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INFLUENCE OF MANAGEMENT ON CROP MICROCLIMATE AND CONTROL OF COTTON BOLLWORM AND BOLL WEEVIL

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Abstract

Low relative humidity and high temperatures in cotton fields in the New Mexico Chihuahuan desert dramatically reduced immature boll weevil *Anthonomus grandis grandis* Boheman survival. The degree of survival was also affected by cultural practices that affected crop microclimate. Boll weevils in infested squares placed in cotton furrows for 10 days in early season had 100% mortality. After canopy closure when temperatures were lower and relative humidity higher, some adults emerged from squares, but emergence varied with management practices. Rows oriented north/south had 38% emergence compared to 9% emergence in rows oriented east/west. Narrow row cotton with 17-cm row widths had higher survival of boll weevils, lower temperatures and higher relative humidity than standard 96-cm row widths. Mean daily high temperature in-furrow was 22°C lower in 17-cm rows compared to 96-cm rows with mean highs of 32°C and 54°C respectively. Relative humidity in-furrow was also significantly lower in 96-cm rows with lows of 17% RH compared to 24-25% RH in 34-cm and 17-cm rows. Squares under the plant canopy had 34% emergence of adults compared to 6% emergence of squares in the center of the furrow. In a controlled chamber test at 26°C, low RH reduced adult emergence, and resulted in an extended emergence time and a shorter adult lifespan. Adult emergence was 91% at 50% RH vs. 41% at 17% RH. Adult lifespan was much shorter at 17% RH with mean lifespan of 20 days compared to 42 days for those reared and maintained at 50% RH. Adult emergence was also delayed 2 days at 17% RH compared to those at 50% RH. Results for cotton bollworm, were more variable but hatch rates were lower in east-west oriented rows and 96 cm row spacing. These results indicate that natural mortality to insects due to high temperatures and low RH can be very high in the desert valleys of the Chihuahuan desert. Also, higher relative humidity, lower temperatures and higher survival of boll weevil in narrow row cotton suggest that the increasing use of narrow row cotton in arid/semi-arid areas will result in higher boll weevil populations and damage.

Introduction

In the last 10 years, boll weevil has become established in much of New Mexico. Conditions along the NM eastern High Plains are similar to those of the Texas High Plains. However, much NM cotton is grown in desert river valleys in the Chihuahuan desert with environmental conditions that were once considered too harsh for boll weevil. Boll weevil establishment as an economic pest in Arizona demonstrated that it could attain pest status in a desert environment. However, high in-season temperatures and low relative humidity should have a significant impact on boll weevil mortality in NM. Desiccation of larvae or pupae in cotton squares is the primary source of natural mortality in west central Texas (Sturm and Sterling 1990). Frequent and prolonged periods of high temperatures in Arizona had a strong impact on boll weevil control until late season when shading increased survival on the soil surface (Fye and Bonham 1970, Fye and Parencia, Fye 1972). Hunter (1907) claimed that in dry seasons more than 90% of immature boll weevils were killed by heat and dryness. Isely (1932) indicated that relative humidity during the summer was the most important factor affecting survival of immature weevils.

Much of NM cotton is grown in the Chihuahuan desert at an altitude of 975-1128m with conditions that were once considered too harsh for boll weevil. The climate in these desert valleys during the growing season is characterized by high temperatures and low relative humidity during the day and relatively cool nights with higher relative humidity. Winter temperatures are moderate with light freezes. Previous studies in Texas suggested that high temperature is an important source of boll weevil mortality in relatively dry areas of midwestern Texas. Dissections of squares collected throughout Texas indicated that desiccation caused 57% of total mortality compared to only 9% in east coastal Texas during a similar period (Sturm and Sterling 1990). Mortality from desiccation was also highly variable with 0-51% mortality from desiccation in east Texas (Strum and Sterling. 1990). In the Rolling Plains of Texas, rows oriented east/west had lower boll weevil damage than those oriented north/south (Slosser et al. 1986).

Boll weevil lays eggs in flower buds (squares), which generally shed from the plant within a few days. The larva continues to feed on pollen inside the bud and completes its immature development there, emerging from the square as an adult after 16-24 days. The square provides some protection from the environment, however unlike more mobile immatures the immature boll weevil cannot move from the square if it is in unfavorable conditions. The high rate of mortality from desiccation in mid-western Texas suggested that such effects might be greater in environments that are more arid.

Recently, there has been an increasing interest in planting ultra-narrow and narrow row cotton. Planting cotton in narrow row spacing may alter the crop canopy and soil surface microclimate, perhaps making it more favorable for survival of insects including boll weevil. Slosser et al. (1986) found that narrow row spacing increased boll weevil damage. The objective of this study was to determine the impact of row orientation and row spacing on temperature and relative humidity and subsequent survival and development of immature boll weevils.

