# Observations on diapause in *Metaponpneumata rogenhoferi* Möschler in southern Honduras and notes on other lepidopterous species[1]

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**Abstract:** The effect of soil moisture on diapause termination in *Metaponpneumata rogenhoferi* Möschler pupae was observed in areas heavily infested with sicklepod, *Senna obtusifolia* (L.) H.S. Irwin & Barneby, a preferred host for this species, in the foothills and on the coastal plain of southern Honduras. Irrigated soil and soil with no irrigation were treatments established in 2000 in screen cages placed over sites where sicklepod was heavily infested with *M. rogenhoferi* in 1999. *Metaponpneumata rogenhoferi* and *Acrolophus* spp. accounted for 34 and 64%, respectively, of the moths collected in the foothills, whereas *M. rogenhoferi*, *Tripudia limbatus* Edwards, and *Ommatospila narcaeusalis* Walker accounted for 1.4, 12.6 and 81.1%, respectively, of the moths collected on the coastal plain. Soil moisture was the stimulus for eclosion of *M. rogenhoferi* moths, but it appeared to have acted only as a secondary factor in diapause termination. Time spent in the diapause state may be one factor that is associated with termination of the dormant period in this species. Soil samples from irrigated plots immediately outside the screen cages resulted in collection of two pupae at each location, which could suggest high larval and pupal mortality in this species. Land preparation for crop planting on the coastal plain using tractors appeared to negatively influence densities of *M. rogenhoferi* when compared with low disruption land preparation practices used by farmers in the foothills. This information contributes to our understanding of why *M. rogenhoferi* can be a significant defoliator of sorghum and maize in some years, but not in other years in southern Honduras.

**Key words:** *Metaponpneumata rogenhoferi*, diapause, Honduras

**Resumen:** El efecto de la humedad del suelo en la terminación del estado de diapausa en pupas de *Metaponpneumata rogenhoferi* Möschler fue observado en áreas altamente infestadas con frijolillo, *Senna obtusifolia* (L.) H.S. Irwin & Barneby, hospedero preferido por esta especie, en laderas y planos costeros de la región sur de Honduras. Suelos irrigados y sin riego fueron los tratamientos establecidos en el 2000 utilizando cajas de malla situadas sobre áreas de coyolillo altamente infestadas con *M. rogenhoferi* en 1999. *Metaponpneumata rogenhoferi* y *Acrolophus* spp. constituyeron el 34 y 64%, respectivamente, del total de polillas recolectadas en el área de laderas, mientras *M. rogenhoferi*, *Tripudia limbatus* Edwards y *Ommatospila narcaeusalis* Walker constituyeron el 1.4, 12.6 y 81.1%, respectivamente, de las polillas recolectadas en los planos costeros. La humedad del suelo estimuló la eclosión de las polillas de *M. rogenhofer*, pero aparentemente tuvo solamente un efecto secundario en la terminación del estado de diapausa. El tiempo permanecido en diapausa puede ser un factor asociado con la terminación de este periodo para esta especie. Muestras de suelo procedentes de parcelas irrigadas adyacentes a las cajas de malla resultaron en la recolección de dos pupas en cada localidad, lo que representa alta mortalidad en el estado larval y pupal de esta especie. La preparación de la tierra para la siembra usando tractores en los planos costeros aparentemente tiene un efecto negativo en las densidades de *M. rogenhoferi* comparada con el daño mínimo causado por las actividades de preparación de tierra menos disruptivas usadas por los productores de la zona de laderas. Esta información contribuye a nuestro entendimiento de por qué *M. rogenhoferi* puede ser un defoliador significante para sorgo y maíz algunos años, pero no en otros años en la región sur de Honduras.

