

GROWTH AND DEVELOPMENT OF THE SOUTHWESTERN CORN BORER
ON CORN (LEPIDOPTERA: PYRALIDAE)

by

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B. A., Kansas Wesleyan University, 1971

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

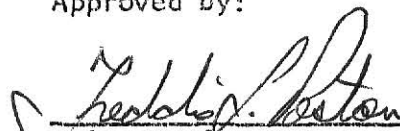
MASTER OF SCIENCE

Department of Entomology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1977

Approved by:


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INTRODUCTION

The southwestern corn borer, Diatraea grandiosella (Dyar), is a severe pest of irrigated corn in southwest and southcentral Kansas. Corn producers in these areas have applied insecticides extensively with inconsistent results. It is felt that these inconsistencies are the result of improper timing of insecticide application. During 1975 and 1976 southwestern corn borer flights were erratic. Flight initiation, peak, and duration varied from year to year and from region to region within a year. Moth flights lasted from 3 to 6 weeks with oviposition occurring over that time span. The time frame between egg hatch and larval entry into the stalk is the critical period for insecticide efficacy. If this time period could be accurately predicted, more consistent results from insecticide applications would probably result.

Studies were conducted during 1976 and 1977 to 1) determine the effects of synthetic and corn diets on southwestern corn borer development times and pupal weights, 2) develop and validate a phenological growth model for the southwestern corn borer based on temperature, and 3) determine seasonal occurrence of the southwestern corn borer in irrigated corn.

REVIEW OF LITERATURE

Taxonomy

The southwestern corn borer, Diatraea grandiosella Dyar (Lepidoptera: Pyralidae), was first described by Dyar (1911) from a single large female taken from Guadalajara, Mexico (type, number

13619, U. S. National Museum; Schaus collection). It was distinguished from other specimens in the lineolata series by color and external morphology. This description, however, was not sufficiently distinct to accurately separate species within the genus Diatraea. Dyar and Heinrich (1927) published a complete revision of the genus Diatraea separating species based on adult genital characteristics and external morphology. Rolston (1955) stated that all records of the southwestern corn borer prior to 1911 were published under the name Diatraea saccharalis.

Box (1956) redescribed grandiosella under the genus Zeadiatraea based on adult genital morphology. This change, however, has not been readily accepted and the majority of literature refers to the southwestern corn borer as Diatraea grandiosella.

Description of Stages

The eggs were described by Rolston (1955) as follows:

. . .approximately 1.0 mm wide, elliptical, and decidedly flattened. They are deposited singly or in chains or masses with the individual eggs overlapping like shingles. . . .

When first laid the eggs are entirely white, dull, and opaque but older, fertile eggs are distinctly marked with three red, transverse bars. Shortly before hatching, the head capsule of the embryo appears as a black spot in the egg and the bars are no longer apparent, the red color being more or less diffused. Infertile eggs, and those with dead embryos, discolor in varying degrees but do not develop the characteristic markings.

Most eggs are laid on the upper basal leaf surface. The lower leaf surface is the second most favored position, and a few eggs are found on the corn stalk (Rolston 1955).

Dyar and Heinrich (1927) originally described the first instar and fully grown larvae. Peterson (1962) gave methods for separating the three common species of Diatraea, the Sugar cane borer, D. saccharalis (F.), the Southern corn stalk borer, D. crambiodoides (Grote), and the Southwestern corn borer, D. grandiosella Dyar. Rolston (1955) provided the following general description:

The first instar larvae have a definite reddish cast that is seen, under magnification, to be more or less confined to the prothorax and to a broad, dorsal band across most abdominal segments. The second instar larvae retain this color in varying degrees, particularly in the prothorax. The head capsule and cervical shield are dark brown in the first instar and become increasingly lighter in following instars. The reddish color of the first and second instars is sufficiently reliable for field identification. The third and succeeding instars are easily distinguished from other larvae commonly found in corn and related crops by the regular pattern of black spots, the pinacula, on a yellowish-white background. The overwintering brood of larvae molt in the field, assuming the immaculate, yellowish-white winter form with this molt. The black pinacula of the summer form gradually fades to a light brown in some, but not all, larvae prior to this molt.

Head-capsule widths were recorded by Rolston (1955) for the larval instars, ranging from 0.36 mm in the 1st instar to 1.77 mm for fifth instar larvae.

Pupae range from 13-25 mm long and are blunt posteriorly with the 8th, 9th, and 10th abdominal segments bearing numerous sharp, stout, black tubercles. The terminal segment lacks a cremaster (Henderson and Davis 1969). Rolston (1955) stated that the anal opening, located on the 10th abdominal segment, was an inverted Y-shape. He reported that the male genital opening was located on the 9th abdominal segment between

a pair of tubercles. The female genital opening is located on the 8th and 9th abdominal segments lacking tubercles on either side.

