1982

Assessment of the Impact of the European Corn Borer at Three Locations in South Dakota

David R. Raemisch
South Dakota State University

ASSESSMENT OF THE IMPACT OF THE EUROPEAN CORN BORER AT THREE LOCATIONS IN SOUTH DAKOTA

BY

DAVID R. RAEMISCH

A thesis submitted
in partial fulfillment of requirements for the
degree Master of Science
Major in Entomology

South Dakota State University
1982

ASSESSMENT OF THE IMPACT OF THE EUROPEAN CORN BORER

AT THREE LOCATIONS IN SOUTH DAKOTA

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

David D. Walgenbach, Thesis Adviser — Date

Maurice L. Horton, Head, Plant Science Department — Date

ACKNOWLEDGEMENTS

I would like to dedicate this thesis to my family. It is my sincere hope that each of us can, in the years to come, retain the character of truly caring for one another while concurrently recognizing that a family should be defined in terms of mutual interest and not merely by biological relationships or economic interest.

Professionally I wish to sincerely thank David Walgenbach for his interest in my life. Also, I will always remember the graduate students I have worked and learned with.

CONTENTS

LIST OF TABLES

INTRODUCTION

The European corn borer (Lepidoptera: Pyralidae) varies as an economically significant pest in South Dakota from south to north. In the northern part of the state the European corn borer (ECB) is limited to one generation per year. In contrast, there are localized sites along the Missouri River in southern South Dakota which usually experience a substantial second brood population. Infestation by either first or second brood ECB occurs at different stages in the developmental sequence of the corn plant. As such, each brood must be considered separately when assessing relationships between yield loss and ECB larval cavities within the plant. Berry and Campbell (1978) reported that plants infested by both first and second generation ECB incurred greater yield reductions than did plants infested by only the first brood. On a yield loss per cavity basis, the first brood had a greater impact on yield than did the second. Contrary to this, Lynch (1980) observed a loss of 4.2 Bu/A/cavity with plants infested during the pollen shedding stage of development, compared to a 3.4 Bu/A/cavity loss for plants infested during the whorl stage. Under equal infestation levels Jarvis et al. (1961) found the first brood to cause more damage than the second. Further investigation by Lynch et al. (1980) revealed greater yield losses due to infestation during the pollen shedding stage (second brood). Differences in varieties and larval survival may partially explain these contradictory results.

Jarvis et al. (1961) observed no synergistic relationship between first and second brood induced yield reductions when plants were infested by both generations. In Prince Edward Island, Canada, Thompson and White (1977) showed differences in grain yield but no significant difference in silage yield between insecticide treated and control plots. The impact of first or second brood ECB at any location is dependent on the relative population levels present. Kwolek and Brindley (1959) illustrated this point by reporting on the inconsistency from state to state with regard to the different impact of the two broods. In Ohio the second brood was found to be the most influential with only a small first brood population present. First brood had a greater impact on yield in Minnesota while Iowa corn was subject to approximately equal infestation by both generations.

Chiang et al. (1960) noted that the ECB females prefer to oviposit on the most vigorous plants in the area. First brood females prefer the earlier planted, taller corn, while the second brood females actively select the later planted more succulent plants that are shedding pollen. The production and use of irrigated long season corn hybrids, early planting and heavy fertilization requires monitoring for both first and second generation ECB.

Artificial infestation studies have elucidated the relationships between generation of attack, cavity counts and yield. To date, however, no quantitative studies have been conducted to ascertain these relationships with naturally occurring populations of the ECB in South Dakota. The objective of this study was to assess the impact of first and second generation ECB on total plant weight and grain yield. Studies were conducted at three locations in South Dakota. Analyses were made on either grain yield or total plant weight (cut 4" above ground) recorded both at the time of harvest and on a dry matter basis.

LITERATURE REVIEW

A. History and Biology

According to Vinal and Caffrey (1919) the European corn borer (ECB) was first described by Jacob Hubner in 1796. He described the male (*Pyralis nubilalis*) and female (*Pyralis silacealis*) as separate species. The organism went through a series of reclassifications until Meyrick (1895) placed it into the genus *Pyrausta*. The name was accepted and much literature was published on *Pyrausta nubilalis* (Hubner) until Marion (1957) changed the classification to *Ostrinia nubilalis* (Hubner).

The ECB is not indigenous to the North American continent. Until the early twentieth century it was found in central and southern Europe, west-central and northern Asia, China, Japan and the Philippines. Vinal and Caffrey (1919) were the first to report the ECB in America. They found it as a serious pest on sweet corn near Boston, Massachusetts in 1917. During 1918 near Medford, Massachusetts they observed a heavily infested field. Dissection of 75 plants resulted in an average of 46 larvae per plant with a high of 117 on one individual plant. By 1918 its distribution included only four counties northwest of Boston. Smith (1920) examined possible sources of entry and concluded that the ECB was probably introduced between 1909 and 1914 in shipments of broom corn from either Hungary or Italy.

Vinal and Caffrey reported two generations per year in 1919. During its spread westward the ECB first developed univoltine behavior then changed back to multivoltinism. In New York Felt (1922) described the ECB as exhibiting one generation per year with only a small portion of the population pupating to form a second brood. This univoltism persisted until the late 1930's. When the ECB first entered Indiana in 1926 it had only one generation per year. Ficht (1939) observed that late planted corn, which normally would escape attack by the first brood, was now being attacked by a second brood. He reported a gradual change from almost no second brood in 1926 to a substantial second brood population by 1938. This two generation per year borer was first reported in South Dakota in 1946 (Anonymous 1972). In Virginia, Walker and Anderson (1936) reported a trend toward three generations per year. Eden (1956) also observed the existence of three generations per year in Alabama. Currently there are three recognized ecotypes of the ECB in North America: (1) The northern ecotype, exemplified by Minnesota and Quebec populations, exhibits one generation per year; (2) A central form typical of Iowa, Nebraska and Ohio has two generations per year; and (3) The southern ecotype represented by Alabama, Georgia and Missouri populations which completes three to four generations per year (Showers et al. 1975).

Vinal and Caffrey (1919) provided a detailed survey of the ECB life cycle. The ECB overwinters as mature, fifth instar larvae in corn stalks, cobs and debris. In the spring when ambient temperatures reach approximately 50°F development resumes. To date, developmental models based on degree day accumulations have not accurately been able to predict the occurrence of the first moth flight. However, once that first flight has been observed, degree days become an accurate device for predicting development (North Central Regional Publication, (1982) In press).