Materials and Methods

All tests were conducted at the New Mexico State University Agricultural Science Center near Artesia, NM, during 1999-2001. Row orientation test plots were 12 rows wide, with 96cm (38") row spacing and 30m long and used the variety Paymaster1244RR. Each treatment was replicated four times for a total of eight plots alternating row orientation. Row spacing treatments were 17, 34, and 96-cm (7, 14, 38in) with plots 40m long. The variety was Paymaster 1220, an early season, relatively determinate variety. All plots were irrigated as needed but no assays were conducted when the soil surface was still moist. Plots were seeded in late April/early May on beds with seeding rates adjusted to produce 14 plants/m.

Twelve field-lab assays were conducted between 1999-2001 to evaluate effects on bollworm egg hatch rates with the different row spacings and row orientation. Eggs were collected from lab colonies when they were 18-24 hours old. In each test group of 30-70 eggs were attached to leaves at mid-canopy. Eggs were removed after 48 hours then maintained in the laboratory at 26°C and 50% RH and checked regularly until hatch. Data was analyzed using JMP (SAS Institute1998) for Tukeys separation of means or t-tests as appropriate.

Four assays were conducted in the field and lab to determine effects on boll weevil mortality. Two assays in row orientation plots were conducted, one before and one after canopy closure. One assay was conducted in the row spacing test before canopy closure. In another similar assay, lines of squares were placed either next to the plant or in the center of the row in 96-cm rows mid-season.

Boll weevil infested flower buds (squares) were collected for tests from infested fields. Squares used for testing were not flared, firm, with white tips, one oviposition puncture and no feeding damage. These criteria ensured that they contained one egg or very small larva. To facilitate placement and retrieval from the field, groups of ten squares each were sewn together with monofilament fishing line. A total of 40 lines of ten squares were used for each treatment in each test.

In the row orientation and row spacing tests, lines of squares were placed on the soil surface in the center of the row for ten days. Each line of squares was then placed in a 440 ml (16 oz) unwaxed paper cup with a vial for adult emergence and held at 27°C and 50% RH until all adults emerged. Adults were held on diet in incubators at 26°C and 50% RH until mortality was recorded. After adult emergence was considered complete, squares were dissected to determine the developmental stage of boll weevil at death.

In all tests, data loggers (Onset Corp, Pocasset**,** MA) were placed in the field in the center of the row and at the base of cotton plants to record temperature and relative humidity. When possible, squares were also maintained in chambers at 26°C and 50% RH as a control.

A test was also conducted in incubators to examine the effect of relative humidity on boll weevil under controlled conditions. Treatments were 17% RH vs. 50% RH. Temperature was constant at 26°C and the photoperiod was L D 16:8. Squares were collected from the field, then held in 237-ml unwaxed paper cups with small holes to ensure airflow and a vial in the lid for emergence of adults. Each cup held ten squares and a total of 100 squares were used in each treatment. After emergence, adults were maintained on artificial diet until their death was recorded.

Data were analyzed using SAS GLM (SAS Institute 1996) and SAS JMP (1998)**.** Specific comparisons of means were tested with least square means or Tukey's multiple comparison test. When appropriate, individual variety or treatment means were compared with t-tests. Preliminary tests with multiple data loggers indicated no significant difference between multiple data-loggers placed in similar positions in the canopy, so single data loggers were used with comparisons calculated between treatments for daily highs, lows or means for temperature and relative humidity.

Results and Discussion

In general, results for bollworm were highly variable but there were some indications that row orientation and row spacing could influence bollworm survival. Mid-late season conditions are more favorable for bollworm than early season. In early September 81% and 91% of bollworm eggs hatched in rows oriented north-south and east-west respectively (Figure 1). Bollworm eggs hatch was slightly reduced in 96 cm rows compared to 34 cm and 17 cm row spacing with 69% hatch in 96 cm rows compared to 84 and 89% hatch in 34 and 17 cm rows respectively (Figure 2).

Prior to canopy closure there was no difference in adult emergence from squares placed in rows oriented east/west or north/south since no adults emerged from any of the 400 squares in each treatment (Table 1). Before canopy closure, mean high temperatures were similar between treatments with 54° and 57°C in north/south and east/west rows, respectively. Relative humidity was lower in the east/west rows with only 3% mean daily low RH compared to 13% in the north/south rows. After canopy closure, there was a difference in mortality between north/south and east/west oriented rows. Squares in north/south rows had 38% emergence of boll weevil adults compared to only 9% emergence from squares in east/west rows. Mean high temperatures were similar between treatments but north/south rows had significantly higher mean RH, with 69% RH compared to 55% RH in east/west rows.

