefoliella* and *P. caryaealbella* ranged from 31 to 95% and 27 to 40%, respectively.

KEY WORDS Microlepidoptera, field biology, overwintering, parasitoids, *Carya illinoinensis, Stigmella juglandifoliella, Cameraria caryaefoliella, Phyllunorycter caryaealbella, Coptodisca lucifluella.*

Pecan leafminers, *Stigmella juglandifoliella* (Clemens) (Lepidoptera: Nepticulidae), *Cameraria caryaefoliella* (Clemens), *Phyllonorycter caryaealbella* (Chambers) (Lepidoptera: Gracillariidae) and *Coptodisca lucifluella* (Clemens) (Lepidoptera: Heliozelidae), are common in commercial and urban plantings and wild stands throughout the southern United States (Payne et al. 1972). Populations of these leafmining Lepidoptera are regulated by a wide range of natural enemies including 35 hymenopterous parasitoids (Heyerdahl and Dutcher 1985a). A general model of the structure of this complex identifies stabilizing and destabilizing elements in the pecan leafminer-parasitoid system (Dutcher and Heyerdahl 1988). Lepidoterous leafmining species are pestiferous in other crops. *Phyllonorycter blancardella* (F.) and *P. crategella* (Clemens) are considered to be major apple pests (Dutcher and Howitt 1978, Maier 1981). The attainment of pest status by these *Phyllonorycter* species occurs when moths evade parasitoid action through invasion of new geographic areas or when a pesticide driven, selective process occurs that favors insecticide resistant moths over parasitoids (Van Driesche and Taub 1983). We have observed pecan leafminer outbreaks usually occur in orchards with a history of repeated applications of organophosphate insecticides.

Pecan leafminers are controlled with insecticide treatment of the foliage (Payne and Ellis 1978, Dutcher and Payne 1979, 1983). Heyerdahl and Dutcher (1985b) demonstrated the effectiveness of timing to increase the efficacy of a single insecticide spray that coincided with peak adult emergence of *S. juglandifoliella.*

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The purposes of this study were to monitor the abundance of larval population densities of four species of pecan leafminers, measure total percent parasitism by all hymenopterous parasitoids throughout the growing season, measure mortality in the overwintering larvae and pupae, and monitor spring emergence of adult *C. cameraria* and *P. caryaealbella.*

Materials and Methods

The overwintering life stages of *C. caryaefoliella* and *P. caryaealbella* were determined in a heavily infested pecan orchard by sampling during the 1981 - 1982 winter (*S. juglandefoliella* and *C. lucifluella* pupate and overwinter in cocoons outside the leaf). Sampling was initiated on 22 November 1981 and continued until adults began to emerge in the overwintering cages or until all mines were found to contain the pupal stage. Leaflets containing mines were randomly collected from lower tree branches or from the orchard floor, and dissected in the lab to determine the stage of development of miners. At least 25 mines of each species were sampled on each date.

To determine abiotically induced mortality in the overwintering generation of *C. caryaefoliella* and *P. caryaealbella,* mines of both species were placed in 0.6 m × 0.6 m wood-cages. The spring emergence of adults also was monitored from these same mines. Four-hundred *C. caryaefoliella* and 720 *P. caryaealbella* mines were placed in overwintering cages in 1980. Seven-hundred-twenty mines of each species were caged in 1981. Two overwintering cages were used for each leafminer speces and each cage contained 360 mines.

Overwintering cages were 60 × 60 × 65 cm plywood boxes with open bottoms and (12.6 × 12.6 cm mesh) nylon screen tops. Barriers of aluminum screen (41 × 46 cm mesh) were folded twice to an overall size of .9 × .9 m and anchored underneath each cage. Tacky Trap® was applied directly to the entire edge of the aluminum screen barrier to prevent the removal of mines by rodents and ground dwelling arthropods. Weather data were collected for max. - min. temperature and rainfall by the Coastal Plain Experiment Station during both years.

Seasonal Dynamics and Parasitism Levels. The four leafminer species were sampled weekly during the 1981 and 1982 seasons from foliage of pecan trees located in Tift County, GA. Sampling was initiated at first leaf expansion (April in both years) and terminated at first frost (November in both years). A total of 35 trees were sampled each week until 10 Sept. (Date 253); then 18 or 17 trees were sampled on an alternating basis every two weeks. Each tree was sampled at two levels, below and above 5 m, with two terminals (current year's stem growth) being taken per level. All samples were collected using a hand-held pruning pole.

All trees were planted in 1972 and were 8 - 10 m high. The orchard (0.40 ha) was planted to the cultivars Stuart (4-trees), Desirable (4-trees), Schley (3-trees), Elliot (3-trees), Farley (5-trees), Success (4-trees), Pensacola Cluster (4-trees), Wichita (7-trees) and seedling (1-tree). Georgia Cooperative Extension Service recommendations were followed for fertilization and cultural practices as well as weed and disease control (Crocker 1982, Ellis and Bertrand 1984). No insecticides were applied from 1980 to 1982.

Mines were examined in the lab using a dissecting microscope and categorized according to species, lifestage (larva and pupa) and presence or absence of parasitoid larvae or exuviae. Mines of *S. juglandifoliella* were classified as vacated if the larva had emerged from the mine. Similar to the method of Pottinger and LeRoux (1971), two larval types were distinguished in samples of *P. caryaealbella* mines. The first and second instars are campodeiform and are called sap feeders as they feed on cell sap. The third, fourth, and fifth instars are eruciform and are called tissue feeders. *C. caryaefoliae* were classified as containing larvae, pupae, or parasitoids. *C. lucifluella* mines were classified as larvae within the pecan leaf, cocoons that contain larvae or pupae, or parasitoids. Vacated mines were not included in the population density counts. Mines sampled in 1982 were further categorized according to the presence or absence of, leafminers or parasitoids. Parasitoids were not classified to species. Generations per season were estimated by inspecting the seasonal fluctuations in leafminer density for each species to identify peaks of larval density.