The larvae pupate in their overwintering site. Upon emergence the adult moths move from the cornfield to areas of dense grassy vegetation, along the field border. Showers et al. (1976) referred to these as "action sites". The humid environment provided by this dense vegetation makes it an ideal habitat for feeding, resting and mating. Sexual activity peaks between 12:00 midnight and 1:00 a.m. The females are capable of first oviposition an average of 2.5 days after emergence. The ovipositional period lasts approximately 15 days. Normal oviposition is 545 eggs per female during the first brood and 337 eggs by each second brood female. Eggs are deposited in masses of from 5-50 eggs each. Caffrey and Worthley (1927) reported peak ovipositional flight activity from shortly after dusk until midnight. The first brood ovipositional peak usually coincides with the whorl stage development in the corn plant. Second brood egg deposition generally occurs on recently tasseled corn plants during the pollen shedding stage. Oviposition usually occurs on the underside of corn leaves along the midrib. Egg masses are initially white and approximately one-quarter inch in diamter. Hatch occurs in 3-7 days depending on the environmental conditions. Shortly prior to hatching the dark head capsules of individual larvae are visible through the translucent chorion.

The leaf feeding activity and survival of first instar larvae is dependent on the size of the corn plant for successful larval establishment. Reed et al. (1972[a]) established a linear relationship between larval mortality and the concentration of Dimboa

(2,4-dihydroxy-7-methoxy-2H-1,4-benzoxazin-3-(4H)one) in corn leaf tissue. Larvae fed a diet of resistent leaf tissue exhibited reduced overall vigor expressed as slower development, lower weight and lower egg mass production as an adult. The concentration of Dimboa is highest in the seedling stage and decreases as plant size increases (Klun and Robinson, 1968). If the concentration of Dimboa is low enough to permit larval establishment the environment then becomes the most limiting factor. Showers et al. (1978) reported that 81-93% of the variation in larval mortality was accounted for by the following three parameters: maximum daily temperature, moisture stress and atmospheric evaporation. The role of predators in ECB population regulation was examined by Sparks et al. (1966). They concluded that although predators may alter ECB populations at some locations in some years, they do not provide consistent or significant regulatory action. Chiang and Hodson (1972) discussed the impact of several factors in the regulation of ECB populations. Their conclusions were as follows: (1) Agricultural practices can have either positive or negative influences on survivorship. Increased plant density creates a more favorable microclimate, thus increasing survival. Negative practices include the use of combines, moldboard plows, reduced corn-oats sequences, and the use of resistent hybrids. (2) Although natural enemies have some impact on ECB populations, it is neither consistent nor density dependent. (3) Climatic factors such as rain can be beneficial or deleterious depending upon seasonal or even daily time of occurrence. Density independent factors such as climatic variation are paramount in the regulation of ECB populations. Due to the major role played by the environment there is little numerical relationship between successive overwintering, first brood and second brood populations even though they follow one another (Chiang et al. 1961). The larvae are able to survive on a wide range of plants. Corn is the preferred host, but field collections have been made from Pigweed (*Amaranthus retroflexus* L.), Lambs Quarters (*Chenopodium album* L.), Foxtail (*Setaria glauca* Beauv.), Crab grass (*Digitaria sanguinalis* Scop.), Thistle (*Cirisium* spp.), Potatoes (*Solanum tuberosum*), Oats (*Avena sativa*) and many more. The ECB has over 200 acceptable host plants (Sparks et al. 1967).

Upon maturity (5th instar) the combined affects of temperature, photoperiod and genetic makeup of the population act to determine the course of development. There are two possible events, either of which can occur on an individual basis. The mature larvae can pupate and subsequently form a second generation or they can enter diapause. Showers et al. (1975) observed a continuum from south to north with regard to the influence of photoperiod and temperature on diapause determination. Larvae of the southern ecotype are more responsive to temperature changes with increasing temperatures causing reduced diapause. Conversely, in the northern ecotype, photoperiod overrides temperature in causing diapause. Maximum diapause, expressed as a percent of the total population, occurs at latitudes where the two factors produce the greatest interaction. If a second brood is formed the larvae must reach full maturity (5th instar) in order to successfully overwinter. Under field conditions Vinal and Caffrey (1919) reported a mean duration of 63 days for completion of the first generation's life cycle and 53 days for the second brood. First generation adult ECB exhibited an average longevity of 14 and 18 days for the male and female, respectively. Second brood females lived an average of 17 days while males survived for only 13.

First and second instar ECB larvae feed on the spirally rolled leaves in the whorl creating small "shot holes". Upon hatching, first brood ECB larvae move from the leaf blade down into the whorl and feed on exposed leaf tissue for several days. The damage is visible as the leaves grow out of the spiral to form the whorl. When the ECB reaches the third instar of development it will also begin to feed on midrib and sheath tissues. Fourth and fifth instar larvae are large enough to bore into and create tunnels in the stalk.

The first and second instars of the second brood feed extensively on pollen accumulated in the leaf axil. Third and fourth stage larvae feed on sheath and collar tissue. During the fourth and fifth instars the larvae will bore into the stalk and ear shank (Everett et al. 1959).

Chiang and Hodson (1950) recognized four ways in which the ECB can reduce corn yields: (1) Physiological damage that results in reduced growth; (2) Direct feeding that destroys kernels; (3) Boring and tunneling into the stalk and ear shank which structurally weakens the plant causing stalk breakage and ear drop; (4) Increased susceptibility to diseases such as stalk rot. Studies by Patch et al. (1941) involving 16 single cross hybrids artificially infested with second brood egg masses resulted in an average yield loss of 1.87% per borer per plant. Of this damage the loss attributable to reduced ear size (physiological damage) was 10 times that caused by broken stalks and unrecoverable ears. Lynch (1980) examined the relationship between stage of plant development and yield loss. He infested plants during 5 of the 6 stages of development: (1) seedling; (2) whorl; (3) late whorl; (4) pretassel; (5) pollen shedding; and (6) kernels blistered. Plots infested during stage 2, 3, 4, 5 and 6 exhibited yield losses (expressed as a percentage of the loss caused by physiological damage) due to unharvestable ears of only 4.9, 3.8, 3.9, 12.8 and 44.7%, respectively. Only during stage 6 (kernels blistered) did unharvestability have an impact near that attributable to physiological damage. He concluded that yield loss caused by the ECB is substantially due to physiological damage.

Guthrie et al. (1975) recorded differences in yield parameters due to second brood infestation. Based on tests which include 12 hybrids, they determined that kernel size reduction was responsible for second brood yield loss. Since pollination had occurred prior to second brood infestation the number of kernels was already determined prior to damage. Weight per 300 kernels was reduced by 8.0 and 22.8% in 1972 and 1973, respectively, when comparing infested (4 masses/ plant) to non-infested hybrids. In 1972 they recorded 0.2 and 4.5 cavities per plant for the non-infested and infested hybrids respectively. During 1973 counts of 0.4 and 11.5 cavities per plant accounted for the larger (22.8 vs. 8.0%) yield loss. Scott et al.

