Effect of Planting Date, Variety and Degree of Ear Maturation on the Colonization of Field Corn by Maize Weevils (Coleoptera: Curculionidae)[1]

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Abstract A 3-yr study evaluated the effect of planting date, variety and degree of ear maturation on maize weevil, *Sitophilus zeamais* (Motchulsky), colonization of corn in the field. Within each plot, paper bags were used to prevent oviposition during one of three consecutive 2-wk periods beginning at the 3/4-milk-line stage. Adult emergence from bagged ears was compared to that from unbagged ears. Maize weevil adults emerged from 15.6% of all ears tested. Numbers of adults emerging from infested ears ranged from 1 to 135 with a mean (±SE) of 11.9 ± 18.5. A greater percentage of Mycogen 7559 ears were infested than those of Pioneer 3167 or Pioneer 3146, and the infested Mycogen 7559 ears also supported the emergence of a greater number of adults. A significant planting date effect was found each year of the study, but the nature of that effect was not consistent. A significant planting date-by-year interaction may have been due to weather affecting the date maize weevils were available for colonization, or more likely, to interference from earlier planted corn near our plots that attracted the first overwintering weevils. Oviposition resulting in successful emergence was found to occur during all 3 of the 2 wk exclusion periods with the last period having the greatest impact on the percentage of infested ears and the second period having the greatest impact on the number of emerging weevils per 500 g of kernels.

Key Words Maize weevil, *Sitophilus zeamais,* cultural control

The warm, humid climate of the southeastern U.S. is conducive to damage from several insect pests of stored grain. The maize weevil, *Sitophilus zeamais* (Motschulsky), is by far the most important pest of stored corn. In addition to causing the more obvious losses in corn weight, grade and nutritional value, maize weevil infestations have been associated with increased growth of aflatoxin-producing *Aspergillus flavus* (Dix and All 1987).

Labeled chemical protectants are an important part of an integrated management plan, but alone, they fail to provide long-term protection (Hagstrum et al. 1999). Aluminum phosphide fumigation is effective, but dangerous to the applicator and numerous regulations make it difficult for private applicators to comply with the label.

In Georgia, maize weevil control in stored corn is further complicated by the fact that infestation routinely occurs in the field prior to harvest. In a previous study, we

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observed adult maize weevil population increases of 3 to 13X only 21 d after corn was harvested and loaded into grain bins (unpubl. data). Assuming a 28-d life cycle (Krischik and Burkholder 1995), this rate of increase is possible only when corn is heavily infested with eggs and larvae prior to harvest. Reductions in maize weevil populations have been observed in corn that has been rapidly dried prior to storage (Keever et al. 1986). However, depending on moisture content at harvest, not all corn is dried with heated air. Many farmers rely instead on ambient temperature aeration.

Maize weevils are known to be very susceptible to temperatures below 0° C and overwintering survival rates are low even as far south as northern Georgia. Observations of adult survival rates in Georgia corn fields ranged from 50% in the extreme south to less than 1% in the north (Dix and All 1986). Observations of maize weevils migrating from storage bins to the field (Kirk 1965, Douglas 1941) have led to the assumption that, at least in the colder range of this insect, field populations are primarily re-established from stored grain. Chestnut (1972), however, found that maize weevils migrating from storage bins failed to infest farther than 0.4 km away from their source.

Field infestations tend to be clumped with a small percentage of the total number of ears supporting most weevil development (Dix and All 1985, Walgenbach et al. 1983). Clumping is thought to be the result of a male-produced aggregation pheromone (Walgenbach et al. 1983). Several investigators have suggested that after initial colonization in corn fields, intrafield movement ceases (Kirk 1965, Chestnut 1972, Dix and All 1985).

Weaver (1983) and Dix and All (1985) failed to find maize weevils infesting corn before kernel moisture dropped below 22%. In Georgia, this moisture level is normally reached between August and mid-September, depending on corn variety, time of planting and weather conditions. Weston et al. (1993) found that moisture content of field corn must be below 31% in order to support infestation by the Angoumois grain moth, *Sitotroga cerealella* (Olivier), in the field.

Maize weevils colonizing ears of corn in the field have been shown to be predominately male, with a sex ratio of 1.6:1.0 (Dix and All 1985). Superior colonizing capabilities of males in conjunction with poor overwintering abilities of females were proposed as causes of the skewed sex ratio. F_1 and laboratory weevil populations were found to be composed primarily of females (0.6 male: 1.0 females) indicating that under periods of continuous reproduction, populations may be skewed in favor of females.

The objectives of this study were to determine (1) if the planting date of corn influenced maize weevil infestations in the field, (2) if there were differences in maize weevil oviposition or survival among some commercially available corn hybrids, and (3) when maize weevil oviposition occurs in the field.