Significantly more boll weevil adults emerged from squares placed in 17-cm rows compared to 96-cm rows with 10 and 0% emergence, respectively (Table 2). Mean daily high temperature was significantly higher, 17-22°C higher, in the 96-cm row spacing compared to the 17- and 34-cm row spacing. Relative humidity daily low was significantly lower in the 96-cm row spacing with mean lows of 17% RH during the test compared to 24-25% in the 17- and 34-cm row spacing. On the other hand, temperature and relative humidity profiles were similar in the 17- and 34-cm row spacings. These results indicate that row spacing can dramatically affect the crop microclimate and the suitability of the environment for survival of boll weevil and perhaps other insects.

Squares placed in-furrow had significantly fewer adults emerge compared to those at the plant base. Only 6% of squares placed in-furrow produced adult boll weevils compared to 34% of those placed at the base of the plant (Table 3). However, days to emergence and adult lifespan were similar in adults from squares in-furrow and at the plant base. ($\alpha<0.05$)

Immature boll weevils in squares maintained in incubators at 50% RH had higher rates of adult emergence, shorter time to emergence and a longer lifespan compared to those maintained at 17% RH (Table 4). Adult emergence was more than twice as high at 50% with 91% emergence compared to 41% at 17% RH. Boll weevils at 50% RH also emerged 2 days earlier, and lived 22 days longer than those reared at 17% RH.

Initial results for bollworm hatch rates suggest that the impact of low relative humidity and high temperatures may be more variable and less intense in the crop canopy where temperature is lower than on the soil surface.

The impact on boll weevil was much more severe. As in Arizona, environment causes very high boll weevil mortality in New Mexico desert valleys. Particularly as the season progresses, microclimate is affected by the presence of and amount of vegetation, which affects boll weevil survival and development. Row orientation, row spacing and location of fallen squares affect the microclimate to which those squares are exposed, affecting boll weevil survival and development.

It is difficult to separate the impact of high temperature and low relative humidity and to determine if high temperatures result in mortality through desiccation or thermal shock. The lack of any survival in two separate tests where in-furrow temperatures were ≥54°C is consistent with the Sterling et al. (1990) model which suggests that such high temperatures result in mortality by thermal shock. In that study low levels of thermal death occurred at ≤3 hours at 54°C. At lower temperatures relative humidity may be the more important factor, but both of them likely impact mortality. Relatively high temperatures 34-36°C have been associated with little to no mortality of eggs and larvae as long as RH was high (Bacheler et. al. 1975, Bacheler and Bradley 1975).

The impact of microclimate particularly with regard to relative humidity may have a greater effect on boll weevil survival in this desert environment than in other areas. However, previous results from midwest Texas suggest that environmental impacts that may be very evident in the desert also influence survival and development of insect pests in less arid environments. In Texas, Sterling and Dean (1989) observed that boll weevil mortality increased from 50% to 98% during a very hot 3-day period. Slosser et al. (1986) found higher rates of damage in narrow row cotton and rows oriented east-west. High temperatures and low relative humidity may be reliably expected to produce very high mortality in desert cotton fields but may also be associated with less predictable or lower levels of mortality in less arid environments.

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Table 1. Boll Weevil Adult Emergence, In-Furrow Temperature and Relative Humidity in Row Orientation Test

Row Orientation	% Adult Emergence (s.e.)	Temperature (°C) In-Furrow[b] Mean (s.e.)	Temperature (°C) In-Furrow[b] High (s.e.)	RH In-Furrow[c] Low (s.e.)	RH In-Furrow[c] Mean (s.e.)
		Prior to Canopy Closure			
N-S	0 (0)	30 (1.1)	54 (2.5)	13 (5.0)	50 (2.7)
E-W	0 (0)	34 (1.1)	57 (1.6)	3* (1.5)	40* (2.4)
		After Canopy Closure			
N-S	38 (4.8)	23 (1.2)	40 (1.6)	35 (2.8)	69 (2.8)
E-W	9* (2.2)	28 (1.3)	40 (2.0)	23 (2.1)	55* (3.0)

[a] Means of orientation treatments followed by * are significantly different by t-test (P<0.05)
[b] Mean and mean daily high temperature for the 10 days squares were in field plots.
[c] Mean and mean daily low relative humidity for the 10 days squares were in field plots.

Table 2. Boll Weevil Emergence, Temperature and Relative Humidity with Various Row Spacings of Cotton[a]

Row Width (cm)	% Adult Emergence (s.e.)		Temperature(°C)[b] Mean (s.e.)		Temperature(°C)[b] High (s.e.)		% Relative Humidity[c] Low (s.e.)		% Relative Humidity[c] Mean (s.e.)	
96	0a	(0)	33a	(1.2)	54a	(3.0)	17a	(6.0)	50a	(3.2)
34	4ab	(1)	27ab	(1.1)	37b	(2.2)	24b	(8.3)	59b	(2.8)
17	10b	(3)	26b	(1.1)	32b	(2.2)	25b	(6.0)	61b	(3.1)
Incubator Check	86c	(14)	26		26		50		50	

[a] Means followed by different letters are significantly different by Tukey's Comparison. (α<0.05)
[b] Overall mean and mean daily high temperature for the 10 days squares were in the field.
[c] Overall mean and mean daily low relative humidity for the 10 days squares were in the field.

