EFFECTS OF FERTILIZERS ON RESISTANCE OF ANTIGUA CORN TO FALL ARMYWORM¹ AND CORN EARWORM²

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ABSTRACT

Larvae of the fall armyworm, Spodoptera frugiperda (J. E. Smith), and the corn earworm, Heliothis zea (Boddie), were exposed to excised foliage of an intermediately resistant Antigua corn that had been fertilized at the recommended level with a complete fertilizer (NPK) or with all possible combinations of the component nutrients. Both the fall armyworm and the corn earworm larvae preferred foliage from plants having N treatment over foliage from plants treated with P, K, or PK or the unfertilized check. Also, the weight gains of the corn earworm and fall armyworm and the days to pupation, pupal weight, and percentage larval mortality of fall armyworms indicated that treatment with N or with combinations of N increased susceptibility. The preference ratings of the fall armyworm and corn earworm on corn were significantly associated. Also, the fall armyworm preference ratings were significantly correlated with larval weights, pupal weights, days to pupation, and foliage production. Thus, the preferential responses were the predominant factors even though several characters measured were expressions of antibiosis. The corn earworm preference ratings were significantly correlated with larval weight and longevity. The percentage mortality before pupation, an expression of antibiosis, showed that the fertilizer treatments had a detrimental effect on fall armyworm larvae compared with no treatment (unfertilized check). It also appears that Antigua corn has an extremely high level of antibiosis since all corn earworm larvae died, even on the unfertilized check.

Painted (1951) listed 3 mechanisms of resistance: nonpreference, antibiosis, and tolerance, and noted that tolerance was perhaps subject to more variation as a result of environmental conditions than nonpreference or antibiosis. Numerous researchers have since reported the effects of host-plant nutrition of agricultural pests (Singh 1970). For example, van Emde (1966) stated that modification of the environment could induce an acceptable level of resistance in plants. Also, Leuck (1972) reported extreme expressions of nonpreference, antibiosis, and tolerance when the fall armyworm, Spodoptera frugiperda (J. E. Smith), was given a choice or force-fed foliage of ‘Gahi’ millet treated with all possible combinations of NPK fertilizers in greenhouse tests.

The studies described herein were designed to determine the effects on

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larvae of the fall armyworm and the corn earworm, *Heliothis zea* (Boddie), when they were fed 'Antigua' corn, a composite that is resistant to the fall armyworm, after the corn had been treated with all possible combinations of the median recommended rates of a complete (NPK) fertilizer.

**Methods and Materials**

Antigua Group 2 corn, Antigua FAW Resistant Composite, was selected for the present study based on the intermediate level of leaf-feeding resistance to the fall armyworm demonstrated in our earlier (unpublished) tests. Ten seeds of the corn were planted in each 6-in.-diam plastic pot containing sterile vermiculite. The test was replicated 6 times. The treatments consisted of a complete NPK fertilizer at the median recommended rate which is equivalent to 130-60-90 lb/acre (Anonymous 1968) and all possible combinations of the constituents (N, P, K, NP, PK, and NK) plus an unfertilized check.

The nitrogen was from ammonium nitrate, 34.5% available; the phosphorus from super phosphate, 23.7% available; and the potassium from potassium oxide (K₂O), 62.0% available. A complete factorial arrangement of the treatments (N, P, K, NP, NK, PK, NPK, and unfertilized check) was used. Treatments were applied at the time of planting. Then each pot received 500 ml of water (maximum amount without leaching). After emergence of the seedlings and each 4th day thereafter until completion of the tests, each pot received 300 ml of water.

Excised foliage was obtained from each treatment and force-fed (choice of feeding or starving) to individually caged fall armyworm larvae beginning when the corn in the NPK treatment was 6-8 in. high, a stage similar to that evaluated by Wiseman et al. (1966). The larvae used in the test were obtained from the colony of fall armyworms maintained at this laboratory. Tests were conducted in a constant temperature room maintained at 26.7 ± 1°C. Each treatment consisted of 6 replications of 10 larvae each. The measurements obtained were: larval weight after 8 days of force-feeding, larval mortality before pupation, days to pupation, pupal weight, days to adult emergence, and production of foliage.

