Effects of Micrometeorological Conditions on Survival and Fecundity of the Mexican Bean Beetle[1] in Soybean Fields

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ABSTRACT

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Contrasting soybean canopy microclimates were obtained in two experiments: (1) field cage modifications and watering schedules and (2) canopy modification through alteration of plant spacing and pruning. The first experiment produced small but significant differences in the mean daily maximum temperature (34.2 to 38.1°C) but not in the mean RH (70.3 to 72.2%). In the second experiment, differences in both factors were significant (29.3 to 32.5°C and 89 to 96%). In the first experiment, differences in temperature were associated with marked differences in survival of adults, larvae and eggs of the Mexican bean beetle, *Epilachna varivestis* Mulsant (Coleoptera: Coccinellidae). This relationship was not evident in the second experiment where the field temperatures were more moderate. However, significant differences in fecundity were observed under contrasting microclimates of the second but not the first experiment.

Introduction

Temperature and moisture (relative humidity) have been recognized as important factors in the population dynamics of the Mexican bean beetle (MBB), *Epilachna varivestis* Mulsant, and have been the subject of several studies. In one of the earlier laboratory investigations, Sweetman and Fernald (1930) examined temperatures from 17 to 37°C and relative humidities (RH) from 32 to 93%. Under constant conditions, 37°C killed all stages regardless of RH. Varied conditions (32°C for 8 hours and 22°C for 16 hours) gave high oviposition, poor egg hatch and larval survival of 65.0 (32 to 40% RH) to 86.7% (86 to 92% RH).

Single 3-h exposures of adult MBB to 38.5 and 41.5°C (73% RH) resulted in 9.6 and 81% mortality, respectively (Miller 1930). No survival occurred at 42.5°C regardless of the RH, while a temperature of 37.5°C gave survival rates of 93 to 99% at the RH used. Survival of larvae of an unspecified age at 73% RH was 100, 96, 89 and 91% at temperatures of 37.5, 38,5, 39.5 and 40.5°C, respectively. At temperatures of 41.5 and 42.5°C (73% RH) survival was considerably less (10.7 and 0%, respectively).

Host plant species and phenology, as well as their interactions with temperature and humidity, influence larval survival (Wilson 1979) and adult longevity and fecundity (Lockwood *et al.* 1979, Kitayama *et al.* 1979). These authors found tolerance to high temperature and low humdity was reduced in MBB reared on soybeans as compared to those on *Phaseolus* spp.

Outbreaks of MBB in North Carolina soybeans have been sporadic, usually widely scattered, variable in location, and have been thought to be negatively associated with hot dry weather (Deitz *et al.* 1976). Howard (1931) and Eddy and McAlister (1927) also suggested that high temperature and low RH reduced survival in the field. Thus, there is a rationale for the hypothesis that fluctuations in canopy microclimatological factors above or below tolerance limits are of major importance in MBB population dynamics in North Carolina. However, studies designed to investigate sensitivities of the MBB under the range of temperature and RH found in soybean fields are lacking. For this reason the following experiments were accomplished.

Materials and Methods

Two experimental strategies were used: in experiment 1, temperature and RH were variously modified in large field cages by shading, plastic covers, and varying irrigation. In experiment 2, these microclimatological factors were modified by varying the spacing and the pruning of the plants. Both experiments were conducted in a field of Bragg variety soybeans planted at the Central Crops Research Station (CCRS), Clayton NC on May 19, 1977 in 96 cm rows at an average seeding rate of 7.8 seeds/0.3 m of row. Temperature and RH were recorded daily at 1000 h 20 cm above the soil in the soybean canopy. Temperature was taken with a maximum-minimum thermometer and RH was taken with an aspirating psychrometer.

Experiment 1

The following 4 treatments of 4 replicates each were carried out in a randomized block design in 6.4 × 9.1 m plots each containing two 1.8 × 1.8 × 1.8 m saran cages:

(1) HW—plots were watered 1–2 times weekly with an oscillating sprinkler (ca. 1 cm/week), and the sides and top of the cages were covered with a layer of clear polyethylene film (6 mil) with 10 cm diameter holes for ventilation; (2) AD—unmodified, ambient temperature cages that received no additional watering; (3) AW—similar to (2) but the plots were watered as in the HW plots; (4) LW—plots were watered as in the HW plots and the cages were placed under a 1.9 × 3.7 m canopy which shaded the cages from ca. 1000 to 1700 h. The canopies were made with a layer of aluminum foil between layers of clear polyethylene film (6 mil) fastened to a wooden frame.

Two cages were placed in each plot: one to study egg and larval mortality and another to study adult longevity and fecundity.

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Ten male and ten female MBB, collected from overwintering sites during the winter of 1976–77 and held at 10°C in 473 ml cartons with damp paper towels, were marked with a dot of paint on the left elytron and placed in each cage on June 18. After 13 days, the beetles in the egg-and-larval-survival cage were removed and the eggs and egg masses counted and their location on the plant marked. When a visual check indicated that most of the larvae that developed from these eggs had pupated, the plants were cut at ground level and all stages of the MBB were counted. When the pupae were harvested, a sample of 4 to 6 of the marked egg masses/treatment were collected and the percent hatch determined. In the adult-longevity-and-fecundity cage, adults, egg masses and eggs were counted semi-weekly. After each census, the egg masses and dead adults were removed.

Experiment 2

Canopy modifications to provide contrasting microclimates for MBB were made on August 18, 1976. Two environments (treatments) were compared: (1) full canopy—normal between-row (96.5 cm) and within-row (1.6 plants/20 cm of row) spacing; and (2) reduced canopy—thinned to 1 plant per 20 cm of row and with side branches removed to produce an open canopy. Four saran cages (1.8 × 1.8 × 1.8 m) were installed in each of the experimental areas. The introduction of adults (collected from soybeans in Pasquotank Co., NC on August 15) and subsequent counts of immature stages and adults were made as in experiment 1.