**Palabras clave:** *Metaponpneumata rogenhoferi*, diapausa, Honduras.

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## Introduction

*Metaponpneumata rogenhoferi* Möschler (Lepidoptera: Noctuidae) damages seedling sorghum and maize in southern Honduras (Pitre, 1988; Castro, 1990; Portillo *et al.*, 1991; Calderón, 1998; Vergara, 1998; Cordero *et al.*, 1999). Most studies involving this lepidopterous pest in this region have been conducted in the hills where it occurs on these crops soon after the rainy season begins in late April to early May. The density of this pest in the region varies from year to year. In some years it may be a contributor, as a member of a larval complex, to crop destruction. In other years it may be almost singly responsible for complete destruction of sorghum and maize during early plant developmental stages (Pitre, 1995).

Although *M. rogenhoferi* is recognized as an important pest of sorghum and maize, larval feeding preferences and performance studies in the laboratory indicate that these plants are not suitable hosts for *M. rogenhoferi* compared with some broadleaf weeds (Portillo, 1991; Portillo *et al.*, 1996; Calderón, 1998; Portillo *et al.*, 1998; Cordero *et al.*, 2002). Portillo *et al.* (1991, 1998) suggested that areas of noncrop vegetation could serve as source habitat for origin of *M. rogenhoferi* populations and that sorghum and maize serve as sink habitats where populations decline as explained by Pullian (1988) and Lewin (1989). Calderón (1998) reported that sicklepod, *Senna obtusifolia* (L.) H.S. Irwin & Barneby, a common weed in southern Honduras, is a more suitable host for *M. rogenhoferi* compared with sorghum or maize. In similar studies, Cordero *et al.* (2002) reported that sicklepod is a more suitable host for *M. rogenhoferi* compared with maize or artificial diet. The insect appears to have one and possibly two generations each year in southern Honduras (Portillo, 1994; Calderón, 1998; Cordero *et al.*, 2002).

*M. rogenhoferi* is recognized to diapause as pupae during the dry season (November to May) in southern Honduras (Portillo, 1994; Pitre *et al.*, 1997; Calderón, 1998; Portillo *et al.*, 1998; Cordero *et al.*, 2002). The causes of induction and termination of diapause in this species are not clearly identified. Cordero *et al.* (2002) suggested that the induction of diapause does not appear to be associated with food source alone, but may be related to climatic conditions. Calderón (1998) suggested that food plants have limited influence on termination of diapause in this species, and this biological characteristic could be associated with moisture and time spent in the diapause condition. Moisture did not appear to be required for diapuse termination in all individuals.

According to Hayes *et al.* (1967), soil moisture allows pupae of some lepidopterous insects to be soaked by a solution containing organic and inorganic materials. This condition can change ionic concentration of the environment surrounding pupae in the soil, thus affecting permeability in the insect's body and facilitating the termination of diapause. The present experiment was designed to investigate the response of diapausing *M. rogenhoferi* to soil moisture. Other lepidopterous species encountered inside experimental units were identified.

## Materials and Methods

### Screen cage study

The study was conducted at two locations in southern Honduras in 2000. One location was in the foothills at El Chorro (coordinates 13° 31' N and 87° 40' W) in the Department of Valle. The second location was on the coastal plain at Namasigue (coordinates 13° 13' N and 87° 07' W) in the Department of Choluteca. The two locations are about 91.7 km apart. *Metaponpneumata rogenhoferi* has been reported to be present at both locations with population levels and crop damage being greater in the foothills (Pitre 1988, Portillo *et al.* 1991).

Twelve 1.8 × 1.8 × 1.8 m lumite screen (32 × 32 mesh) cages (Chicopee Company, Gainesville, Georgia 30503, USA) were placed over areas where sicklepod was abundant and infested with *M. rogenhoferi* in 1999. Six cages were installed on March 1 at El Chorro and six on March 2 at Namasigue. No green vegetation was visible above ground in the cages. Water was applied to the soil in three cages at each location beginning March 1 at El Chorro and March 2 at Namasigue; water was not applied in the other cages. The cages without irrigation water simulated conditions that *M. rogenhoferi* pupae experience at these locations during the dry season. However, diapausing pupae are exposed to soil moisture from the time they enter diapause until the beginning of the dry season, generally in November. Pupae in diapause remain in the soil for many months, possibly from May until April or May the next year.