Also, fall armyworm larval preferences were determined by placing 4-5 excised leaves from each treatment in a circular arrangement in a randomized complete block design on the outer edge of a 10-in.-diam circle of moistened filter paper in a round plastic dish. After ca. 1,000 1st instar larvae were placed in the center portion of each dish, the dish was covered with a tight-fitting plastic cap. After 24 hr, the consumed foliage of each treatment was rated visually by using a rating scale of 1-10, with 1 = 0-10% and 2-10 = 20-100%.

Evaluations of the corn earworm larval responses (preference, weight gains, and duration of life span) were similar to the tests for the fall armyworm, except that the foliage were ca. 2 weeks older and the larval weight was determined at the end of 10 days. Also, the force-feeding trials for the corn earworm had 4 replicates of each treatment, and the preference ratings were made after 48 instead of 24 hr. A second preference test of fall armyworm was conducted with the same age foliage used for the corn earworm.

Analyses of variance and Duncan's multiple range test were used for all characters measured to separate differences among treatments. Percentages were transformed to $\sqrt{\text{arcsin} \ X + 1}$ for analysis. Correlations were prepared to
detect any association of preference ratings and 8-day weight gains, of preference ratings and pupal weight, of preference ratings and days to pupation, of preference ratings and foliage growth, of foliage growth and 8-day weight for fall armyworm, of early preference ratings and late preference ratings for the fall armyworm, and of preference ratings for the fall armyworm and preference ratings for the corn earworm. Similar correlations were tested for fall armyworm preference ratings among crops (Leuck 1972) such as corn and millet, corn and peanuts, and peanuts and millet.

Results and Discussion

Preference Tests.—In the early preference test of corn (6-8 in. high), 1st-instar fall armyworm larvae preferred foliages (after 24 hr) treated with N and combinations of N (Table 1). The more nonpreferred foliages included the unfertilized check, P, PK, and K. In the later preference test of corn, generally all of the foliages treated with fertilizers were more preferred than the unfertilized check. Also, a significant association (P = 0.05) was found between the results of the preference tests with the early and the late (foliage was 2 wk older) fall armyworm preference tests, though several treatments had ratings that were slightly higher for the late corn [2.7 (P) to 7.7 (NPK) compared with 2.2 (P) -8.2 (NK)]. It seems reasonable that the difficulty experienced in detecting leaf-feeding resistance in field screenings of the fall armyworm thus may occur, in part, because of fertilization practices.

Preferences of the corn earworm larvae after 48 hr were not as striking as those of the fall armyworm (Table 2). Foliages receiving no fertilizer, P, PK, NK, and K were the least preferred; foliages treated with N, NP, and NPK were the most preferred. The significant correlations found for earworm preference ratings vs. 10-day weight and number of days lived (P = 0.05) indicated that the most preferred treatments were those on which the larvae made the most gains and lived the longest.

In addition, a significant correlation was found between the preference ratings for fall armyworm and corn earworm on late corn (P = 0.05). However, the visual ratings for corn earworm feeding averaged 56% lower than those of the fall armyworm. Fall armyworm larvae feed much more on the foliage than the corn earworm, which is more of a fruit feeder.

Correlations of the early fall armyworm and corn earworm preference ratings were nonsignificant (P = 0.05). Late preference tests using fall armyworm larvae and the preference tests using corn earworm larvae were conducted during the same period. Thus, when the nutrient content of the foliages was most likely nearly equal, the preferences of the 2 species were essentially the same though of different magnitudes.

The significant correlation between foliage production and the preference rating for the fall armyworm (P = 0.05) indicated that larvae preferred the vigorous growing (highly fertilized) plants and, inversely, preferred least the plants with the least or no fertilization. This difference may explain why Wiseman et al. (1966) found differences among varietal corn seedlings tested in corns planted in unfertilized river-washed sand. Thus, fertilizers could be adjusted when high levels of resistance do not occur.

We found no significant associations between the preference ratings of fall armyworms on corn and millet, corn and peanuts, or millet and peanuts. However, as noted, the preference ratings for the corn earworm and the fall
TABLE 1. Ranking of fall armyworm feeding responses* to an intermediately resistant corn, Antigua FAW resistant composite, treated with a complete (NPK) fertilizer and all combinations of NPK.