Overwintering and Adult Emergence Studies. Mines of *C. caryaefoliella* and *P. caryaealbella* were collected from the lower branches of trees located in various orchards in Tift County and placed in the overwintering cages in the orchard on 6 November 1981 (Date 310) and 22 November 1982 (Date 326). Collections were made as foliage dropped from the tree. *C. caryaefoliella* mines that contained cocoons visible through the upper mine surface, and *P. caryaealbella* mines, in which the frass cocoon had been constructed, were used in both years. The presence of the frass cocoon was verified by candling each mine to prevent mechanical damage caused by mine dissection. The exact stage of development of the leafminer and the presence of parasitoids were not determined. Mines were placed (ten mines per cup) in 28 ml plastic rearing cups. Each cup bottom was replaced by 12.6 × 12.6 cm mesh nylon screen. The top of each cup was left open. Cups were placed in cardboard rearing trays that had the cardboard removed beneath each cup. The cups and cardboard trays then were placed in an overwintering cage. Sections of cork (2 mm thick) were glued to the bottom of each tray for water drainage.

Cages were checked weekly from the time they were placed in the orchard until the first adults were captured the following spring. After the first adults were captured, cages were checked daily. Mines were removed from the orchard and examined when a period of 30 days elapsed after the capture of the last adult. Mines were classified as vacant or occupied. The stages of development of those mines that were occupied were recorded. Parasitized mines were not included in overwintering mortality calculations.

Results and Discussion

Seasonal Development. Spring emergence curves and averge daily temperatures are presented in Fig. 1. First spring emergence of *P. caryaealbella* adults occurred on 22 March 1981 and 11 March 1982. First spring emergence of *C. caryaefoliella* adults occurred on 22 March 1981 and 17 March 1982. The adult emergence period of both leafminer species lasted about 5 weeks in 1981. In 1982, *P. caryaealbella* adults emerged over a period of 4 weeks, and *C. caryaefoliella* adults emerged over a period of 7 weeks. In 1981, 50% of the *P. caryaealbella* had emerged by 30 March and 50% of the *C. caryaefoliella* adults had emerged by 6 April. In 1982, 50% cumulative emergence of *P. caryaealbella* and *C. caryaefoliella* occurred on 15 March and 15 April, respectively. Peak emergence of *P. caryaealbella* occurred both years at the beginning of the emergence period while peak adult emergence

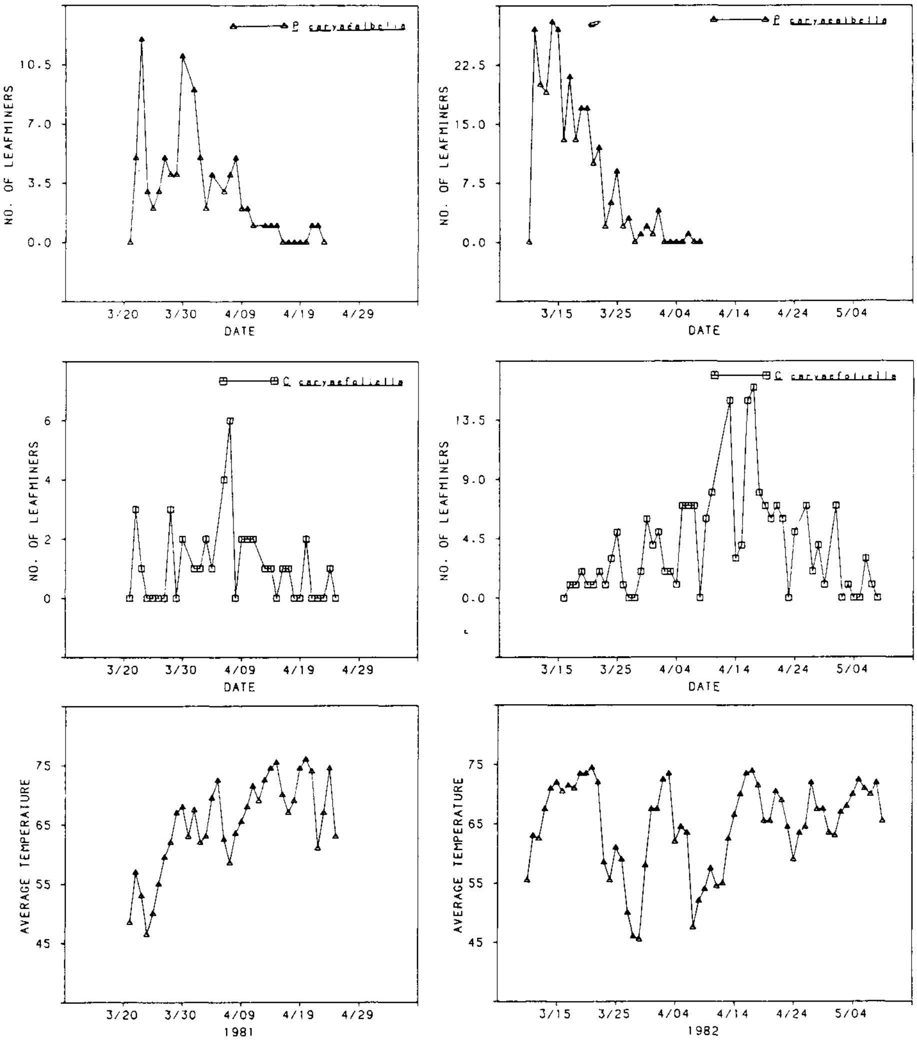

Fig. 1. Spring emergence of *C. caryaefoliella* and *P. caryaealbella* adults from mines placed in overwintering cages. The number of leafminer adults that emerged and average ambient temperature are recorded on each collection date.

of *C. caryaefoliella* occurred both years soon after the middle of the emergence period. Decreases both years in the emergence of both leafminer species corresponds with downward temperature fluctuations.