Water was applied to the soil in the irrigated cages on eight dates (generally about 7-d intervals with each cage receiving eight irrigations) during a 10-wk period. The soil was wetted to a depth of about 5 cm using 180 L of water per cage. No attempt was made to quantify levels of soil moisture as the amount of water added to each cage simulated rainfall saturation of the upper 5 cm of soil in this area at each irrigation. *M. rogenhoferi* larvae pupate in the soil close to the soil surface, generally from 1.5 to 2.5 cm deep (Pitre, personal communication). Water was applied slowly to achieve penetration to the desired level. Rain gauges were used to record rainfall at each location.

A honey:water solution (1:2) on cotton balls placed in four 29.6-ml plastic cups per cage (Fill-Rite Inc., Newark, New York 07104, USA) served as food source for moths that emerged in the cages. The soaked cotton balls were replaced every 2 days. Moths were collected twice weekly during the 10-wk sampling period within each cage, individually held in 29.6-ml plastic cups and taken to the Biological Control Laboratory at the Panamerican School of Agriculture, Zamorano, Honduras. All moths were pinned and brought to Mississippi State University to be identified. Moths not identified at the Mississippi Entomological Museum, Mississippi State University, were sent to the Systematic Entomology Laboratory in U. S. National Museum, Washington D.C. for identification. Noncrop vegetation inside irrigated cages in both locations was collected on March 28 and identified at the Panamerican School of Agriculture, Zamorano, Honduras.

Cages were placed over field sites at random but the data were not statistically analyzed because of the small number of moths collected.

### Field study

Areas outside of the field cages at the two test locations were established as duplicate sites for examination of the soil for pupae in 2000. The same surface area and irrigation procedure used in the cage study were employed in the test sites where sicklepod grew profusely in 1999. The soil at each sample site (four 1.8 × 1.8 m plots) was subdivided into four 0.9 × 0.9 m subplots. Each subplot was irrigated once with 34 L of water and allowed to dry for 2-d so that the soil could be easily searched by hand. This procedure was done over a 3-mo period, irrigating one subplot in March, one in April and two in May. Two subplots were irrigated in early May because the rainy season was predicted to begin earlier than anticipated. The soil to a depth of at least 5 cm in the irrigated area was examined for pupae and the number of pupa/m$^2$ (soil surface area) recorded. Pupae were placed individually in 29.6-ml plastic cups with dry soil and transported to the laboratory for identification. As in the cage study, soil moisture levels or deficits were not determined.

Noncrop vegetation was searched for *M. rogenhoferi* larvae before planting and during the early crop growing season to determine the relationship of host plants to survivorship of immatures. Most searches were on sicklepod in an area where this host was infested with *M. rogenhoferi* during the past two years. Larvae were collected, placed in 29.6-ml plastic cups and transported to the laboratory for identification.

Additional soil samples (*ca.* 30 m$^2$) were taken in mid-June from a large area under sicklepod to search for pupae. No statistical analysis was conducted because of the small number of pupae collected at the two study locations.

## Results and Discussion

### Screen cage study

*M. rogenhoferi* and *Acrolophus* spp. accounted for 34 (n = 17) and 64% (n = 32), respectively, of the moths collected in cages in the foothills, whereas *M. rogenhoferi*, *Tripudia limbatus* Edwards, and *Ommatospila narcaeusalis* Walker accounted for 1.4 (n = 2), 12.6 (n = 18) and 81.1% (n = 116), respectively, of the moths collected in cages on the coastal plain (Table 1). These data agree with previous observations that *M. rogenhoferi* is present in greater numbers in the foothills than on the coastal plain (Castro, 1990; Portillo *et al.*, 1991; Portillo *et al.*, 1994). Vegetation in the two study locations was similar (Table 2). The close proximity of the two study locations and similarities of environmental conditions and noncrop vegetation makes this observed difference in populations of *M. rogenhoferi* difficult to explain.