Adult moths are usually 15-20 mm long with a wing expanse of 30-40 mm, and males are generally smaller than females (Wilbur et al. 1950). Both male and female moths are solid-white to pale-yellow with lighter hind wings, and when at rest, the wings are folded about the body (Kansas Agricultural Experiment Station 1975). Palpi are prominent and snoutlike (Rolston 1955).

Distribution

The geographical distribution of the southwestern corn borer has been reported in detail by several workers (Davis et al. 1933, Wilbur et al. 1950, Rolston 1955, Henderson et al. 1966, Elias 1970, Chippendale and Reddy 1974). It spread northward from Mexico and was first reported from Lakewood Eddy County, New Mexico, in February, 1913; from Las Palomas, N. Mexico, in December, 1913; and from Carlsbad, N. Mexico in 1914. By 1931 it had spread north and eastward reaching central Oklahoma, southeastern Colorado, and southwestern Kansas (Davis et al. 1933). Wilbur (1950) reported that the species disappeared from Kansas from 1933-1938 when corn failed because of drought, and that it reinvaded the state about 1941. By 1942 heavy infestations of corn in southwest and southcentral Kansas were recorded, and by 1943 it had spread through Kansas, reaching as far as the south-central portion of Nebraska (Tate and Bare 1945). Chippendale and Reddy (1974) stated that the northern limit of the borer's range had receded from Nebraska and northern Kansas

because of cold winter temperatures which prevail in these areas. The eastern limit had extended across Oklahoma into west-central Arkansas (Rolston 1955) and southwestern Missouri (Chippendale and Reddy 1974) by 1950 and 1953, respectively. Floyd et al. (1969) first reported the borer in Louisiana in 1955. It reached Mississippi, Tennessee, and Alabama in 1958, 1960, and 1962, respectively (Henderson et al. 1966). Large populations of overwintering larvae were reported in Illinois in 1964 (Fairchild 1965). The current southwestern corn borer distribution is confined mainly to Arizona, New Mexico, Texas, Oklahoma, Kansas, Nebraska, Illinois, Louisiana, Arkansas, Mississippi, Alabama, Tennessee, Kentucky, and Missouri (United States Department of Agriculture 1976).

Biology and Physiology

Walton and Bieberdorf (1948) reported that southwestern corn borer moths were nocturnal with mating and oviposition occurring during the scotophase. Davis et al. (1933) found that females laid 150-400 eggs. Stewart and Walton (1964), however, recorded only 61-78 eggs/female with most oviposition occurring the first two nights after mating. Egg production rapidly diminished thereafter until females became spent by the fifth day.

Davis et al. (1972) and Clymer (1973) stated that eggs hatch in 3-7 days, depending on temperature, and the newly hatched larvae move into the whorl of the corn plant where they feed for ca. 10 days.

Chippendale and Reddy (1974) conducted extensive nutritional requirement studies and found that glucose, fructose, sucrose, dextrin, and amylopectin stimulated feeding and permitted optimum growth and development of the larvae. Pentose, arabinose, ribose, xylose, galactose, mannose, and sorbose inhibited larval growth.

Chippendale (1975) stated that ascorbic acid (0.5% concentration, wet weight) was essential for normal growth, development, and fertility, but that it had no effect on larval feeding behavior. He showed that ascorbic acid was most critical during the second and third larval instars.

After feeding in the whorl, 3rd and 4th instar larvae bore into the stalk and start tunneling (Davis et al. 1933, Rolston 1955). On tassel-stage corn plants larvae move into the ear and feed between the husk layers. Few larvae may be found between the ear and ear shoots. Corn cobs, kernels, and shanks are also utilized as food (Kansas Agricultural Experiment Station 1975).

After feeding and before pupation mature larvae construct a pupal cell. The larval tunnel is extended to the base of the stalk where an emergence "window" is made and only a thin "pane" is left (Knutson (1975). Pupation usually takes place at the lower end of the tunnel, and emergence occurs in ca. 10 days (Rolston 1955).

Overwintering larval habits differ from summer larval habits (Clymer 1973, Davis et al. 1933, Rolston 1955). Mature larvae of the diapausing generation become pale yellow and begin to girdle the

interior of the corn stalk from late August to early September. Larvae usually diapause in the extreme lower tip of the tap root (Kansas Agricultural Experiment Station 1975).

Chippendale and Reddy (1972) found that the southwestern corn borer possessed a facultative diapause. Diapause was indicated when mature spotted larvae had transformed to immaculate polymorphic variants. Alexander and Chippendale (1973) found spermatogenesis was arrested and secondary spermatocytes degenerated during the first phase of larval diapause. A resumption of spermatogenesis was observed during the last diapause phase.