At the time of first adult emergence in both 1981 and 1982, there was no completely expanded pecan foliage available for leafminer oviposition. On 22 March 1981, 55% of all buds counted were broken (swelling of the bud and splitting of the outer bud scales) with 100% bud break occurring on 5 April. In 1982, 42% of all buds were broken on 11 March, and 100% were broken on 8 April. Full leaf expansion occurred in both years about 15 April. *S. juglandifoliella,* also has been observed on hickory, walnut, butternut (Payne and Ellis 1978) and hophorn bean (Needham et al. 1912). Small amounts of fully expanded hickory foliage were available in 1981 and 1982 at the time of first spring emergence of *P. caryaealbella* and *C. caryaefoliella.*

Sampling of *S. juglandifoliella* mines in 1981 and 1982 indicated five population "peaks" or periods of significant increase in larval density with similar levels of parasitoids in both years (Fig. 2 & 3). Whether or not these peaks correspond to generations of the leafminers during the season will require research on the duration of each generation.

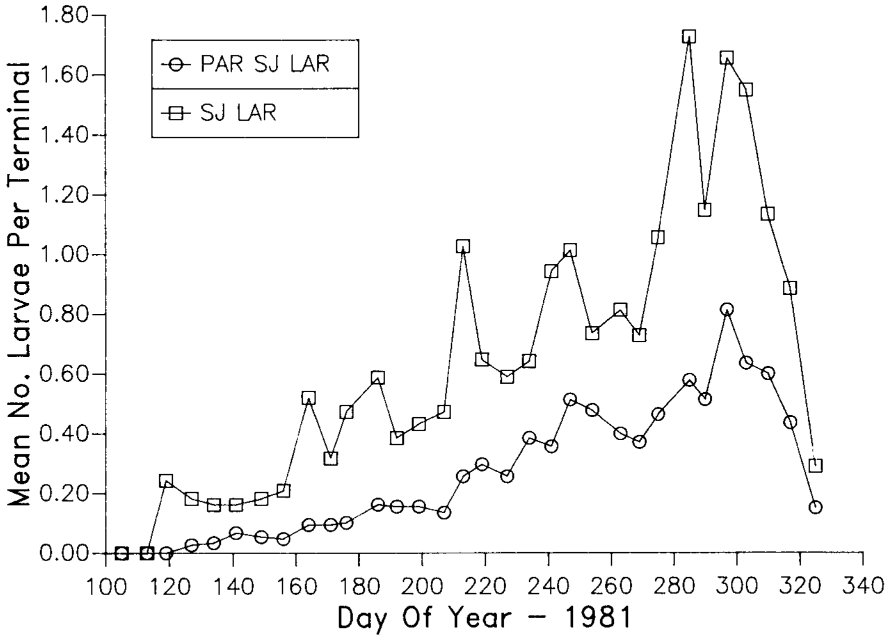

Fig. 2. Seasonal development and parasitism of *S. juglandifoliella* (SJ) larvae in 1981. PAR SJ LAR = parasitized larvae, SJ LAR = live larvae.

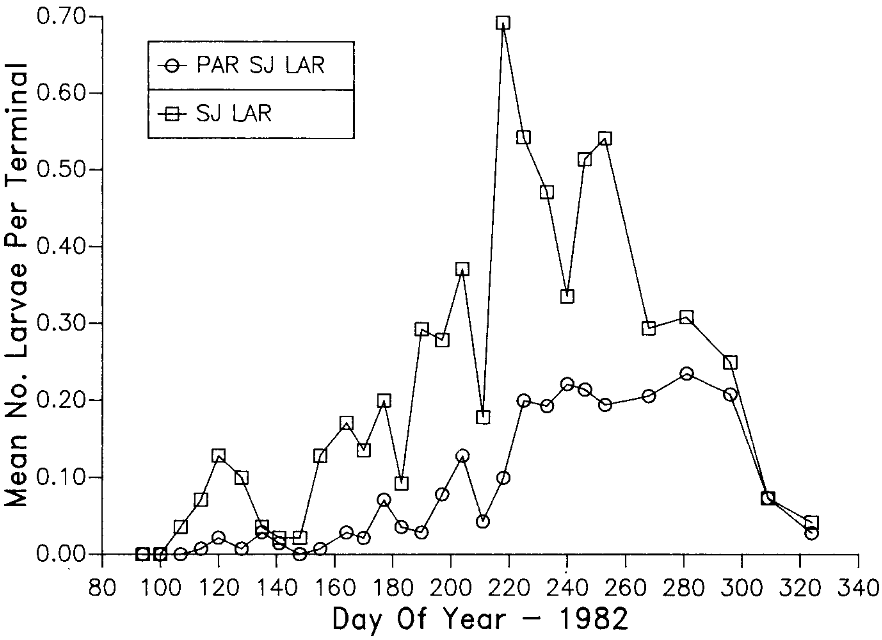

Fig. 3. Seasonal development and parasitism of *S. juglandifoliella* (SJ) larvae in 1982. PAR SJ LAR = parasitized larvae, SJ LAR = live larvae.

Four significant increases in the larval density of *C. caryaefoliella* were observed in 1981 and 1982 (Fig. 4 & 5). The sampling of sap feeding larvae of *P. caryaealbella* revealed only three significant peaks in 1981 (Fig. 8) although a fourth may have occurred between late July and early August (Date 207). Four significant increases in the density of sap feeding larvae were discernible from sampling data in 1982 (Fig. 9). *P. caryaealbella* tissue-feeding larvae were present during the summer season in 1981 (Fig. 10) at a constant level near 0.5 mines/terminal. The 1982 (Fig. 11) population of tissue feeding larvae had three significant increases in larval density. Four significant population peaks of *C. lucifluella* larvae occurred in 1981 and 1982 (Fig. 12 and 13). Puape of *C. caryaefoliae* and cocoons of *C. lucifluella* (Fig. 6 & 7, 14 & 15) were found at lower population densities than corresponding larvae indicating a significant reduction by parasitoids in the larval stage.