Table 1. Lepidopterous species collected in six cages placed over sicklepod, *Senna obtusifolia*, in the foothills and in six cages on the coastal plain from March to May in southern Honduras, 2000.

| | | No. Insects (% of population) | |
|---|---|---|---|
| Family | Species | Foothills | Coastal plain |
| Acrolophidae | *Acrolophus* spp. | 32 (64.0) | 2 (1.4) |
| Danaidae | *Danaus gillipus* (Cramer) | 0 (0.0) | 1 (0.7) |
| Noctuidae | *Metaponpneumata rogenhoferi* Möschler | 17 (34.0) | 2 (1.4) |
| Noctuidae | *Spragueia margana* Fabricius | 0 (0.0) | 1 (0.7) |
| Noctuidae | *Tripudia limbatus* Edwards | 0 (0.0) | 18 (12.6) |
| Pyralidae | *Ufa rubedinella* Séller | 1 (2.0) | 3 (2.1) |
| Pyralidae | *Ommatospila narcaeusalis* Walker | 0 (0.0) | 116 (81.1) |

Table 2. Weed vegetation inside cages at test locations in the foothills and on the coastal plain in southern Honduras. 2000.

| Family | Species | Common name |
|---|---|---|
| **Foothills** | | |
| Capparaceae | *Cleome viscosa* L. | Spiderflower |
| Convolvulaceae | *Ipomoea trifida* (HBK) G. Don | Morningglory |
| Cyperaceae | *Cyperus rotundus* L. | Nutgrass |
| Fabaceae | *Senna obtusifolia* (L.) H. Irwin & Barneby | Sicklepod |
| | *Mimosa pudica* L. | Sensitive plant |
| | *Aeschynomene americana* L. | Shyleaf |
| Malvaceae | *Sida acuta* Burm. f. | Common wireweed |
| Poaceae | *Digitaria* sp. | Crabgrass |
| Sterculiaceae | *Waltheria indica* L. | Uhaloa |
| **Coastal plain** | | |
| Asteraceae | *Baltimora recta* L. | Beauty head |
| | *Tagetes* sp. | Marigold |
| Cecropiaceae | *Cecropia* sp. | Pumpwood |
| Fabaceae | *Mimosa pudica* L. | Sensitive plant |
| | *Senna obtusifolia* (L.) H. Irwin & Barneby | Sicklepod |
| Malvaceae | *Sida acuta* Burm. F. | Common wireweed |
| Sterculiaceae | *Waltheria indica* L. | Uhaloa |

In the foothills, *M. rogenhoferi* moths were collected on April 4 in cages receiving four irrigations and on April 18 in cages not irrigated, but receiving 24 mm of natural rainfall on April 16 (first rain of year in this area) (Figure 1). Moths were collected 14, 21, 31 and 38 days after the first collection, suggesting that this species emerged from the soil during a period of over a month. The area was without rainfall from April 17 to May 6 (20 days) during which time the soil was dry and compact. Rainfall occurred on May 7 (54 mm), May 8 (25 mm) and May 9 (6 mm) (Figure 1). On the coastal plain, *M. rogenhoferi* moths were collected first in cages without irrigation on April 18, after two consecutive rains on April 16 (19 mm) and April 17 (8 mm), while moths were collected first in the irrigated cages on May 5 (Figure 2).

Results from the foothills and coastal plain suggest that water may not be the main factor that triggers diapause termination in *M. rogenhoferi*. Moths were not collected in cages, where pupae were in irrigated soil until the pupae were exposed to moisture for a period of 35 days in the foothills and 66 days on the coastal plain. If moisture alone regulated diapause termination, moths should have been collected in irrigated cages several weeks earlier than April 4 in the foothills or May 5 on the coastal plain. This observation is supported by results obtained on the coastal plain where *M. rogenhoferi* moths were collected in cages without irrigation 17 days before moths were collected in irrigated cages. Soil in the irrigated cages had been wetted for almost two months (Figure 2). Furthermore, after pupae of this species enter diapause in May or June, the rainy season is still present in Honduras. There is no apparent response by this species to complete development through the pupal stage during the following 10 to 12 months, or longer, thus surviving in diapause through the long dry season.