Results may have been influenced by alterations of the plant material per se, rather than, or in addition to, the alterations in the microclimate. Therefore, data on fecundity and survival of adults and immatures were recorded in an insectary on caged plants obtained from both the full and reduced canopy treatments, beginning simultaneously with the field experiment. The insectary comparisons were replicated 3 times, each replicate consisting of ten marked beetles of each sex introduced into a 0.4 × 0.4 × 1.2 m screen cage on an experimental soybean plant. The plants were kept in water and replaced semi-weekly. Data on the adults and immature stages were taken as described for the field experiment.

Results

Experiment 1

The experimental modifications resulted in significant differences among the treatments in the mean maximum temperature (a range of 3.9°C with a low of 34.2°C (LW) and a high of 38.1°C (HW), Table 1). The mean daily minimum temperature of the HW treatment (22.2°C) was significantly higher than for the other treatments. The mean daily minimum temperature did not differ significantly between the AD, AW and LW treatments. The mean RH measured at 1000 h did not vary significantly among treatments.

During the period of egg development, the treatment (HW) with the highest mean daily maximum temperature (38.7°C) and highest RH (74.7%) gave the lowest percent egg hatch (4.8%) (Table 2). In contrast, the highest percentage egg hatch (68.6%) was recorded in the treatment (LW) with the lowest temperature (34.7°C) and humidity (70.4%). Adult and larval survival were also significantly higher in the LW than in all the other treatments (except for larvae in AW) (Table 1). No significant differences in fecundity were found among the treatments.

Table 1.—Adult and larval survival and fecundity of MBB as associated with contrasting microclimates (June 18 to July 27, 1977).

Microclimate types[1]	Daily temp. °C[2,3] Mean max.	Mean min.	Single highest	Mean RH %[2]	Mean No. adults	% Larval survival[4]	Mean No. eggs/♀ per day
HW	38.1a	22.2a	44.4	72.2a	5.6b	3.5b	6.0a
AD	37.7b	21.8b	43.9	70.5a	5.7b	5.4b	7.1a
AW	36.8c	21.7b	44.2	70.3a	5.8b	9.5a	8.6a
LW	34.2d	21.7b	39.4	71.0a	7.8a	46.1a	7.0a

[1] See text.
[2] Taken daily at 1000 h throughout the experiment.
[3] Means in each column followed by the same letters are not significantly different at the 5% level using Duncan's new multiple range test.
[4] From egg to pupal stage.

Table 2.—Percent hatch and daily temperatures and relative humidities taken during period of egg development (July 3–10) in caged soybeans.

Microclimate types[1]	Daily temperature °C[2,3] Mean Maximum	Mean Minimum	Mean RH %[2]	% Hatch
HW	38.7a	22.8a	74.7a	4.8b
AD	38.0ab	22.6a	73.2ab	18.6b
AW	37.3b	22.6a	73.1ab	23.5ab
LW	34.7c	22.4a	70.4b	68.6a

[1] See text.
[2] Taken daily at 1000 h July 3–10.
[3] Means in each column followed by the same letters are not significantly different at the 5% level using Duncan's new multiple range test.

Table 3.—Adult and larval survival and fecundity of the Mexican bean beetle in full and reduced soybean canopies (August 18–September 28, 1977).

Soybean canopy	Mean Max. daily temp. °C	%RH[a]	Mean No. adults[b]	% Larval survival	Mean No. eggs/♀ per day
Full	29.3*	96*	5.5NS	50.4NS	3.9*
Reduced	32.5	89	5.1	63.8	8.0

[a] Taken daily at 1000 h from August 19-30.
[b] Average number of adults throughout experimental period.
* Significant at 5% level.

Experiment 2

Temperature was significantly higher and RH lower in the reduced-foliage treatment (Table 3). However, these changes did not significantly influence adult and larval survival. Fecundity, however, was significantly higher for beetles in the reduced-foliage treatment. This appears to have been in response to the difference in temperature and/or RH rather than plant density, since no differences in fecundity could be detected for beetles held in the insectary under the same conditions of temperature and RH on foliage from the two field treatments.

Discussion

A major factor inhibiting satisfactory studies of the effect of weather factors on population dynamics is the difficulty of designing acceptable experimental procedures which provide contrasting micrometeorological conditions realistically and within appropriate ranges of meteorological factors. The procedures used were moderately successful and show promise for future development.

Procedures in experiment 1 produced significant differences in mean maximum temperatures. These differences, though small (34.7 to 38.7°C), were imposed near the upper tolerance limits of MBB. In this range, small temperature differences resulted in large differences in adult and larval survival. For example: the mean maximum daily temperature of the LW treatment (34.7°C) was only 2.6°C lower than in the AW treatment, but under the latter conditions egg hatch and larval survival were reduced 3-fold and 5-fold, respectively.

Procedures of experiment 2 (i.e., modification of canopy through spacing and pruning) produced small but significant differences between treatments in temperature and RH. The temperature range (29.3–32.5°C) was below values previously found lethal (experiment 1 and earlier literature citations). Procedures of this experiment might be used more successfully in studying the response of the MBB to meteorological factors if utilized under more extreme weather conditions.

While this study suggests that microclimatological factors may have a major influence on MBB survival (and hence on wide-area spatial and temporal patterns), a definitive test of this hypothesis will require much additional information on the variation in soybean canopy microclimates throughout the state, as associated with monitored MBB populations.

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