(1967) observed effects of second brood ECB on 45 single cross hybrids. They artificially infested resistant by resistant (R x R) and susceptible by susceptible (S x S) produced hybrids and compared them to a noninfested control. The (R x R) yielded 4% lower than the control while (S x S) varieties yielded 12% lower. Percent moisture at harvest was reduced 0.85 and 1.8% below that of the control for (R x R) and (S x S) varieties, respectively. Finally, the number of dropped ears was 0.1 and 2% more than the respective control. Chiang and Holdaway (1959) reported that heavy infestation resulted in a reduction in plant height of 9.8% in a susceptible variety and 2.9% in a resistant variety. Plant height reduction was due primarily to reduction of internode length. This reduction of internode length was initiated prior to any stalk tunneling. Leaf feeding alone was found sufficient to cause the shortening. ECB infestation caused reduced internode length, leaf size and delayed tasselling and silking in both resistant and susceptible varieties. Chiang and Holdaway (1965) observed a significant correlation between reduction in plant height and reduction of grain yield in susceptible varieties. No such relationship was found to exist in resistant strains.

B. Yield Studies

Salter and Thatcher (1927) were among the first to conduct yield investigations involving the ECB. They relied on natural infestations, comparing ear weights of infested plants to those of noninfested corn. Observed losses ranged from 5.19 to 9.14% in these comparisons. Due to consideration of ovipositional preferences, Neiswander and Herr (1930) made the following statement: "If an attempt is made to compare yields from infested plants with those from non-infested plants where both have been equally exposed to attack, the data are of but little, if any, value. It has been shown that the larger and better plants within an area are more susceptible to infestation. Hence, the infested stalks, by reason of their greater vigor, may be able not only to carry their borer load, but actually may outyield the weaker uninfested ones." It follows that any yield difference detected (comparing individual infested and non-infested plants from the same plot) would actually be smaller than in a natural situation, due to any extra yield potential of the larger more vigorous plants. Thus, if any error in yield assessment occurs due to this experimental method the investigator would be underestimating actual yield loss. From an economic threshold viewpoint this is a "safe" error, if any error must be made. The current use of random artificial infestation also ignores this ovipositional preference problem.

Since 1933 yield studies of the ECB have almost exclusively relied upon artificial infestation techniques. Patch and Peirce (1933) were the first to produce a large number of egg masses in the lab for artificial infestation studies. Second brood egg masses have been obtained in the past by capture of, and later oviposition by, second brood adults from either infested, caged, green sweet corn or sweep net collection near cornfields (Guthrie et al. 1965). First brood egg masses were obtained by placing second brood infested corn stalks into emergence cages in the fall. In the spring upon emergence, the moths were collected and placed into oviposition cages (Guthrie et al. 1965). The modern era of mass rearing phytophogous lepidopteran larvae was initiated following the development of meridic (wheat germ) diets (Chippendale 1972). Lewis and Lynch (1969) developed a meridic diet specifically suited to the ECB. Current methods of mass rearing the ECB were described by Reed et al. (1972[b]). Mass rearing of the ECB has greatly accelerated biological study of the species.

Early attempts to develop some type of damage assessment index depended upon counts of living borers in mid-August with October harvest. Patch et al. (1938) used artificial infestation of first brood ECB to test two varieties. They reported a yield reduction of 1.8 bu/acre/borer/plant when compared to a control which yielded 55 bushels/acre. In a later study Patch et al. (1941) observed yield reductions of 2.99 and 3.71%/borer/plant on hybrids and open-pollinated varieties respectively. They measured reductions in ear size of 30.5 and 29.5%, respectively. In further studies Patch et al. (1942) related yield ability to percent loss. On a local clarage strain, with a range of 28 to 85 bu/A, percent yield loss decreased with increases in normal yield. Yield was reduced 1.37 bushels (4.8%)/acre/borer/plant when the plot yielded 28.2 bu/A and 2.27 (2.6%) when control yield was 84.6 bu/A. On hybrids the percent reduction was greatest at the highest levels of yield. They reported a loss of 3.0% at 85 bu/A and 3.9% at 105 bu/A.

Deay et al. (1949) were among the first to study second brood ECB via artificial infestation techniques. In a test of 16 single cross hybrids they recorded a yield loss of 1.85%/borer/plant. Reduction in yield expressed as a percentage was found to be directly related to the yield of the hybrid, with higher yielding hybrids experiencing the largest loss on a percentage basis.

Chiang et al. (1954) observed that the work by Patch resulted in a base value of 3% loss/borer/plant when considering first brood damage. Since much of the north central region was experiencing two generations per year Chiang showed that the 3% estimate was in fact too high. It attributed all the damage (1st and 2nd brood) to only the first brood population. They recognized the importance of consideration of both first and second brood populations. Penny and Dicke (1959) developed an assessment method for use in breeding for resistance to the ECB. They devised a system to measure degree of resistance to first brood leaf feeding damage. Varieties were artificially infested with first brood egg masses, then three weeks later rated on a 1-9 scale as to severity of leaf feeding damage. The first use of cavities in the stalk as a yield estimate was reported by Kwolek and Brindley (1959) when citing the unpublished work of Beck 1954. Beck used both cavities and borer counts to estimate yield loss. Cavities per plant (1 cavity = 2.5 cm tunneling) proved to be more closely correlated to yield than did borer counts.

Berry et al. (1978) developed a regression equation relating the leaf damage rating scale (1-9) to yield. Also, another equation related percent of plants showing leaf feeding damage to yield. This equation demonstrated losses of 0, 3.5 and 6.9% for 0, 50 and 100% of the plants showing leaf feeding damage based on a control yield of 131 bu/A. This type of study is the basis for currently employed first brood thresholds.

A study which closely parallels my own research was conducted by Lynch et al. (1980). They artificially infested individual plants (rather than plots) according to a Poisson distribution. This was an attempt to simulate natural oviposition. Plants were infested during stages 2 (whorl) and 5 (pollen shedding) to simulate first and second brood damage. Ear and shelled grain weight were determined by labeling and hand harvesting individual ears. They related number of egg masses/plant to yield loss for first and second brood separately.

C. Current Thresholds

First generation ECB economic thresholds are based on leaf feeding damage during the whorl stage of development. Representative samples are taken with the percent of plants showing fresh leaf feeding damage calculated. Also, two of every twenty plants sampled should be inspected for the presence of live larvae. This is to ensure that larval establishment is actually occurring. Insecticidal treatment of dry land field corn is recommended when 50% of the plants sampled exhibit leaf feeding damage and live larvae are observed. Due to difference in yield potential, treatment thresholds have been established at 35% leaf feeding damage for irrigated corn and 25% for popcorn and seed corn due to crop value. Only one author has given consideration to silage corn thresholds. The Ontario, Canada Ministry of Food and Agriculture recommended treatment when 75% of the plants sampled showed leaf feeding (Anonymous 1977).

Thresholds for second brood ECB involve scouting from the pre- to post-tasseling stages. Recommendations are based on egg mass counts. Currently treatment is justified when egg mass counts are at or above .25 mass/plant for those plants sampled. Due to the extended nature of the second brood oviposition period, current recommendations call for a second treatment 7 to 10 days after the first spraying (North Central Regional Publication-Management of the ECB).