Although water does not appear to be the principal factor that triggers diapause termination in *M. rogenhoferi*, it is important in preventing them from being trapped in the soil. Soil moisture may be important in diapause because the pupae can be soaked with a solution containing organic and inorganic materials. This solution changes the ionic concentration of the environment surrounding the pupal cell, affects permeability of the pupa and facilitates termination of diapause (Hayes *et al.*, 1967). Tzanakakis (1959) reported that the absorption of water is necessary for many species to resume development after diapause has been broken. Water alone, or high atmospheric humidity, does not seem to initiate the diapause-ending processes. No pupal dissections were made in the present study to support these concepts because of the limited number of pupae collected from the soil.

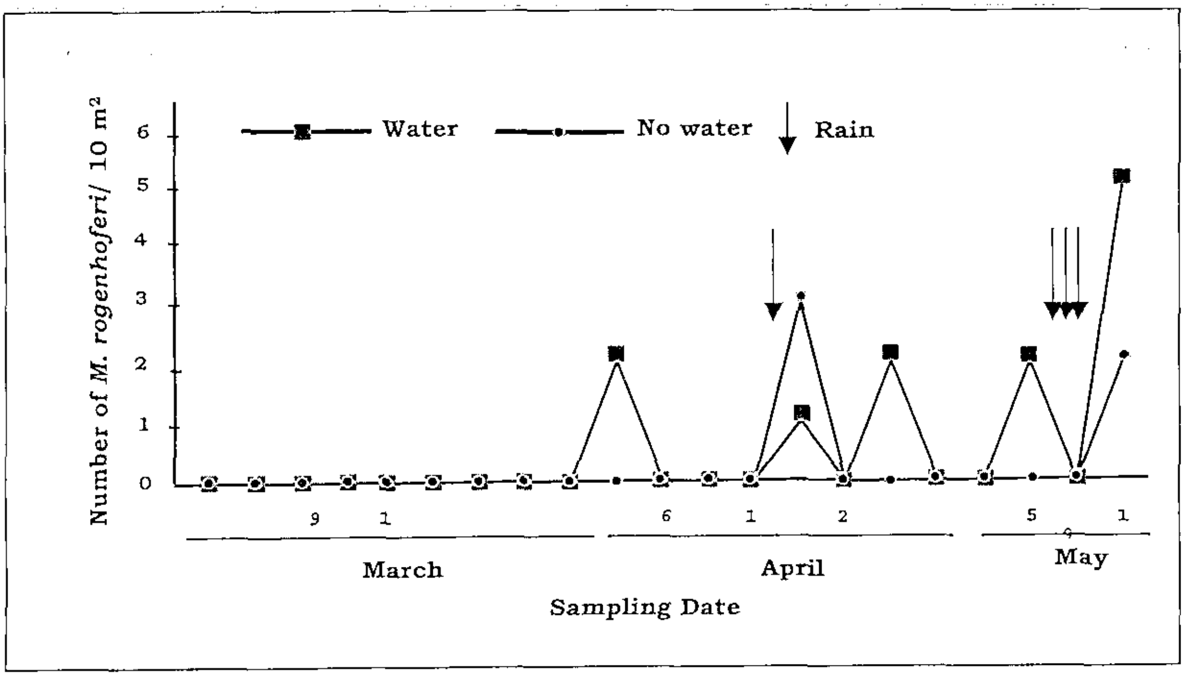


Figure 1. Emergence of *Metaponpneumata rogenhoferi* moths in cages with irrigation and without irrigation in the foothills in southern Honduras, 2000.

