COMBINED IMPACTS OF WESTERN CORN ROOTWORM LARVAL FEEDING, EUROPEAN CORN BORER AND GIANT FOXTAIL ON FIELD CORN

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Introduction

The corn plant *Zea mays* L. plays host to a variety of insect pests. Among the most important of these are the western corn rootworm beetles and the European corn borer. Crop losses and control costs associated with these pests run into the millions of dollars annually.

Corn rootworm (CRW) beetles exhibit a univoltine life cycle. Feral adults deposit their eggs into the soil of cornfields during July and August where they undergo diapause and overwinter. The following spring eggs hatch beginning in late May and continuing on into the middle part of June. Larvae of the new generation feed on developing corn roots. After reaching the third instar larvae pupate in the soil, and emerge as adults during June and July. Adults live between 75 and 85 days and feed on pollen, silks, and leaf material. Damage occurs as roots from corn plants are fed upon and pruned by larvae. This eventually hinders the plants' ability to uptake water and nutrients. Extensive root damage may also cause plants to lodge (fall over), resulting in yield losses and an increased harvesting time.

The European corn borer (ECB) is a foreign pest introduced to the North America in 1912. Since its arrival this insect has hindered corn production throughout the major growing regions of the US and Canada. The ECB exhibits a bivoltine (2 generations per year) lifecycle in southern Wisconsin and the majority of the Midwest. ECBs overwinter as fifth instar larvae, and emerge during mid to late June. Adult females of the first generation mate and deposit masses of 15-25 eggs into the whorls of developing corn plants. Following egg hatch larvae feed on corn pollen, ear silks, and leaf tissue. As the larvae mature they begin to bore into the stalk or leaf midrib of the plant. Tunneling larvae continue to feed and develop inside the plant and eventually pupate. Adults emerging from these plants commonly mate in grassy areas near the field margins, and return to lay eggs on the leaves of corn near the pollenation stage. Larvae of second generation ECBs feed on sheath collar and leaf tissue before tunneling into leaf midribs, ear shanks, and stalks. The second generation continues development until early to mid fall when the larvae undergo diapause. Damage from ECB feeding results in broken stalks, dropped ears, and physiological damage. Larval tunneling can inhibit the plants ability to uptake water and nutrients which results in yield losses due to small ears and a general reduction in plant growth.

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Insect feeding may detrimentally affect plants photosynthetic capabilities by interfering with photochemical and light reactions, disturbing the physical process of the transfer of CO_2 from the ambient air to the chloroplast, and by disrupting the biochemical reactions that involve CO_2 incorporation.

The experiment described here was undertaken with the goal of gaining a further understanding of the impact of ECB and CRW on and their combined interactions on the physiological processes. The goal of this study is to assess the impact of ECB and the CRW on the photosynthetic capability of the corn plant. Experiments were performed to examine effect of both ECB and CRW feeding separately as well as potential interaction effects on the corn yield and physiology. Weed infested treatments of giant foxtail (GFT) were added to compare the effects of plant competition and herbivory on gas exchange. A further understanding of these processes will help us better combat these pests by increasing our knowledge of their damage potential as well as aid in the development of more accurate predictive models and economic thresholds.

Materials and Methods

Field studies were performed during the growing seasons of 1999 and 2000 at the University of Wisconsin Agricultural Research Station at Arlington, Wisconsin. A randomized complete block design (RCB) with four replications was used. The DeKalb hybrid 493RR (Roundup Ready) was used for all plots.

Plots consisted of rows 30 feet in length and 10 feet in width in 15 and 30-inch row spacings. Final stand density was 28,000 plants/acre. The center two rows were used for experimental purposes, while the outer rows provided a border between adjacent plots to prevent migration of ECB larvae between plots.

The treatments consisted of: ECB infested plants 30-inch rows; ECB infested plants in 15-inch rows; CRW infested plants in 30-inch rows; GFT (9 plants m^2) in 30 inch rows; ECB and CRW infested plants in 30-inch rows; ECB and GFT infested plants in 30-inch rows; and check plots of uninfested plants in both 30-inch rows and 15-inch rows.

ECB infestations were performed at two dates to simulate first and second generation ECBs. In 1999 CRW treatments were established using an artificial infestation of CRW eggs. In 2000 natural populations of CRWs were supplemented with an artificial infestation of CRW eggs. Plots not intended to be infested with CRW larvae were treated at planting with a banded application of tefluthrin (Force 3G).

CRW populations were monitored in all plots using emergence cages. Corn roots from both insecticide protected and non-insecticide protected plots were evaluated for CRW larval feeding.