Table 3. Boll Weevil Adult Emergence, from Infested Squares at Plant Base vs. In--Furrow.[a]

Location	% Emergence (s.e.)	Mean Days to Emergence (s.e.)	Mean Adult Lifespan (s.e.)
In-Furrow	6a (3.7)	16a (0.2)	49a (9.6)
Plant Base	34b (5.1)	16a (0.1)	43a (6.3)
Incubator Check (26°C/50% RH)	89c (3.0)	16a (0.1)	54a (5.1)

[a]Means followed by different letters are significantly different by Tukey's Comparison. (α<0.05)

Table 4. Relative Humidity influence on Boll Weevil Development at a Constant Temperature of 26°C[a].

RH	% Adult Emergence (s.e.)	Days to Emergence (s.e.)	Lifespan (s.e.)
50	91 (4)	16 (0.2)	42 (1.7)
17	41* (4)	18 (0.2)*	20 (1.8)*

[a]Means within columns are significantly different by the t-test *P*<0.0001

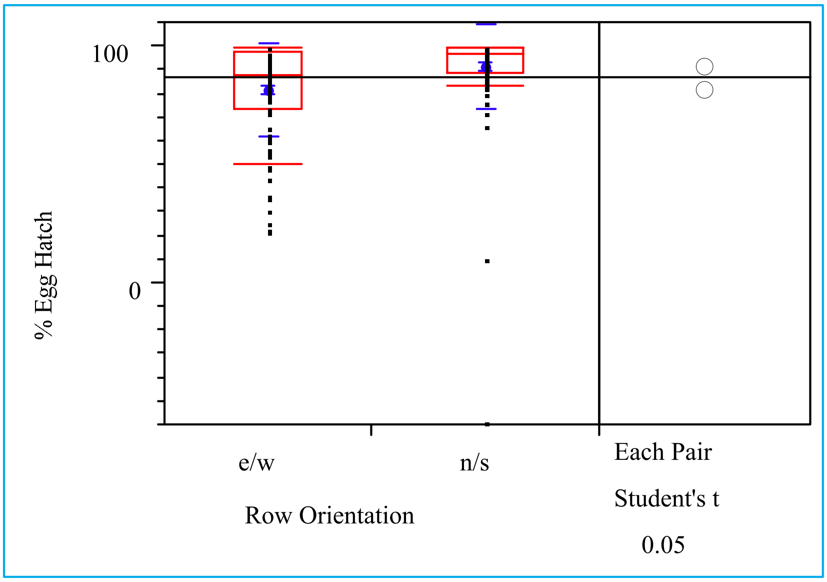

Figure 1. Percent Egg Hatch by Row Orientation.

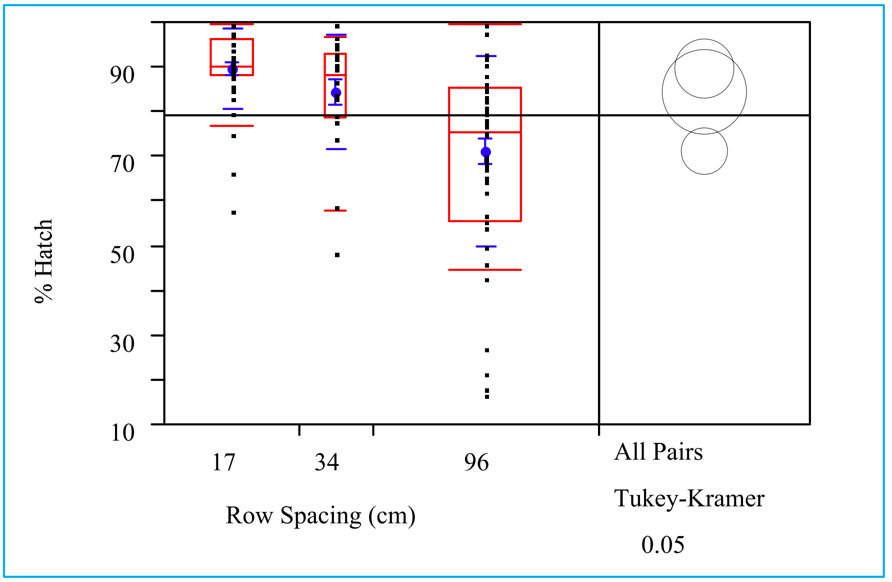

Figure 2. Percent Hatch by Row Spacing.