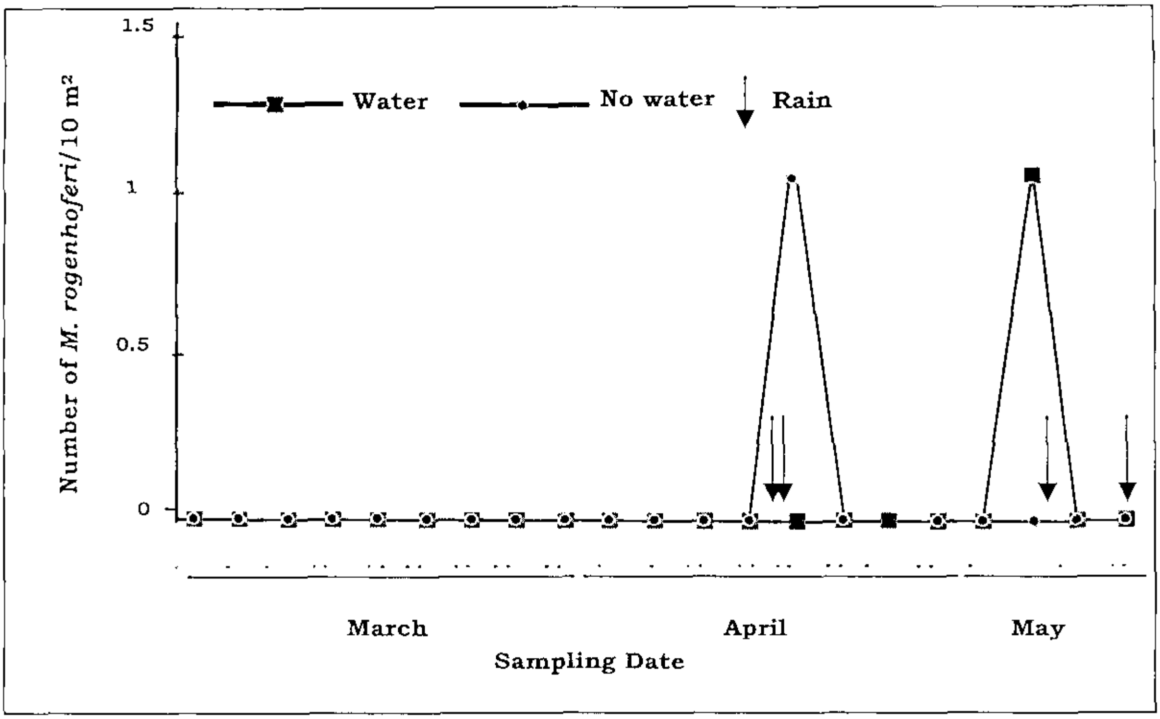


Figure 2. Emergence of *Metaponpneumata rogenhoferi* moths in cages with irrigation and without irrigation on the coastal plain in southern Honduras. 2000.

Time in the diapause state may be a factor associated with termination of this dormant period as documented for this species by Calderón (1998). The period in diapause appears to vary among individuals in the population. This period could vary as much as one month or more as observed in cages in the foothills (Figure 1). Although *M. rogenhoferi* has been reported to be mostly a univoltine species in field studies, it has been observed to develop successfully through more than one generation in the laboratory. Calderón (1998) and Cordero *et al.* (2002) observed that *M. rogenhoferi* appeared to develop into a second generation in the field in southern Honduras. This would suggest that *M. rogenhoferi* may have staggered initiation of diapause in May, June or July, with staggered emergence from diapause the next year, giving the appearance of more than one generation. This behavior may have evolved as a survival mechanism for this species in southern Honduras.

Portillo (1994) reported that *M. rogenhoferi* pupae remained in diapause for about seven months in laboratory conditions at 100% RH and 29°C, whereas, Calderón (1998) observed this species to remain in diapause for 10 months after pupation. Considering that *M. rogenhoferi* enters diapause in May or June, our observations of moth emergence suggest that diapause in this species could last from 10 to 12 months, or longer, in southern Honduras.

**Field study**

Two *M. rogenhoferi* pupae were collected from soil samples in the foothills and two on the coastal plain in early March. These pupae were collected from soil under vegetation which was mostly sicklepod covering 14 $m^2$ of ground. Using this observation, one might calculate that about 1,429 adults might emerge per hectare of soil completely covered with sicklepod, if all pupae survived to adulthood in this area.