Peak larval density of *S. juglandifoliella* occurred in late September (Dates 285 - 297, Fig. 2) in 1981 and in August. (Dates 225 - 253, Fig. 3) in 1982. Peak larval density of *C. caryaefoliella* (Fig. 4 & 5), *P. caryaealbella* (Fig. 8 & 9) and *C. lucifluella* (Fig. 12 & 13) occurred from early September to late October (Dates 246 - 303) in both years. In both 1981 and 1982, sap feeding larvae of *P. caryaealbella* (Fig. 8 & 9) began mining leaves 1-2 weeks earlier than the next earliest species (*S. juglandifoliella* both years, Fig. 2 & 3). In all species and years, larval densities declined drastically in late October and early November (after date 290). All data demonstrate the results of sampling active mines only. The potential to reach peak population levels as early as August (Date 218, 1982, Fig. 3) may partially explain the occurrence of *S. juglandifoliella* outbreaks in commercial orchards. Peak

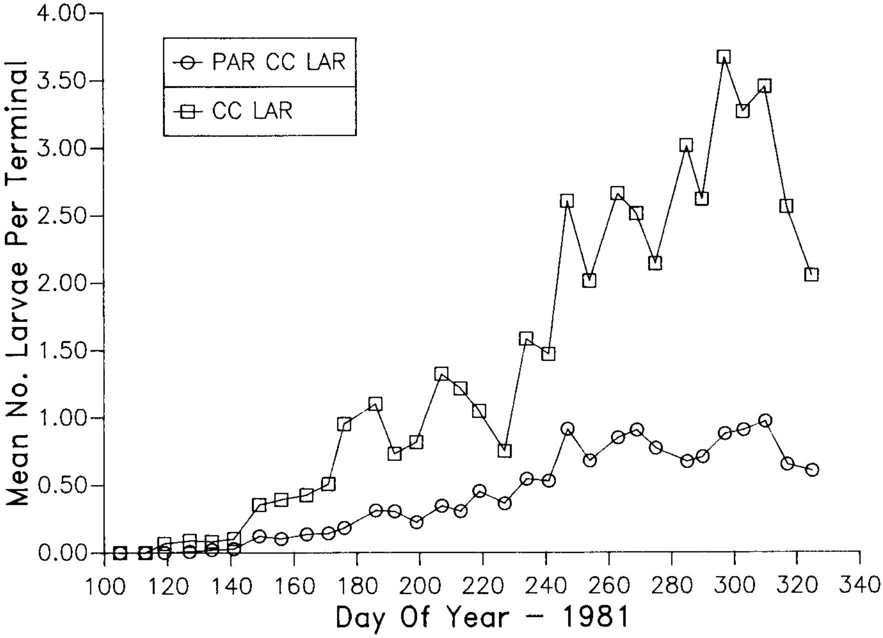

Fig. 4. Seasonal development and parasitism of *C. caryaefoliella* (CC) larvae in 1981. PAR CC LAR = parasitized larvae, CC LAR = live larvae.

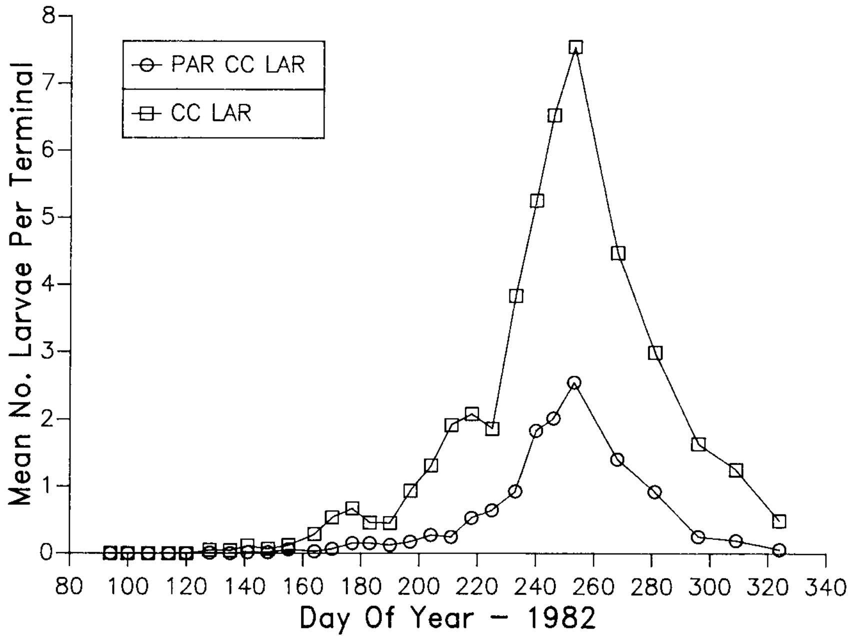

Fig. 5. Seasonal development and parasitism of *C. caryaefoliella* (CC) larvae in 1982. PAR CC LAR = parasitized larvae, CC LAR = live larvae.

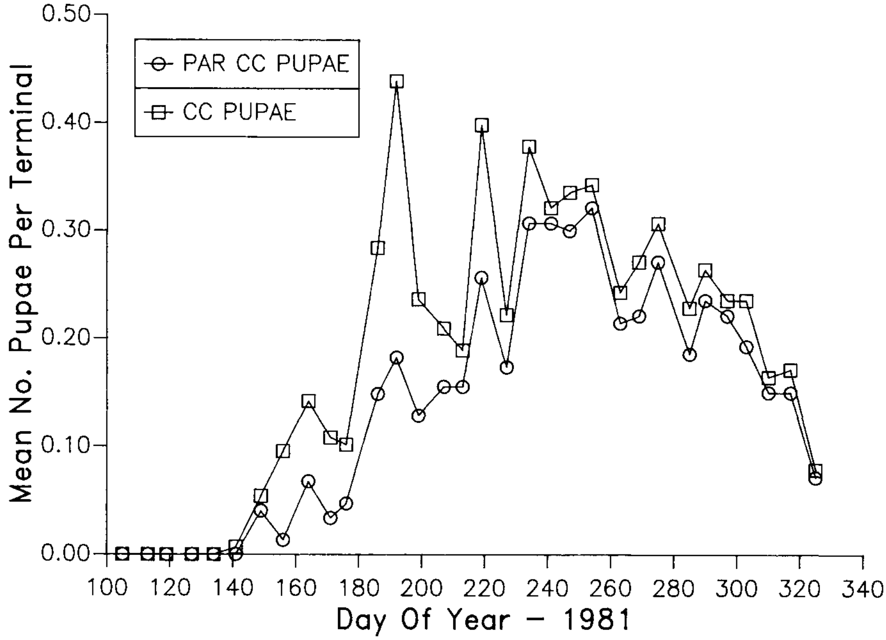

Fig. 6. Seasonal development and parasitism of *C. caryaefoliella* (CC) pupae in 1981. PAR CC PUPAE = parasitized pupae, CC PUPAE = live pupae.