METHODS AND MATERIALS

1981 Field Season

A. Generation Impact Study - Platte

During 1981 a field of irrigated corn near Platte, South Dakota was chosen for study based on a history of European corn borer infestation. The observational study was a completely randomized design, with individual plants serving as the experimental units. Three treatments were obtained by tagging individual plants based on time of infestation. The control (treatment one) consisted of plants that had experienced no damage, either leaf feeding or cavities within the stalk. Treatment two included plants infested by the second brood. These plants were tagged in the pretasseling stage as having no first brood damage. The third treatment was composed of a group of plants that had known first brood infestation and an undetermined level of second brood damage. These were obtained by tagging plants in the 40" extended leaf height stage of development as exhibiting first brood leaf feeding.

The corn variety used was Den Besten SX60. It was planted May 1 at a population of 28,000 plants per acre. At physiological maturity, stalks were split, cavity counts recorded (1" tunnel = 1 cavity), and individual ears harvested for yield determination. Ears were dried, hand shelled and converted to a 15.5% moisture basis.

B. Grain Yield as Influenced by Cavity Counts - Platte

The plants harvested in experiment A (Generation Impact Study) were grouped into treatments based on time of infestation. In this experiment those same plants are grouped into treatments based on cavity counts, irrespective of time of infestation. Individual ears were removed from the plants and placed into paper bags labeled as to the number of cavities within the stalk. After drying and hand shelling both cavity count and grain yield were recorded for each of the 736 plants. Individual plants were then categorized into six treatments based on the number of cavities per plant. The treatments were as follows: (1) no cavities; (2) one cavity; (3) two cavities; (4) three cavities; (5) four cavities; (6) five cavities. Cavity counts were recorded without documentation of the generation of ECB which caused them.

C. Total Plant Weight as Influenced by Cavity Counts - Platte

To ascertain the relationship between cavity counts and yield the following study was conducted. Plants were chosen for harvest at random from a second irrigated cornfield in the Platte area. Upon maturity, stalks were split, cavity counts recorded and individual total plant weight measured. Total plant weight was recorded at the approximate time that silage would normally be harvested (65% moisture). The corn (Curry 1451) was planted April 20 at a population of 30,000 plants per acre. The plot was harvested August 19. Plants were categorized into treatments based on the number of cavities per stalk.

D. Total Plant Weight Study - Flandreau

To assess the relationship between infestation by the ECB and reductions in total plant weight, one irrigated field and one field with both irrigated and dryland plots were chosen for investigation.

The single irrigated field (A) was planted May 5 with Pioneer 3780 at a population of 22,000 plants per acre. Field B, with both irrigated and dryland plots, was planted May 9 at a population of 22,000 plants per acre. The variety was Pioneer 3732. In each plot there were two treatments. Treatment one consisted of plants that had each experienced first brood damage and also been exposed to infestation by the second brood. Treatment one was obtained by tagging individual plants in the 40" extended leaf height stage of development as exhibiting first brood damage. Treatment two was composed of individual plants tagged in the pretasseling stage as having experienced no first brood damage. The plants in treatment two were infested only by the second brood. At harvest, stalks were split, cavity counts recorded and individual total plant weights recorded. Total plant weights were measured at the approximate time that silage would normally be harvested (65% moisture).

From each of the three fields the relationship between cavity counts and total plant weight was examined. Plants were categorized into treatments based on the number of cavities per stalk.

RESULTS AND DISCUSSION

1981 Field Season

A. Generation Impact Study

Data from the 1981 study indicates that the second brood (treatment 2) caused a yield reduction of 20.4 Bu/A compared to a noninfested control that yielded 178.8 Bu/A (Table 1). The plant population at harvest was 24,000 plants/A. The control had no cavities per plant while those plants infested by the second brood exhibited an average of 2.8 cavities per plant. This represents a yield reduction of 4.1% per cavity due to second brood infestation. Based on plants with an average of 3.2 cavities per plant, Lynch et al. (1980) reported yield losses of 3.3% and 1.7% where plants were artificially infested during the pollen shedding stage of development in 1973 and 1974, respectively. Those plants tagged as known to be infested by the first brood and possibly second brood (treatment 3), yielded 129.8 Bu/A, a yield reduction of 7.6% per cavity. This loss of 7.6% per cavity associated with first brood damage compared to the smaller 4.1% loss per cavity due to second brood infestation supports the findings of Jarvis et al. (1961) while at the same time is contrary to observations by Lynch et al. (1980). The relative impact of either first or second brood, on a yield loss per cavity basis, is dependent upon many variables. The specific variety of corn along with the particular environmental conditions in any given year are probably the two major contributors to this variation in experimental results.

Table 1. Generation Impact Study, Platte (1981).

Treatments	No. Plants	Cavities (#/plant)	Yield (Bu/A)	LSD*
(1) Control	57	0	178.8	a
(2) Second Brood	151	2.8	158.4	b
(3) Each plant infested by 1st brood and potentially 2nd brood	212	3.6	129.8	c

*Means followed by a common letter are not statistically significant at 5% level.

B. Grain Yield as Influences by Cavity Count, Platte

An inverse relationship was shown to exist between cavity counts and grain yield (Table 2). At zero cavities per plant the yield was 176 Bu/A based on a harvestable population of 24,000 plants per acre. Yield was reduced to 135 and 133 Bu/A at four and five cavities per plant, respectively, a loss of approximately 42 Bu/A when comparing a noninfested control to plants with either four or five cavities per stalk. A comparison of the control (zero cavities) to treatment two (one cavity per plant) reveals a measured yield difference of 10 Bu/A. However, this difference is not statistically significant (.05 level). Since there is no documentation of the generation which caused the cavities, the plants that exhibited only one cavity per plant would have a great deal of variation with regard to yield impact. That single cavity could have been caused when the plant was in the late whorl stage or it could have occured as late as a week prior to harvest. This could explain the nonsignificance of such apparently large yield differences.

Table 2. Grain Yield as Influenced by Cavity Counts, Platte (1981).

Treatment # cavities/plant	No. Plants	Yield (Bu/A)	LSD*
0	94	176	A
1	154	166	AB
2	161	163	B
3	152	152	C
4	99	135	D
5	76	133	D

*LSD comparisons at .05 level.

C. Total Plant Weight as Influenced by Cavity Count, Platte

Due to light infestation, plants were categorized into only three treatments: (1) no cavities; (2) one cavity; (3) two cavities. Plants with no damage obtained a yield of 32.1 ton/A based on a harvestable population of 25,000 plants per acre. Yield was reduced by 2.2 and 4.5 ton/A at the one cavity and two cavities level of damage, respectively (Table 3). To date, very little has been published on the impact of the ECB on silage yield. Many irrigated corn producers along the Missouri River harvest their corn in the form of silage for animal feed. These growers have a need for thresholds based on silage yield data.

Table 3. Total Plant Weight as Influenced by Cavity Count, Platte (1981).