Materials and Methods

A 3-yr study was conducted at the Coastal Plain Experiment Station near Tifton, GA. Four corn hybrids were planted on four dates in 1997, three dates in 1998, and four dates in 1999. The first planting date each year was 26 March 1997, 31 March 1998 and 26 March 1999. Subsequent planting dates were spaced 2 wks apart. The hybrids tested were Mycogen 7559 (formerly, Mycogen Plant Sciences, Prescott, WI), Pioneer 3245, Pioneer 3167 and Pioneer 3146 (Pioneer Hi-Bred International, Inc. A DuPont Company, Des Moines, IA). Plots were arranged in a randomized complete block design with four replications of each combination of hybrid and planting date. Each plot consisted of four rows spaced 0.91 m apart. Plant population was approximately 74,100 plants per ha. All plots were irrigated.

In each plot, paper bags (#404 tassel bags, Lawson Bag Co., Northfield, IL) were used to prevent maize weevil oviposition during three consecutive 2-wk exclusion periods. Beginning at the 3/4-milk-line stage, ten randomly selected ears were bagged in each plot. After 2 wks, these ears were labeled and bags were removed. Ten different ears were then covered for a subsequent 2-wk period in the same manner. When these bags were removed, ten more ears were covered for a final 2-wk period. At harvest, these 30 ears were hand harvested along with ten more ears which had not been bagged. Immediately after the 1997 harvest, each ear was examined for exit holes. Due to the very low number of exit holes found, these data were not collected in 1998 or 1999. Kernels from each individual ear were removed using a John Deere Model 1B ear sheller, placed in sealed and labeled paper bags, and stored in an empty grain bin. After 30 d, each sample was removed from the bin, weighed and sieved to remove adult maize weevils. The number of maize weevil infested ears and the number of adult weevils per 500 g of kernels were calculated. All data were subjected to analysis of variance (ANOVA) and means were separated by a protected LSD test ($\propto = 0.05$ PROC GLM, SAS, 1996).

Results and Discussion

Time of oviposition. Only 15.6% of all ears evaluated over the 3-yr study were infested with maize weevils. As few as one and as many as 135 adults emerged from single infested ears. Infested ears supported an mean (ISE) emergence of 12.5 ± 14.2, 12.6 ± 16.7, and 11 ± 9.2 F_1 adults for 1997 to 1999, respectively, and 11.9 ± 14.1 F_1 adults for the entire 3-yr study. These results are consistent with non-random distributions noted in previous studies. After the 1997 harvest, but prior to shelling and bagging, only 5 exit holes (<0.1% of eventual emergence) were found indicating that almost all weevil emergence occurred after harvest.

With regard to percentage of infested ears, there were no significant exclusion period-by-year (df = 5, F = 0.0, P = 1.0), exclusion period-by-planting date (df = 9, F = 1.28, P = 0.25), or exclusion period-by-variety (df = 9, F = 1.06, P = 0.39) interactions and data from all years, planting dates and varieties were pooled. The same was true for weevils per 500 g of kernels with no significant exclusion period-by-year (df = 5, F = 0.0, P = 1.0), exclusion period-by-planting date (df = 9, F = 1.44, P = 0.17), or exclusion period-by-variety (df = 9, F = 1.37, P = 0.20) interactions and these data were pooled as well. Table 1 shows that levels of infestation significantly differed among exclusion periods (P = 0.0002 for percentage of infested ears and P = 0.0002 for number of weevils per 500 g of kernels).

These results indicate that preventing weevil oviposition during any of the three 2-wk exclusion periods resulted in significantly reduced maize weevil emergence compared to that found in unbagged ears. Therefore, some degree of successful larval development and adult emergence occurred following oviposition which occurred any time during the 6 wks following the 3/4-milk-line stage. The second exclusion period resulted in the largest reduction in number per 500 g of kernels (Table 1). The importance of this time period is uncertain, but the percentage of eggs surviving to adult may be highest during this stage of phenological development of corn. However, the greatest impact on the percentage of infested ears occurred when

Table 1. Percentage of maize weevil infested ears and number of emerged weevils per 500 g of kernels in uncovered ears and ears protected from oviposition during successive two-week periods, 1997-1999

Exclusion period	N	% Ears infested*	No. weevils/500 g*
None	1120	26.0a	14.22a
1	1760	20.0b	8.68b
2	1760	19.0bc	7.13bc
3	1760	16.0c	5.44c

* Means followed by the same letter are not significantly different ($P < 0.05$).

oviposition was prevented during the last 2-wk exclusion period (Table 1), suggesting that, even though larval survival may be slightly less in the drier kernels, colonization continues to increase with time. These results suggest that delayed harvest could significantly increase maize weevil infestation in the field, and indeed, field observations support that hypothesis.