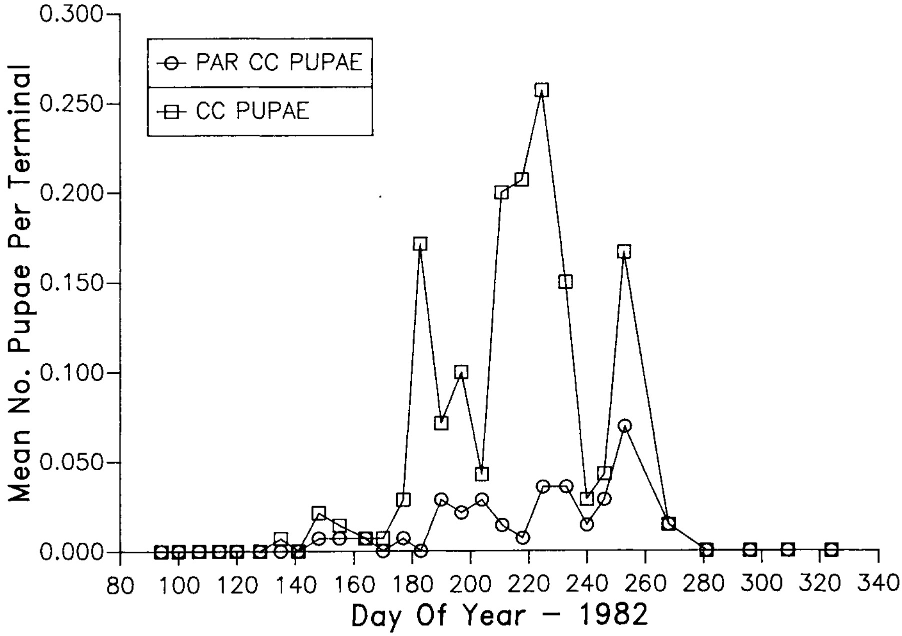

Fig. 7. Seasonal development and parasitism of *C. caryaefoliella* (CC) pupae in 1982. PAR CC PUPAE = parasitized pupae, CC PUPAE = live pupae.

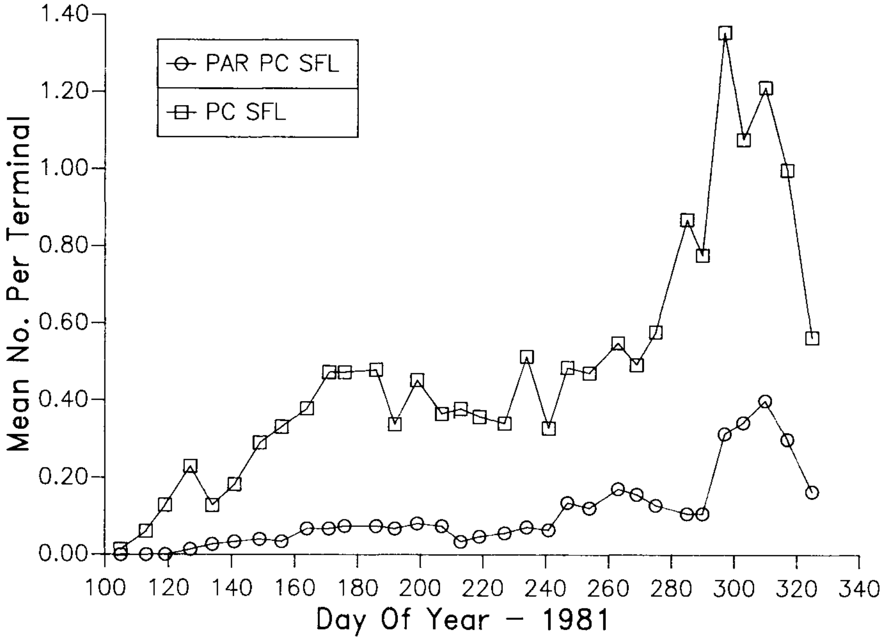

Fig. 8. Seasonal development and parasitism of *P. caryaealbella* (PC) sap feeding larvae (SFL) in 1981. PAR PC SFL = parasitized sap feeding larvae, PC SFL = live larvae.

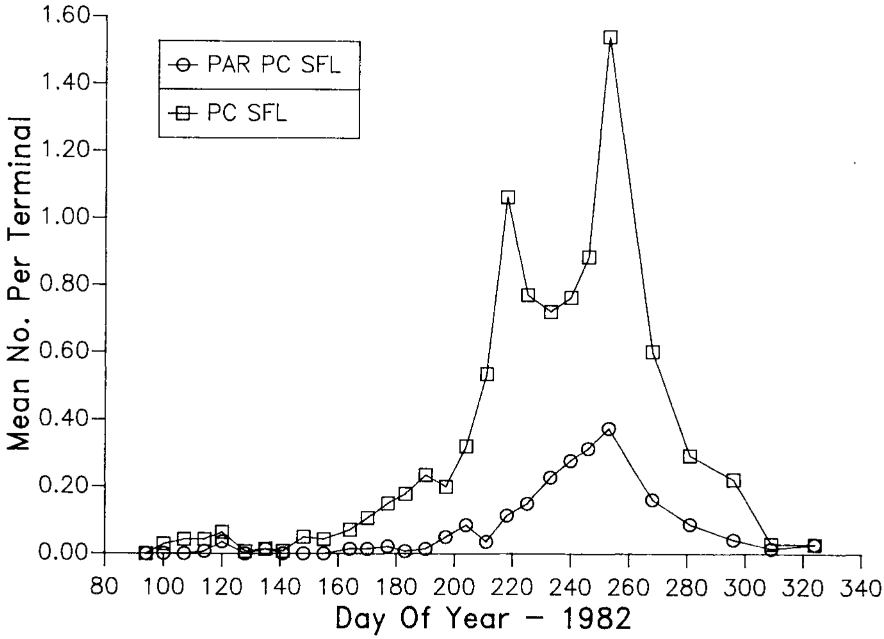

Fig. 9. Seasonal development and parasitism of *P. caryaealbella* (PC) sap feeding larvae (SFL) in 1982. PAR PC SFL = parasitized sap feeding larvae, PC SFL = live larvae.