<table>
<thead>
<tr>
<th>Fertilizer treatment</th>
<th>Preference**</th>
<th>Foliage† production</th>
<th>Wt./larva (mg) at 8 days</th>
<th>% larval mortality</th>
<th>Days to pupation</th>
<th>Wt./pupa (mg)</th>
<th>Potential†† egg production/♀</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>2.2 a</td>
<td>2.7 a</td>
<td>28.9</td>
<td>155.7 a</td>
<td>10.0 b</td>
<td>14.0 ab</td>
<td>145.0 b</td>
</tr>
<tr>
<td>CK</td>
<td>2.3 a</td>
<td>3.1 bc</td>
<td>25.9</td>
<td>144.8 a</td>
<td>1.7 c</td>
<td>13.7 ab</td>
<td>190.4 c</td>
</tr>
<tr>
<td>K</td>
<td>2.5 a</td>
<td>5.6 cd</td>
<td>27.2</td>
<td>167.2 ab</td>
<td>10.0 b</td>
<td>13.5 b</td>
<td>196.7 c</td>
</tr>
<tr>
<td>PK</td>
<td>2.5 a</td>
<td>4.8 bc</td>
<td>29.2</td>
<td>136.3 b</td>
<td>58.3 a</td>
<td>14.4 a</td>
<td>117.3 a</td>
</tr>
<tr>
<td>NP</td>
<td>5.8 b</td>
<td>6.0 cd</td>
<td>38.8</td>
<td>225.6 c</td>
<td>1.7 c</td>
<td>12.7 c</td>
<td>197.7 c</td>
</tr>
<tr>
<td>NPK</td>
<td>6.8 bc</td>
<td>7.7 d</td>
<td>38.8</td>
<td>220.4 c</td>
<td>3.3 c</td>
<td>12.7 c</td>
<td>219.5 d</td>
</tr>
<tr>
<td>N</td>
<td>7.7 c</td>
<td>7.1 d</td>
<td>39.6</td>
<td>244.9 c</td>
<td>5.0 bc</td>
<td>12.4 c</td>
<td>219.1 d</td>
</tr>
<tr>
<td>NK</td>
<td>8.2 c</td>
<td>8.5 cd</td>
<td>39.6</td>
<td>225.4 c</td>
<td>5.0 bc</td>
<td>12.4 c</td>
<td>235.3 d</td>
</tr>
</tbody>
</table>

* Fertilizer treatments or combinations followed by the same letter are not significantly different (P=0.05). Treatments consisted of equivalents of 130 lb N, 60 lb P₂O₅, and 90 lb K₂O per acre.
**Preference was based on a visual rating of 1 to 10 with 1 = as much as 10% of foliage damaged and 10 = 100% of foliage damaged.
† Foliage was measured in cm from tap of pet to tips of leaves.
††Potential egg production was calculated by using the formulas developed by Leuck and Perkins (1972) based on weight of pupae.
TABLE 2. **Rankings of Fertilizer Treatment by the Average* Weight per Larva (mg), Number of Days Lived, and Preference Ratings for Corn Earworm Larvae Fed or Exposed to Antigua Corn Treated with Various Combinations of NPK.**

<table>
<thead>
<tr>
<th>Fertilizer treatment*‡</th>
<th>Preference ratings‡</th>
<th>Wt/larva (mg)</th>
<th>Avg. no. days lived</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>1.3 a</td>
<td>2.0 a</td>
<td>7.2 b</td>
</tr>
<tr>
<td>CK</td>
<td>1.4 a</td>
<td>2.3 ab</td>
<td>7.0 b</td>
</tr>
<tr>
<td>PK</td>
<td>2.0 a</td>
<td>3.5 ab</td>
<td>5.3 a</td>
</tr>
<tr>
<td>NK</td>
<td>2.5 a</td>
<td>4.1 b</td>
<td>9.8 c</td>
</tr>
<tr>
<td>K</td>
<td>2.8 a</td>
<td>6.6 c</td>
<td>7.4 b</td>
</tr>
<tr>
<td>N</td>
<td>4.6 b</td>
<td>8.0 c</td>
<td>10.0 d</td>
</tr>
<tr>
<td>NP</td>
<td>5.2 b</td>
<td>8.0 c</td>
<td>9.0 c</td>
</tr>
<tr>
<td>NPK</td>
<td>5.8 b</td>
<td>10.6 d</td>
<td>10.0 ed</td>
</tr>
</tbody>
</table>

* Fertilizer treatments or combinations followed by the same letter are not significantly different (P=0.05).