A portable photosynthesis system (LI-6400, LI-COR Inc.) was used to measure gas exchange rates. Three plants were chosen from each plot for measurement of gas exchange. Plants of similar height and growth characteristics were selected to minimize variation within plots.

Grain yields were taken at harvest time. Plot grain weight and moisture content were recorded, and final yields were normalized to 15.5% moisture. Using each block as a repli-cate a multifactor ANOVA was performed on the data to evaluate and make comparisons among the six treatments.

Results and Discussion

ANOVA results from yield data showed significant differences among the plot treatments. ECB infested plots were significantly lower in yield compared to the respective check plots in both 15 and 30-inch rows. The CRW infested treatment, however, significantly affected grain yield only in 2000. This is due to the poor establishment of manually infested CRW eggs. The interaction treatment of CRW x ECB showed a reduction in yield as did the interaction of GFT x ECB when compared to the 30 inch row check plot.

Evaluation of ECB infestations indicated that a high percentage of larvae survived after being placed in the field. Guthrie ratings of leaf feeding for first generation ECB infestation averaged 5.9 (1-9 scale) when both row spacings were combined. When Guthrie ratings were compared between row spacings a significant difference was observed. ECB infested corn planted in 15 inch rows sustained less leaf feeding (Guthrie rating of 5.3) than did ECB infested corn planted in traditional 30 inch rows (Guthrie rating of 6.0). Average tunnel length per plant was 7.1 cm in ECB infested plots. No significant difference in stalk tunneling was detected between 15 and 30 inch row spacings in ECB infested plots.

Differences in leaf feeding damage between 15 and 30 inch rows did not translate into significant differences in tunnel lengths or grain yield. The impact of ECB infestation on grain yields between the two different row spacings as measured by percent yield reduction showed a slightly higher reduction in plots of 15 inch rows (28%) compared with plots in 30 inch rows (24%). These differences did not however prove significant.

In 1999, the emergence of CRW beetles was non-uniform across those plots receiving CRW eggs in agar solution. Adult emergence in infested plots averaged 44 beetles m^{-2}. Differences in the numbers of emerging beetles in plots of 15 inch rows (28 beetles m^{-2}) and 30 inch rows (60.8 beetles m^{-2}) did not prove significant. The average visual root rating of CRW infested plots was 3.0 in 1999 and 3.9 in 2000 using the Hills and Peters scale. No significant differences were observed among the CRW infested plots or between 15 and 30 inch rows. Measurements of photosynthetic rates showed a significant reductive effect in treatments containing ECB, ECBxGFT, and ECBxCRW.

Measurements of extended leaf height showed corn plants in treatments infested with ECB and CRW were shorter than uninfested treatments, across the majority of the sampling dates, however, treatments containing GFT stands did not differ from the uninfested check treatment. After plants had finished growing, plots of treatments containing ECB infestations were shorter than those without ECBs by an average of 6.4%.

Based on field observations, and results from the three different methods used to evaluate CRW populations it is clear that plots infested with CRW in 1999 did not contain larval populations sufficient to cause significant physiological damage to corn plants. Variations in emergence trap captures of the surviving beetles suggest that differential survival among artificially infested CRW eggs can also contribute to non-uniform CRW feeding pressure. This was one of our initial concerns entering the 2000 season which prompted us to artificially infest fields planted with a trap crop the previous year.

While manual infestations with ECB visibly damaged corn plants the effects on plant physiology were variable. Results from measurements of gas exchange rates showed the most marked reduction in photosynthesis (A), however this trend was not apparent in the simultaneous measurements of intercellular CO2 (c_i), and stomatal conductance (g_c).

Results of A measurements taken during 1999 were slightly more pronounced than those conducted in 2000. Initial measurements taken 10 days after infestation showed a significant reduction of A in 50% of the treatments containing ECB infestation. 85% of the treatments containing ECB infestation showed a significant reduction in A at 26 days after simulated 1st infestation. At this point 1st generation larvae would have ceased feeding. Measurements taken 35 days after 1st generation infesation also showed a pronounced effect of ECB on A.

These results suggest that different growth stages of the corn plants may vary in their susceptibility to ECBs. It is also possible that the plants' physiological characteristics are differentially impacted by ECBs depending on the instar. Our third measurement was taken in coincidence with fourth instar larval feeding by ECBs simulating a second generation infestation. Fourth instar larvae are the most actively feeding instar, and subsequently most likely to disrupt water and nutrient flow within the corn stalk. Additionally, this time period occurs when the corn plant is at the early grain fill stage, so it is also possible that late instar larval feeding disrupts carbon source-sink relationships between leaf and ear.