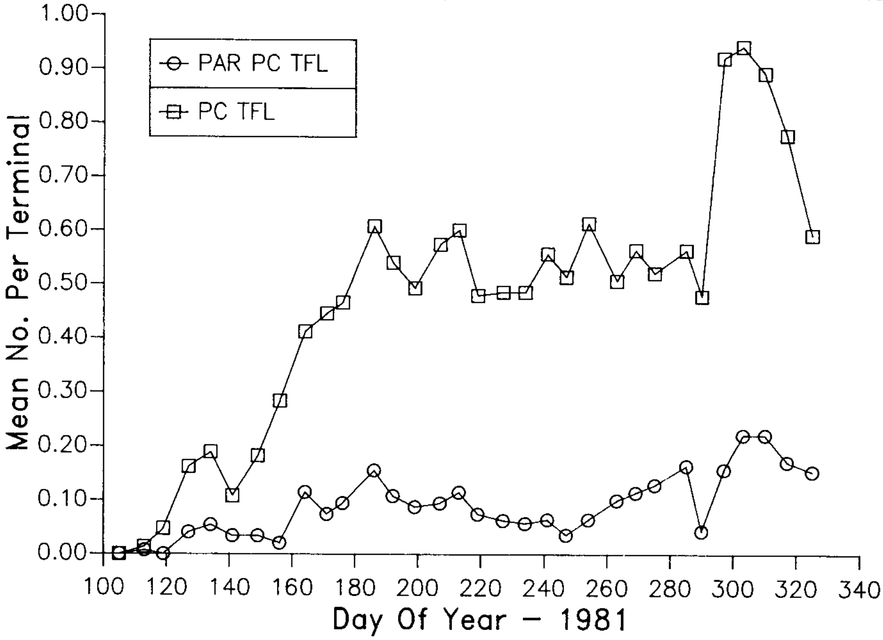

Fig. 10. Seasonal development and parasitism of *P. caryaealbella* (PC) tissue feeding larvae (TFL) in 1981. PAR PC TFL = parasitized larvae, PC TFL = live larvae.

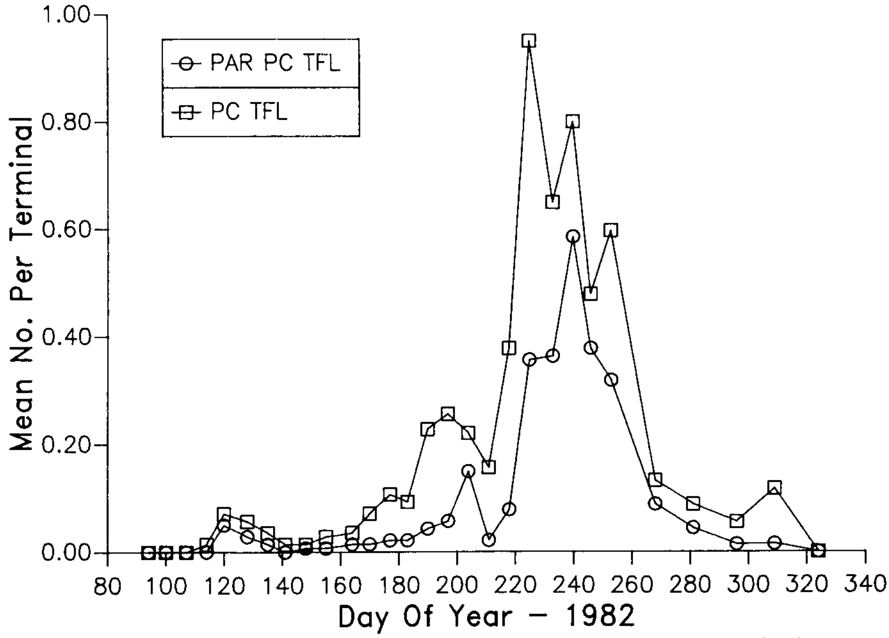

Fig. 11. Seasonal development and parasitism of *P. caryaealbella* (PC) tissue feeding larvae (TFL) in 1982. PAR PC TFL = parasitized larvae, PC TFL = live larvae.

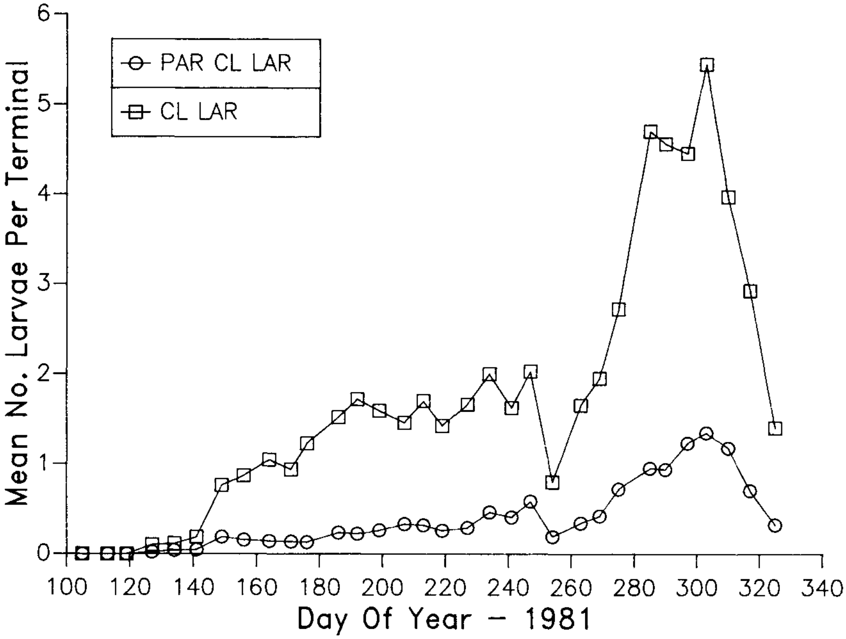

Fig. 12. Seasonal development and parasitism of *C. lucifluella* (CL) larvae in 1981. PAR CL LARV = parasitized larvae. CL LARV = live larvae.