However, the low number of eggs (20 to 100) deposited per female (Cordero *et al.*, 2002), the ratio of females to males (1.2:1) in the population (Portillo, 1994) and apparent high mortality levels of all developmental stages could be responsible for the low populations in certain years in southern Honduras.

As indicated previously, *M. rogenhoferi* has been reported in some years to be almost singly responsible for total destruction of sorghum and maize during the early plant developmental stages (Pitre, 1995). This may occur if crops are planted early, particularly if planted immediately after the first rains that are followed by an extended dry period. The early rains provide moisture for the crops to emerge and establish a stand. Weeds also emerge and compete with the crops. In years when the rainy season begins in this irregular fashion and farmers plant maize and sorghum early, the early rains provide the environment for emergence of *M. rogenhoferi* moths and the beginning of egg laying activities. The young seedling crops are attacked and often destroyed. Farmers that delay planting until the rains occur frequently can escape this crop destruction because *M. rogenhoferi* develops through its destructive generation on noncrop host vegetation before the crops are available.

In sampling noncrop vegetation to determine occurrence and initial infestations of *M. rogenhoferi* larvae following emergence of adults, two second-instar *M. rogenhoferi* larvae were observed feeding on *Cucurbita mixta* L. seedlings on April 28 (10 d after moth collection) in fields on the coastal plain. Fourth- and fifth-instars were observed in big numbers feeding on sicklepod in late May (6-7 weeks after moth collection) in the foothills. These immatures were likely offspring of adults emerging from diapause in mid-April on the coastal plain and in late April or early May in the foothills, after the first rains in each area.

*Metaponpneumata rogenhoferi* pupae were not found in soil samples taken under sicklepod in mid-June. Results of these observations suggest that mortality of larvae and pupae is high, and thus, survival from one year to the next through the adverse environmental conditions in this region of southern Honduras is low. This observation is supported by the low numbers of pupae found three months earlier in early March in the foothills and on the coastal plain. The low survivorship rate of *M. rogenhoferi* from one year to the next may be associated with the relative small size of the pupae [8–9.1 mm (Cordero *et al.*, 1999)] and their vulnerability to environmental stress and natural enemies in pupation sites close to the soil surface. The high soil temperatures at pupation sites during the dry season may be associated with desiccation and resultant low survival of pupae.

Mortality of this species on the coastal plain might be expected to be greater than in hillside fields because of differences in land preparation before planting. Vergara (1998) reported that farmers on the coastal plain use improved crop production technology, compared with farmers in the foothills. Tractors are used to prepare land for planting on the coastal plain. This tillage can destroy pupae, thus reducing the number of adults that emerge to contribute to establishment of populations of this species. However, sicklepod is widespread in the area and serves as a suitable host for this insect when it emerges from diapause. In the foothills, most of the farmers plant sorghum and maize by hand and remove weeds with a machete, thus disrupting the soil relatively little from one year to the next. In this environment the pupae can survive in greater numbers, potentially resulting in higher populations in hillside fields than in fields on the coastal plain. Regulation of pest infestations by naturally occurring predators and parasites was not investigated in this study, however previous studies indicate that these natural enemies apparently are not effective in reducing *M. rogenhoferi* populations below damaging levels on sorghum and maize in southern Honduras (Cordero *et al.* 2000).

This study contributes to understand some aspects of diapause in *M. rogenhoferi* and its survivorship in the field in southern Honduras. More information is needed to determine definitive generations in the field. Pupae in diapause should be examined using physiological procedures to elucidate the extent of this condition during the dormant period. With this information and that obtained in this study, farmers in southern Honduras can more accurately develop insect pest management systems by adjusting planting dates to avoid plant damage in early plant growth stages. The importance of land preparation as a cultural crop management tactic should be further investigated and integrated into effective insect pest management strategies on sorghum and maize.

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