Treatment # cavities/plant	No. Plants	Yield (Ton/A)	LSD*
0	108	32.1	A
1	88	29.9	B
2	75	27.6	C

*LSD comparisons at .05 level.

D. Total Plant Weight Study, Flandreau

Data from both the irrigated field (Plot A) and the field with irrigated (Plot B) and dryland (Plot C) plots indicated a low level of damage due to infestation by the second brood at Flandreau. From each of the three plots two studies were conducted, one related cavity counts to yield, the other related levels of first brood infestation to yield.

In Plot A, the cavity count study documents yields of 24.4, 23.2 and 21.4 Ton/A at zero, one and two cavities per plant, respectively (Table 4). Table 5 establishes that the second brood caused 0.4 cavities per plant. The yield associated with second brood infestation (treatment 1) was 25.0 Ton/A, this is similar to the 24.4 Ton/A for noninfested plants in the cavity count study of plot A. The low level of second brood infestation had no impact on yields in plot A. Treatment one of Table 5 had no first brood damage while plants in treatment two were all infested by the first brood. A yield loss of 2.7 Ton/A was attributable to the first brood based on a harvestable population of 20,000 plants per acre.

Table 4. Total Plant Weight as Influenced by Cavity Count, Flandreau (Plot A) 1981.

Treatment (# cavities/plant)	No. Plants	Yield (Ton/A)	LSD*
0	136	24.4	A
1	87	23.2	B
2	62	21.4	C

*LSD comparisons at .05 level.

Table 5. Total Plant Weight Study, Flandreau (Plot A) 1981.

Treatment	No. Plants	Cavities (#/plant)	Yield* (Ton/A)
(1) Second brood	98	0.4	25.0
(2) Each plant infested by 1st brood and natural level of 2nd brood	224	1.4	22.3

*F-test significant at .01 level

Silage yields were inversely proportional to cavity counts in Plot B (Table 6). The yields of 21.3 and 20.3 Ton/A at zero and one cavities were not significantly different at the .05 level. However, the 18.5 Ton/A at two cavities per plant caused a significant yield reduction. The first brood impact study from Plot B had a very low level of second brood damage. Only 0.1 cavities per plant were observed in those plants exposed to second brood attack (treatment 1). Again the yield associated with second brood infestation (21.7 Ton/A) was similar to the yield of noninfested plants from the cavity count study (21.3 Ton/A). Yield was reduced from 21.7 to 19.8 Ton/A by first brood infestation (Table 7).

Table 6. Total Plant Weight as Influenced by Cavity Count, Flandreau (Plot B) 1981.

Treatment (# cavities/plant)	No. Plants	Yield (Ton/A)	LSD*
0	169	21.3	A
1	59	20.3	A
2	49	18.5	B

*LSD comparisons at .05 level.

Table 7. Total Plant Weight Study, Flandreau (Plot B) 1981.

Treatment	No. Plants	Cavities (#/plant)	Yield* (Ton/A)
(1) Second brood	99	0.1	21.7
(2) Each plant infested by 1st brood and natural level of 2nd brood	194	1.0	19.8

*F-test significant at .01 level

In Plot C, the dryland plot, yields were lower, as was expected. The cavity count study did not produce an inverse relationship, rather, yield dropped sharply from zero to one cavity per plant then leveled off. Yields of 17.9, 15.7, 15.4 and 15.4 Ton/A were recorded for zero, one, two and three cavities per plant, respectively (Table 8). Similarities in yield between plants infested by the second brood (treatment 1, Table 9) and noninfested plants in the cavity count study (Table 8) indicate that the second brood had no impact on yield. The first brood was responsible for a reduction of 3.4 Ton/A in Plot C (Table 9).

Table 8. Total Plant Weight as Influenced by Cavity Count, Flandreau (Plot C) 1981.

Treatment (# cavities/plant)	No. Plants	Yield (Ton/A)	LSD*
0	119	17.9	A
1	86	15.7	B
2	52	15.4	B
3	21	15.4	B

*LSD comparisons at .05 level.

Table 9. Total Plant Weight Study, Flandreau (Plot C) 1981.

Treatment	No. Plants	Cavities (#/plant)	Yield* (Ton/A)
(1) Second brood	100	0.4	18.6
(2) Each plant infested by 1st brood and natural level of 2nd brood	195	1.5	15.2

*F-test significant at .01 level

Reductions in yield due to cavity counts indicates that the ECB may have a significant impact on silage yields. Also, reductions of 2.7, 1.9 and 3.4 Ton/A were recorded for plots A, B and C, respectively, when comparing yields from plants infested by the second brood (already shown to be near those of unifested plants) to those of plants known to be infested by the first brood and exposed to second brood infestation.

METHODS AND MATERIALS

1982 Field Season

A. Total Plant Weight Study, Platte

To assess the impact of the ECB on total plant weight (silage), the following study was conducted. A single irrigated field with two varieties of corn was chosen for investigation. Each variety was considered a separate field. Field one was planted May 4 at a population of 28,000 plants per acre. The corn variety was Curry 1520. Field two was planted on May 5 with Curry 1455 at 28,000 plants per acre. In both fields one and two there were two treatments. Treatment one was obtained by tagging plants in the 45" extended leaf height stage of development as exhibiting first brood leaf feeding damage. The plants in treatment one would have each experienced first brood damage, and also been exposed to second brood infestation. The plants in treatment two were tagged in the pretasseling stage as having no damage, thus no infestation to that point. These plants were exposed to infestation by only the second brood.

From both fields evaluations of total plant weight at harvest (wet) and dry matter weight were made. At maturity, stalks were split, cavity counts recorded and individual total plant weight measured. To determine dry matter accumulation, samples were taken from each treatment in both fields. Sampling consisted of choosing at random approximately 20 plants per treatment and chopping them into silage. Two pounds of wet silage was then placed into each of 10 sample bags per treatment. The silage was oven dried and reweighed to determine percent moisture. Analyses were made on both total plant weight at harvest (wet) and dry matter accumulation. Both fields were harvested on August 31.

B. Total Plant Weight Study, Flandreau

A field of irrigated corn was chosen for study based on 1981 data. The field experienced moderate first brood infestation and almost no second brood damage in 1981. The field was planted on May 4 with Pioneer 3780 at a population of 22,000 plants per acre. Individual plants were tagged based on time of infestation. Eighty plants were tagged in the 45" extended leaf height stage of development as exhibiting first brood leaf feeding damage. Treatment two was obtained by tagging 80 plants in the pretasseling stage as having no first brood damage. At harvest stalks were split, cavity counts recorded and total plant weight measured. Analyses were made on both total plant weight at the time of harvest (wet) and dry weight. The field had a harvestable population of 18,000 plants per acre. The field was harvested on September 6.