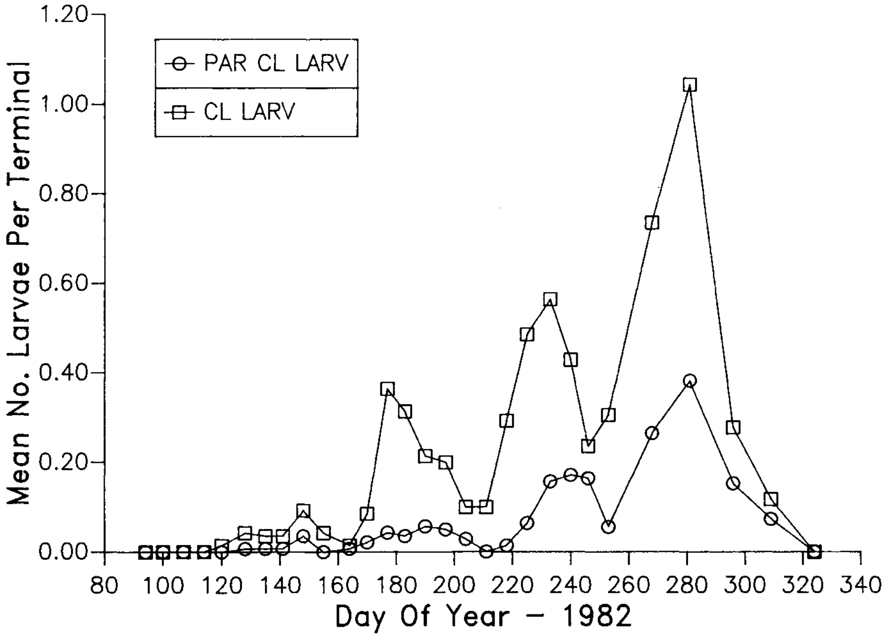

Fig. 13. Seasonal development and parasitism of *C. lucifluella* (CL) larvae in 1982. PAR CL LARV = parasitized larvae. CL LARV = live larvae.

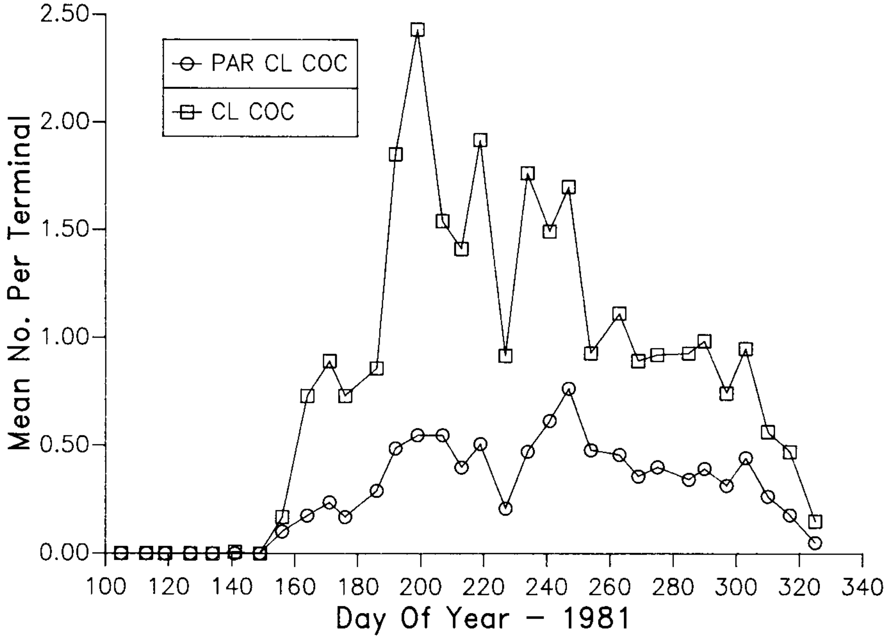

Fig. 14. Seasonal development and parasitism of *C. lucifluella* (CL) pupae in 1981. PAR CL COC = parasitoid in cocoon. CL COC = live larva or pupa in cocoon.

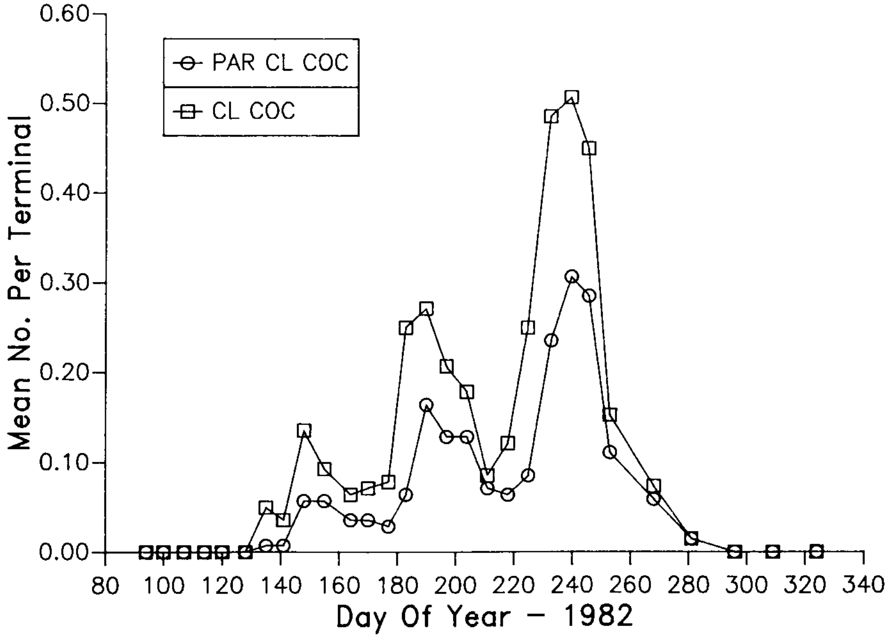

Fig. 15. Seasonal development and parasitism of *C. lucifluella* (CL) larvae in 1982. PAR CL COC = parasitoid in cocoon. CL COC = live larva or pupa in cocoon.

densities reached at this time coincide with repeated applications of foliar insecticides. These sprays are applied to control major foliage and nut feeding pests and may reduce or remove the natural control mechanisms associated with *S. juglandifoliella.* Leafminer outbreaks in August and September may contribute to the premature defoliation of trees that can lead to reduced fruit set the following year. Peak leafminer densities reached in October may be of little consequence because natural declines in densities soon follow. This natural decline represents the effects of increased rates of leaf abscision and natural mortality factors such as parasitoids.