Planting date effect. Weston et al. (1993) reported that earlier planting increases the risk of infestation by the Angoumois grain moth. Significant planting date effects on maize weevil infestation were seen in each year, but the nature of that effect was inconsistent. Planting date-by-year interactions (df = 5, F = 8.31, P = <0.0001 for percentage of infested ears and df = 5, F = 3.86, P = 0.003 for weevils per 500 g of kernels) make it difficult to draw conclusions about the impact of this variable.

In 1999 (4 planting dates), the first planting date had a significantly higher percentage of infested ears ($P < 0.0001$) and the greatest number of weevils per 500 g of kernels ($P < 0.0001$). In 1997 (4 planting dates), the last planting date had the highest percentage of infested ears ($P = 0.001$) and the greatest number of weevils per 500 g of kernels ($P = 0.012$). The second planting date was significantly lower than the other planting dates in both measurements (P = <0.0001 for percentage of infested ears and $P = 0.003$ for weevils per 500 g of kernels). In 1998 (three planting dates), the first planting date had a lower level of infested ears than the second or third planting dates ($P = 0.035$) and the second planting date had the greatest number of weevils per 500g of corn kernels ($P = 0.008$). The planting date-by-year interaction may have been due to differences in the date when overwintering populations began to colonize corn, or emergence from earlier infestation in adjacent experiments may have confounded our analysis of the planting date effect. F_1 adults migrating from nearby corn in a later stage of phenological development could have colonized one or more of our planting dates rather than, or in addition to, overwintering adults.

In south Georgia, overwintering weevils appear to be present and ready to oviposit in the first corn that reaches an acceptable stage of phenological development. The aggregation pheromone of the maize weevil results in heavily-infested ears adjacent to numerous non-infested ears. Early infestation allows time for emergence of the first field generation of adults and subsequent oviposition in the same field, or possibly, nearby fields prior to harvest. Factors influencing migration from the point of origin are not understood.

If overwintering adults are consistently available to colonize the first suitable corn of the season, then planting a trap crop would seem to be a feasible method of control, but these data indicate sporadic results. Coordination of planting dates among adjacent farms may be necessary. Successful trap cropping may require delayed planting of the actual crop in order to allow establishment of the trap crop during colder weather. These problems and others may override any possible advantages that trap cropping may offer.

Effect of variety. Four different corn hybrids were tested in each of the 3 yrs of our study. These commercially available hybrids were selected due to their popularity in south Georgia and for their variation in physical characteristics such as husk coverage and kernel hardness.

Statistical analysis indicated no variety-by-year (df = 6, F = 0.54, P = 0.78) or variety-by-planting-date (df = 9, F = 1.2, P = 0.3) interactions; therefore, data for percentage of infested ears were pooled. Likewise, no variety-by-year (df = 6, F = 0.6, P = 0.73) or variety-by-planting-date (df = 9, F = 0.46, P = 0.9) interactions were found for weevils per 500 g of kernels and these data were also pooled. Pioneer 3146 and Pioneer 3167 had significantly fewer infested ears (P = 0.015) and significantly fewer weevils per 500 g of kernels (P = 0.034) than Mycogen 7559. Pioneer 3245 was intermediate and not significantly different from the others.

There are many corn hybrids available to Georgia corn producers and only four were evaluated in this experiment. These results indicate that hybrid selection can impact maize weevil infestation and suggests the need for evaluation of additional hybrids. The nature of differences in corn varieties as maize weevil hosts is unknown. Physical or biochemical mechanisms could contribute to less oviposition and/or lower larval survival rates. Maize weevils gain entry to the ear through the tip of the husk, and Eden (1952) has previously suggested that a tighter husk could provide some degree of physical exclusion. Kernel hardness and how quickly the kernels dry may also affect larval survival. Husk tightness, kernel hardness characteristics and time required for maturity of the four varieties tested in this experiment (as published in Mycogen Plant Sciences and Pioneer Hi-Bred International, Inc. sales catalogs) are shown in Table 2. Although more hybrids need to be tested in order to confirm correlations between hybrid characteristics and maize weevil infestations, significantly higher maize weevil reproduction on Mycogen 7559 (with its relatively looser

Table 2. Percent maize weevil infested ears, number of weevils/500 g and agronomic characteristics for tested varieties, 1997-1999

Hybrid	N	% Infested ears*	No. weevils/ 500 g*	Husk tightness	Kernel hardness	Cumulative relative maturity (days)
Mycogen 7559	1760	25.5a	12.27a	loose	medium	115
Pioneer 3245	1760	20.6ab	9.66ab	med.	med. - hard	115
Pioneer 3167	1760	18.7b	6.80b	med. - tight	med. - hard	124
Pioneer 3146	1760	15.5b	4.59b	med. - tight	med. - hard	120

* Means followed by the same letter are not significantly different (P < 0.05).

husk, softer kernels and quicker maturity) would support a hypothesis that one or more of these characteristics may play a role.

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