C. Total Plant Weight Study, Beresford

To assess the impact of infestation by first brood ECB from a different perspective the following study was conducted. Rather than tagging plants based on time of infestation, insecticides were used to eliminate the ECB from certain plots. Two tests were conducted near Beresford, South Dakota. Test one was a randomized complete block design with two treatments and five replications. Test two also had two treatments, but only four replications per treatment. Treatment one was obtained by application of cypermethrin at 0.1 lbs. AI/A during the late whorl stage of development. The cypermethrin was applied with a carrier of 15 gallons per acre of water. The insecticide was applied with a hand operated spray buggy. Treatment two was an untreated check. At maturity, 10 plants per replication were split, cavity counts recorded and total plant weight (wet) measured. Percent moisture was also determined for each treatment from both tests. Both tests were planted May 7 at populations of 18,000 plants per acre. The corn variety was Lynks 4340. Both tests were conducted on dryland corn.

RESULTS AND DISCUSSION

1982 Field Season

A. Total Plant Weight Study, Platte

Both fields in this study were infested by only the first brood. The plants comprising treatment two were tagged as having no damage by the first brood. Those plants were exposed to infestation by the second brood. Cavity counts recorded for treatment two from both fields indicate no cavities, thus no damage due to the second brood. This area normally experiences a second brood infestation. The field chosen for this study was planted much earlier than most fields in the vicinity. This could account for the absence of second brood infestation on either field one or two.

Plants infested by the first brood in field one had an average of 3.3 cavities per plant (Table 10). This caused a wet yield reduction of 5.0 Ton/A when comparing infested to noninfested plants. The plants infested by the first brood contained 69% moisture at harvest while nondamaged plants were 71% moisture. Infestation by the first brood caused a dry matter yield reduction of 1.0 Ton/A. The plant population at harvest was 21,000 plants per acre.

Table 10. Total plant weight recorded at harvest (wet) and dry matter yield as influenced by first brood infestation, Platte (Field 1) 1982.

Treatment	No. Plants	Cavities (#/plant)	Wet Yield* (Ton/A)	Dry Yield* (Ton/A)
First Brood	75	3.3	23.8	7.4
No Damage	75	0	28.8	8.4

*F-test significant at .01 level

The first brood was responsible for a wet yield reduction of 3.3 Ton/A in field 2 (Table 11). The plants in both treatments were 71% moisture at harvest. Based on a harvestable population of 21,000 plants per acre, dry matter was reduced by 0.9 Ton/A when comparing plants infested by the first brood to noninfested plants. There was a lower level of damage in field 2 with 2.2 cavities per plant recorded for treatment one.

Table 11. Total plant weight recorded at harvest (wet) and dry matter yield as influenced by first brood infestation, Platte (Field 2) 1982.

Treatment	No. Plants	Cavities (#/plant)	Wet Yield* (Ton/A)	Dry Yield* (Ton/A)
First Brood	75	2.2	25.4	7.4
No Damage	75	0	28.7	8.3

*F-test significant at .01 level

This data indicates that the ECB can have a significant impact on silage yield. The data collected in 1981 also indicated a reduction in silage yield due to ECB infestation. That data was based on wet yields at the time of harvest. Without percent moisture data it was difficult to document an actual yield loss. This year's data (1982) does document an actual reduction in dry matter. Many corn producers in South Dakota harvest part or all of their corn in the form of silage. Thresholds based on silage yields would be helpful in pest management decision making.

B. <u>Total Plant Weight Study, Flandreau</u>

The corn in this study experienced only first brood damage. Plants tagged in treatment two as having no first brood damage at the pretasseling stage remained undamaged up to harvest. Treatment two had no cavities per plant while plants tagged as known to be infested by the first brood had 1.3 cavities per plant. First brood was responsible for a reduction of 2.3 Ton/A wet yield (Table 12). Plants in both treatments were 65% moisture at harvest. Based on dry matter, a yield reduction of 0.8 Ton/A was recorded.

Table 12. Total plant weight recorded at harvest (wet) and dry matter yield as influenced by first brood infestation, Flandreau, 1982.

Treatment	No. Plants	Cavities (#/plant)	Wet Yield* (Ton/A)	Dry Yield* (Ton/A)
First Brood	80	1.3	19.2	6.7
No Damage	80	0	21.5	7.5

*F-test significant at .01 level

C. Total Plant Weight Study, Beresford

During the pretasseling stage ten plants per replicate were split to document cavity counts in the untreated check of test 1. At that time there were 2.5 cavities per plant. At harvest another ten plants per replicate from the control were split and cavity counts recorded. At harvest there were 2.4 cavities per stalk. This indicates that no further damage was incurred after the pretasseling stage. Damage in this field was due only to the first brood. In field 1 the cypermethrin treatment reduced cavity counts from 2.4 to 0.1 cavities per plant when compared to an untreated control. Chemical treatment was responsible for a yield increase at harvest (wet) of 2.8 Ton/A (Table 13). The plants from the cypermethrin treated plots were 71% moisture at harvest while the untreated plants averaged 72% moisture. On a dry matter basis insecticide treatment increased yields by 1.1 Ton/A.

Table 13. Total plant weight recorded at harvest (wet) and dry matter yield as influenced by first brood infestation, Beresford (Field 1) 1982.

Treatment	Cavities (#/plant)	Wet Yield* (Ton/A)	Dry Yield* (Ton/A)
Cypermethrin, 0.1 lbs. AI/A	0.1	25.0	7.3
Untreated Control	2.4	22.2	6.2

*F-test significant at .01 level

The untreated control in field 2 yielded 23.2 Ton/A compared to 26.8 Ton/A (wet) for the cypermethrin treated plots (Table 14). Cavity counts of 2.0 and 0.1 cavities per plant were measured for the untreated control and cypermethrin plots, respectively. Dry matter yield was reduced by 1.0 Ton/A where no insecticide was applied. Plants from both treatments were 74% moisture at harvest.

Table 14. Total plant weight recorded at harvest (wet) and dry matter yield as influenced by first brood infestation, Beresford (Field 2) 1982.

Treatment	Cavities (#/plant)	Wet Yield* (Ton/A)	Dry Yield* (Ton/A)
Cypermethrin, 0.1 lbs. AI/A	0.1	26.8	7.0
Untreated Control	2.0	23.2	6.0

*F-test significant at .01 level

The preceding data establish that insecticide treatment of silage corn can be a profitable undertaking. Development and refinement of thresholds for use in silage pest management decision making should proceed based on this data as a starting point.

CONCLUSIONS

1. Infestation by second generation European corn borer can have a significant impact on corn yields. The Generation Impact Study conducted in 1981 documented that a second brood infestation of 2.8 cavities per stalk resulted in a yield reduction from 178.8 Bu/A in the uninfested control to 158.4 Bu/A.
2. Increased cavity counts resulted in greater yield reductions in irrigated corn. In all irrigated fields studied during 1981 both grain and silage yields were reduced as a result of higher levels of corn borer damage as measured by cavity counts.
3. Silage yield reductions were documented as a result of first brood infestation. During 1982, data from five fields was used to compare plants known to be infested by first brood to an uninfested control. Silage yield recorded at the time of harvest was reduced by 17.4%, 11.5%, 10.7%, 11.2% and 13.4% where the first brood cavity counts were 3.3, 2.2, 1.3, 2.4 and 2.0 cavities per plant, respectively. The respective controls all had zero cavities per stalk.