Parasitism Levels. Parasitism levels found for each species and each season (Fig. 2-15) increased as host densities increased. Peak parasitoid densities coincided with peak host densities in all cases. Percent parasitism at peak leafminer density ranged from 14% (*C. caryaefoliella* pupae in 1982) to 61% (*C. lucifluella* cocoons in 1982). Parasitism levels in sap feeding larvae of *P. caryaealbella* were similar to those found in tissue feeding larvae of the same species (compare Fig. 8 & 9 with Fig. 10 & 11). Percent parasitism was generally higher in 1981 than 1982 in populations of *P. caryaealbella.* This similarity in parasitism levels existed throughout both seasons. Percent parasitism at the time of peak host density is presented for the four species in Table 1. The action of parasitoids during periods of lower host densities serves to reduce increases in leafminer densities. In addition, the amount of pecan leafminer control attributable to parasitoids may be greater than that measured through the presence of parasitoid immatures or remains. Van Driesche and Taub (1983) found that adults of *Sympiesis marylandensis* (Girault) caused mortality of *P. crataegella* through feeding and stinging without oviposition as well as stinging followed by oviposition. There also are occasions when pecan leafminer parasitods demonstrate the ability to significantly reduce large host populations. The decrease in *C. lucifluella* cocoons observed in early September 1982 (Date 225-240, Fig. 9) can be partly attributed to a high level of parasitism (61%) at peak host density. However, larva in cocoons will migrate from the sample unit.

Table 1. The percent parasitism, measured at peak host density, of 4 species of pecan leafminer. Tifton, GA. 1981 and 1982.

Leafminer Species	Life Stage	Percent Parasitism/ 1981			1982		
		N	%	DAY	N	%	DAY
S. juglandifoliella	Larva	242	33	285	97	14	218
C. caryaefoliella	Larva	514	24	296	544	34	254
	Pupa	66	42	191	36	14	229
P. caryaealbella	Sap feeder	190	23	296	122	22	254
	Tissue feeder	132	23	302	133	38	225
C. lucifluella	Larva	764	25	302	71	37	281
	Cocoon	360	22	198	71	61	240

* All parasitoid species were combined. % = 100* [n. mines with parasities/N] where N = no. mines sampled. Inactive mines were included in parasitism calculations. DAY = Day of year when peak host density occurred.

Overwintering Study. Random sampling of leafminers from the floor of the second orchard during the 1981-82 winter, revealed the overwintering stages of *C. caryaefoliella* and *P. caryaealbella* to be the last larval instar and pupa, respectively. *C. caryaefoliella* overwintered as last instar larvae during 1981-82. The molt to the last instar occurred between 22 November and 22 December. On 27 November 1981, 94 of 100 mines contained next to last instar larvae. On 2 December 1981, 45 of 100 mines contained next to last instar larvae. After 22 December. 1981, all overwintering mines were collected to determine mortality of the overwintering stages. Results indicated that 244 of 1055 mines contained pupae. *P. caryaealbella* overwintered as a pupae. Eleven of 100 mines sampled on 22 November 1981 contained last instar larvae and 89 contained pupae. By 9 December 1981, all 100 mines in the sampled contained pupae. However, examination of larger samples of mines that were collected to determine mortality of the overwintering stages indicated that 30 of 1356 mines contained last instar larvae.

Mortality in the cages containing *C. caryaefoliella* mines was 78 and 79% during the 1980-81 winter and 31 and 95% during the 1981-82 winter. Mortality among *P. caryaealbella* mines placed in overwintering cages was 75 and 49% during the 1980-81 winter and 27 and 48% during the 1981-82 winter. Examination of the *C. caryaefoliella* mines, that failed to emerge, revealed that the majority (ca. 80% in 1981 and 70% in 1982) were last instar larvae. Almost all (97% or greater both years) occupied *P. caryaealbella* mines were found to be in the pupal stage. Two percent of the *C. caryaefoliella* mines collected in 1980 and 1981 were parasitized by hymenopterous parasitoids. *P. caryaealbella* mines collected in 1980 and 1981 were found to be parasitized at the respective rates of 2 and 17%. Both leafminers overwinter in a cocoon. The protection provided by the cocoon may increase survival in the overwintering generation. *P. blancardella* (F.) also overwinter as pupae (Pottinger and LeRoux 1971), and tissue feeding larvae did not survive the winter in the study area. Overwintering mortality in last instar larvae of *C. caryaefoliella* and pupae of *P. caryaealbella* was high in comparison to mortality of overwintering pupae of *P. blancardella,* measured at 18% before predation began in the spring (Pottinger and LeRoux 1971). Higher mortality rates in samples of both leafminer species in 1981 may be due in part to lower temperatures. Average temperatures for the months of November and December 1980, and January, February, and March 1981 were 5°C lower than the same months in 1982.

Summary

Pecan leafminers colonize pecan foliage in discrete increases in population density during the spring and summer. Fall populations occur in an extended peak of larval density. Total percent parasitism usually increases with leafminer population density and ranges from 14 to 61 percent during peak leafminer densities (Table 1). Of the 35 parasitoid species, 14 species attack a single pecan leafminer host, seven attack two hosts, eight attack three hosts, five attack four hosts, and one is a hyperparasite (Heyerdahl and Dutcher 1985a). Fall leafminer populations provide a constant supply of larvae to support the 20 polyphagous parasitoid species.

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