† Treatments consisted of 130 lb N, 60 lb P2O5, and 90 lb K2O/acre.

‡ Preference ratings were based on a visual rating scale of 1-10, with 1= as much as 10% damage and 2-10=20-100% of foliage damaged.

armyworm in our tests were significantly correlated. If fertilizers similar to those used on corn had been applied to millet and peanuts in the earlier tests by Leuck (1972), we might have found significant associations for the same insect on the 3 crops (corn, millet, and peanuts).

Expression of Antibiosis.—The weight gains of fall armyworm larvae at 8 days were greatest on foliages treated with N or combinations of N (Table 1) and corresponded with the preference ratings. The significant association (P=0.05) thus obtained indicated that measurements of nonpreference could be used as an indicator for this expression of antibiosis. Also, a significant association (P=0.05) existed between foliage production and weight of the larvae at 8 days. Larvae that fed on the more vigorously growing plant foliages were the largest, and, conversely, those that fed on the unfertilized foliage or the P or K foliage weighed less.

The weight gains at 10 days by corn earworm larvae for all treatments were not nearly as striking as those for the fall armyworm. However, corn earworm larvae weighed less when they were fed on foliages that had less fertilization, that is, K, P, PK, and the check (Table 2). Again, the foliages that received N or combinations of N were more susceptible. Also, the significant correlation (P=0.05) between the preference ratings for corn earworms and larval weight at 10 days indicated that susceptible foliage (high preference ratings) produced the largest gains with one exception: larvae fed NK foliage made gains that caused this corn to be classified as susceptible even though it was nonpreferred in the choice test. Thus, we may have an indication of the 2nd type of nonpreference reported by Wiseman et al. (1961) and Anonymous (1969) in which the insect, when force-fed, will consume preferred and nonpreferred plant material to the same extent.

The mortality of fall armyworm larvae was significantly greater when the larvae fed on foliages treated with PK compared with all other treatments (Table 1); also, foliages treated with K and P had greater larval mortality than those treated with NPK, NP, and the unfertilized check.
Thus, in general, mortality was similar in all treatments to both the preference ratings and the weight at 8 days except for the unfertilized check which had the lowest mortality and was thus classified as susceptible. Therefore, this expression of antibiosis in terms of larval weight may actually occur because of a nonpreferential feeding response on the unfertilized foliage: even though only a small amount of the unfertilized check was consumed, it produced the least mortality.

All corn earworm larvae were dead within 20 days on all treatments except N, which had 98% mortality by that time. However, when the average number of days larvae lived on the treated foliage is considered, the N and combinations of N were susceptible; resistant treatments were PK, unfertilized, P, and K.

The number of days to pupation and the weight per pupa for fall armyworm from the various treatments showed essentially the same ranking (Table 1). Again, the N and combinations of N produced more susceptible corn, fewer days to pupation, and greater pupal weight. In addition, the PK and P treatments generally affected both the corn and the response of the fall armyworms: unfertilized foliage generally ranked in the intermediate-resistant category. Preference ratings vs. pupal weight and days to pupation were significantly correlated ($P=0.05$), indication that the preferred treatments produced the largest pupae and the nonpreferred the smallest. Also, larvae feeding on the preferred treatments seemed to require fewer days to pupate, and those feeding on nonpreferred treatments required more days to complete the life cycle.

**Population Effects.**—Table 1 ranks the several treatments by the present egg production of the fall armyworm based on the information presented by Leuck and Perkins (1972). Estimating the egg reduction based on the weight of the fall armyworm pupae, the PK treatment would produce almost 66% fewer eggs compared with the unfertilized check (100%); and the P treatment would produce as much as 37% fewer eggs. However, the N, NPK, and NK treatments would cause increases in the production of progeny of as much as 20, 21, and 99%, respectively. When larval mortality is used as a compounding factor with pupal weight, the PK treatments would reduce the production of progeny by the fall armyworm as much as 85% compared with the unfertilized check.

**Acknowledgment**

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**Literature Cited**


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