APPENDIX

ANOVA For Generation Impact Study, Platte (1981)

Source	dF	Ms	F
Trt.	2	78542.9	35.16
Error	417	2233.6	

ANOVA For Grain Yield As Influenced By Cavity Count, Platte (1981)

Source	dF	Ms	F
Trt.	9	31619.9	15.44
Error	815	2042.0	

ANOVA For Total Plant Weight As Influenced By Cavity Count, Platte (1981)

Source	dF	Ms	F
Trt.	3	467150.4	7.4
Error	292	63094.2	

ANOVA For Total Plant Weight Study, Flandreau (Plot A) 1981

Source	dF	Ms	F
Trt.	1	1003254.4	28.11
Error	320	35696.4	

ANOVA For Total Plant Weight As Influenced By Cavity Count, Flandreau (Plot A) 1981

Source	dF	Ms	F
Trt.	6	218274.0	6.19
Error	315	35290.3	

ANOVA For Total Plant Weight Study, Flandreau (Plot C) 1981

Source	dF	Ms	F
Trt.	1	1559326.4	81.56
Error	293	19118.2	

ANOVA For Total Plant Weight As Influenced By Cavity County, Flandreau (Plot C) 1981

Source	dF	Ms	F
Trt.	6	183364.4	8.71
Error	288	21044.3	

ANOVA For Total Plant Weight Study, Flandreau (Plot B) 1981

Source	dF	Ms	F
Trt.	1	506579.6	13.71
Error	291	36943.9	

ANOVA For Total Plant Weight As Influenced By Cavity Count, Flandreau (Plot B) 1981

Source	dF	Ms	F
Trt.	5	192460.3	5.37
Error	287	35870.9	

ANOVA For Total Plant Weight Study (Wet), Platte (Field 1) 1982

Source	dF	Ms	F
Trt.	1	1738170.7	53.38
Error	148	32562.2	

ANOVA For Total Plant Weight Study (Dry), Platte (Field 1) 1982

Source	dF	Ms	F
Trt.	1	68865.3	23.99
Error	148	2870.5	

ANOVA For Total Plant Weight Study (Dry), Platte (Field 2) 1982

Source	dF	Ms	F
Trt.	1	59800.2	17.57
Error	148	3403.9	

ANOVA For Total Plant Weight Study (Wet), Platte (Field 2) 1982

Source	dF	Ms	F
Trt.	1	733460.8	18.03
Error	148	40679.3	

ANOVA For Total Plant Weight Study (Dry), Flandreau 1982

Source	dF	Ms	F
Trt.	1	69472.2	12.81
Error	158	5422.8	

ANOVA For Total Plant Weight Study (Wet), Flandreau 1982

Source	dF	Ms	F
Trt.	1	544755.6	12.77
Error	158	42653.6	

ANOVA For Total Plant Weight Study (Dry), Beresford (Field 1) 1982

Source	dF	SS	F
Trt.	1	90120.0	22.4
Rep.	4	34127.9	2.12
Trt. * Rep.	4	1341.0	0.08
Test of H = Trt., E = Trt. * Rep.			
Source	dF	SS	F
Trt.	1	90120.0	268.8

ANOVA For Total Plant Weight Study (Wet) Beresford (Field 1) 1982

Source	dF	SS	F
Trt.	1	669287.6	13.51
Rep.	4	14147.4	0.07
Trt. * Rep.	4	416809.4	2.10
Test of H = Trt., E = Trt. * Rep.			
Source	dF	SS	F
Trt.	1	669287.6	189.2

ANOVA For Total Plant Weight Study (Wet), Beresford (Field 2) 1982

Source	dF	SS	F
Trt.	1	828448.5	12.99
Rep.	3	168850.7	0.88
Trt. * Rep.	3	55538.7	2.90
Test of H = Trt., E = Trt. * Rep.			
Source	dF	SS	F
Trt.	1	828448.5	14.72

ANOVA For Total Plant Weight Study (Dry), Beresford (Field 2) 1982

Source	dF	SS	F
Trt.	1	61549.5	14.01
Rep.	3	42638.7	3.24
Trt. * Rep.	3	13342.9	1.01
Test of H = Trt., E = Trt. * Rep.			
Source	dF	SS	F
Trt.	1	61549.5	13.84

LITERATURE CITED

Anonymous. 1972. The European corn borer and its control in the north central states. North Central Regional Pub. No. 22.

Anonymous. 1977. Field Crop Recommendations. Ontario Ministry of Food and Ag. Pub. N. 296:73 pp.

Berry, E. C. and J. E. Campbell. 1978. European corn borer: Relationship between stalk damage and yield losses in inbred and single cross seed corn. Iowa St. Jour. of Res. 53(1):49-57.

Berry, E. C., W. D. Guthrie and J. E. Campbell. 1978. European corn borer: Relationship between leaf-feeding damage and yield loss in inbred and single-cross corn. Iowa St. J. of Res. 53(2):137-145.

Caffrey, D. J. and L. H. Worthley. 1927. A progress report on the investigation of the European corn borer. USDA Bull. 1476:154 pp.

Chiang, H. C., L. K. Cutkomp and A. C. Hodson. 1954. The effects of the second generation of the European corn borer on field corn. J. Econ. Ent. 47:1015-1020.

Chiang, H. C. and A. C. Hodson. 1950. Stalk breakage caused by the European corn borer and its effect on the harvesting of field corn. J. Econ. Ent. 43:415-422.

Chiang, H. C. and A. D. Hodson. 1972. Population of fluctuations of the European corn borer, Ostrinia nubilalis, at Waseca, Minnesota, 1948-70. Environ. Ent. 1:7-16

Chiang, H. C. and F. G. Holdaway. 1959. Effect of Pyrausta nubilalis (Hbn.) on the growth of leaves and internodes of field corn. J. Econ. Ent. 52:567-72.

Chiang, H. C. and F. G. Holdaway. 1965. Relationship between plant height and yield of field corn as affected by the European corn borer J. Econ. Ent. 58(5):932-938.

Chiang, H. C., F. G. Holdaway, T. A. Brindley and C. R. Neiswander. 1960. European corn borer populations in relation to the estimation of crop loss. J. Econ. Ent. 53:517-22.

Chiang, H. C., J. L. Jarvis, C. C. Burkhardt, M. L. Fairchild, G. T. Weekman, and C. A. Triplehorn. 1961. Populations of European corn borer, Ostrinia nubilalis (Hbn.) in field corn, Zea mays (L.). Mo. Ag. Exp. Stn. Res. Bull. 776 (N.C. Reg. Publ. 129). 95 pp.

Chippendale, G. M. 1972. Composition of meridic diets for rearing plant-feeding lepidopterous larvae. Proc. N. Cent. Br. Ent. Soc. Am. 27:114-21.

Deay, H. O., L. H. Patch and R. O. Snelling. 1949. Loss in yield of dent corn infested with the August generation of the European corn borer. J. Econ. Ent. 42:81-87.

Eden, W. G. 1956. The European corn borer in Alabama. J. Econ. Ent. 49:410-11.

Everett, T. R., H. C. Chiang and E. T. Hibbs. 1959. Some factors influencing populations of the European corn borer Pyrausta nubilalis (Hbn.) in the north central states. Univ. of Minn. Ag. Expt. Sta. Tech. Bull. 229.

Felt, E. P. 1922. The European corn borer. New York St. Coll. of Agric. Ext. Bull. 31, 35-42.

Ficht, G. A. 1939. The development of a second generation of the European corn borer, Pyrausta nubilalis (Hbn.) in Indiana. Proc. Ind. Acad. Sci. 48:211-215.

Guthrie, W. D., F. F. Dicke, G. R. Pesho. 1965. Utilization of European corn borer egg masses for research programs. Proc. N. Cent. Br. Ent. Soc. Am. 20:48-50.

Guthrie, W. D., E. S. Raun, F. F. Dicke, G. R. Pesho and S. W. Carter. 1965. Laboratory production of European corn borer egg masses. Iowa St. J. Sci. 40:65-83.

Guthrie, W. D., W. A. Russell, F. L. Neumann, G. L. Reed and R. L. Grindeland. 1975. Yield losses in Maize caused by different levels of infestation of second-brood European corn borer. Iowa St. J. of Res. 50(2):239-53.

Jarvis, J. L., T. R. Everett, T. A. Brindley, and F. F. Dicke. 1961. Evaluating the effect of European corn borer populations on corn yield. Iowa St. Jour. of Sci. 36(2):115-132.

Klun, J. A. and J. F. Robinson. 1968. Concentrations of two 1,4-benzoxazinones in dent corn at various stages of development of the plant and its relation to resistence of the host plant to the European corn borer. J. Econ. Ent. 62:214-20.

Kwolek, W. F. and T. A. Brindley. 1959. The effects of the European corn borer, Pyrausta nubilalis (Hbn.), on corn yield. Iowa St. Coll. Jour. Sci. 33(3):293-323.

Lewis, L. C. and R. E. Lynch. 1969. Rearing the European corn borer Ostrinia nubilalis (Hub.) on diets containing corn leaf and wheat germ. Iowa St. J. Sci. 44:9-14.

Lynch, R. E. 1980. European corn borer: Yield loss in relation to hybrid and stage of corn development. J. Econ. Ent. 73:159-164.

Lynch, R. E., J. F. Robinson and E. C. Berry. 1980. European corn borer: Yield losses and damage resulting from a simulated natural infestation. J. Econ. Ent. 73:141-144.

Marion, H. 1957. Complement a la classification et nomenclature des Pyraustidae D'Europe. L'Entomologiste 13:130.

Meyrick. 1895. Pyrausta nubilalis. Handb. Brit. Lep., 416.

Neiswander, C. R. and E. A. Herr. 1930. Correlation of corn borer population with degree of damage. J. Econ. Ent. 23:938-945.

North Central Regional Publication. Management of the European corn borer. (In Press).

Patch, L. H., G. T. Bottger, and B. A. App. 1938. Comparative resistance to the European corn borer of two hybrid strains of field corn at Toledo, Ohio. J. Econ. Ent. 31:337-340.

Patch, L. H., H. O. Deay and R. O. Snelling. 1951. Stalk breakage of dent corn infested with the August generation of the European corn borer. J. Econ. Ent. 44:534-539.

Patch, L. H. and L. L. Peirce. 1933. Laboratory production of clusters of European corn borer eggs for use in hand infestation of corn. J. Econ. Ent. 26(1):196-204.

Patch, L. H., G. W. Still, B. A. App and C. A. Crooks. 1941. Comparative injury by the European corn borer to open-pollinated and hybrid field corn. J. Agr. Res. 63:355-368.

Patch, L. H., G. W. Still, M. Schlosberg and G. T. Bottger. 1942. Factors determining the reduction in yield of field corn by the European corn borer. J. Agr. Res. 65:473-482.

Penny, L. H. and F. F. Dicke. 1959. European corn borer damage in resistant and susceptible dent corn hybrids. Agron. J. 54:323-6.

Reed, G. L., T. A. Brindley and W. B. Showers. 1972[a]. Influence of resistent corn leaf tissue on the biology of the European corn borer. Ann. Ent. Soc. Am. 65(3).

Reed, G. L., W. B. Showers, J. L. Huggans and S. W. Carter. 1972[b]. Improved procedure for mass rearing the European corn borer. J. Econ. Ent. 65:1472-76.

Salter, R. M. and L. E. Thatcher. 1927. Agronomic research on the European corn borer in Ohio. J. Amer. Soc. Agron. 19:137-53.

Scott, G. E., W. D. Guthrie and G. R. Pesho. 1967. Effects of second-brood European corn borer infestations on 45 single-cross corn hybrids. Crop Sci. 7:229-30.

Showers, W. B., H. C. Chiang, A. J. Keaster, R. E. Hill, G. L. Reed, A. N. Sparks and G. J. Musick. 1975. Ecotypes of the European corn borer in North America. Env. Ent. 4(5):753-760.

Showers, W. B., M. B. DeRozari, G. L. Reed, and R. H. Shaw. 1978. Temperature related climatic effects on survivorship of the European corn borer. Env. Ent. 7:717-723.

Showers, W. B., G. L. Reed, J. F. Robinson, and M. B. DeRozari. 1976. Flight and sexual activity of the European corn borer. Env. Ent. 5:1099-1104.

Smith, H. E. 1920. Broom corn, the probable host in which *Pyrausta nubilalis* (Hbn.) reached America. J. Econ. Ent. 13:425-30.

Sparks, A. N., H. C. Chiang, C. C. Burkhardt, M. L. Fairchild, and G. T. Weekman. 1966. Evaluation of the influence of predation on corn borer populations. J. Econ. Ent. 59:104-7.

Sparks, A. N., H. C. Chiang, C. A. Triplehorn, W. D. Guthrie, T. A. Brindley. 1967. Some factors influencing populations of the European corn borer, *Ostrinia nubilalis* (Hubner) in the North Central States. Iowa Agric. Home Econ. Exp. Stn. Res. Bull. 559 (N.C. Reg. Res. Publ. 180) 103 pp.

Thompson, L. S. and R. P. White. 1977. Effect of insecticides on European corn borer and yield of silage corn in Prince Edward Island. J. Econ. Ent. 70(6):706-708.

Vinal, S. C. and D. J. Caffrey. 1919. The European corn borer and its control. Mass. Agric. Expt. Sta. Bull. 189. 71 pp.

Walker, H. G. and L. D. Anderson. 1936. European corn borer on the eastern coast of Virginia. J. Econ. Ent. 29(1):202-204.