Several ecological and physiological factors are involved in regulating initiation, development, and termination of diapause. Chippendale and Reddy (1972) reported that mature larval diapause was successfully induced by exposing the immature larval states to 23°C with a 12 hr L:12 hr D photoperiod. The role of temperature and photoperiod in the development of the mature larval diapause was studied in detail by Chippendale and Reddy (1973). They found that diapause induction was an extremely temperature-dependent process, but did not require a period of chilling. The exact role of photoperiod was not found. They were able to demonstrate a photoperiodic response only at 25°C when diapause was initiated following larval exposure to daily photophases ranging from 8-14 hours. Yin and Chippendale (1974) found that a topical application of a juvenile hormone mimic to mature non-diapausing larvae caused them to ecdyse to immaculate diapausing larvae

that were morphologically and physiologically equivalent to normal diapausing larvae. They concluded that larval diapause was initiated and maintained by juvenile hormone.

Chippendale and Reddy (1974) found the supercooling point (-8.5°C) and the freezing point (-2°C) for diapausing larvae. They observed that southwestern corn borer populations do not overwinter in geographical areas where the 10-year mean January ambient temperature fell below -7°C , and the soil was poorly drained.

Overwintering larvae pupate in the spring and adults emerge ca. mid-May in Arizona and Mississippi (Davis et al. 1933, Davis et al. 1974) and June in Oklahoma, Arkansas, and Kansas (Rolston 1955, Walton and Bieberdorf 1948, Wilbur et al. 1950). Adults from the first generation emerge during June to July in Arizona, Arkansas, and Mississippi (Davis et al. 1933, Davis et al. 1974, Rolston 1955), and late July to early August in Oklahoma and Kansas (Kansas Agricultural Experiment Station 1975, Walton and Bieberdorf 1948). A complete generation may take 40-50 days in Arizona (Davis et al. 1933), 41 days in Arkansas (Rolston 1955) and ca. 45 days in Kansas (Wilbur et al. 1950). Davis et al. (1933) found that moths live from 2-6 days with females living ca. 2 days longer than males.

The number of generations per year varies from state to state and sometimes even within a state. Fairchild (1965) reported 2 generations/year in northern areas of Kansas and 3 generations/year in southern Kansas. Three generations/year generally occur in Mississippi, Tennessee and other southern states (Arnold et al. 1970, Davis et al. 1974).

Moths of the southwestern corn borer usually mate at night (Walton and Bieberdorf 1948). Males participate in a precopulatory flight, from ca. 9 p.m. to 12 a.m. some 5-8 hours after emergence (Langille and Keaster 1973). Rolston (1955) found that females mate only once.

Research has indicated the presence of a sex attractant in the virgin female moths (Davis and Henderson 1967). They observed that most females attracted males on the night of emergence, but this ability dropped rapidly after the fourth day and disappeared completely after 8 days.

Host Plants and Economic Damage

Corn (Zea mays L.) is the principal host plant of the southwestern corn borer but it has also been reported feeding on sorghum (Sorghum bicolor (L.)), sugar cane (Saccharum officinarum L.), broom corn (Sorghum bicolor var. technicum (Koern.)), sudan grass (Sorghum bicolor var. sudanense Hitch.), Johnson grass (Sorghum halepense (L.)) (Clymer 1973, Rolston 1955, Walton and Bieberdorf 1948), and cocklebur (Kansas Agricultural Experiment Station 1975).

The southwestern corn borer inflicts various types of damage to corn. Most commonly found are "dead heart," stalk tunneling, and stalk girdling (Arnold et al. 1970, Black et al. 1970, Clymer 1973, Davis et al. 1972, Douglas 1968, Rolston 1955, Scott and Davis 1974). Dead heart results from the larva's penetration of the growing tip of

the young plant where it feeds on meristematic tissue which results in either a dead or a severely stunted plant. Tunneling is usually caused by late instar larvae which may destroy all or part of the stalk's vascular tissue resulting in a reduction of grain yield (Henderson and Davis 1969, Stanley et al. 1962). The most insidious habit of the southwestern corn borer is stalk girdling. Before diapause, overwintering generation larvae weaken stalks by cutting a groove around the inside of the stalk near ground level (Davis et al. 1974, Rolston 1955). Girdling makes the plant susceptible to lodging caused by wind or by ear weight alone. Much of the lodged grain is thus missed during mechanical harvesting operations or damaged by disease and rodents. Thus, girdling usually causes large harvest losses (Chada et al. 1965, Davis et al. 1974). Mitchell and Young (1975) stated that girdling may result in greater than 50% stalk lodging in Mississippi. Arnold et al. (1970) observed more than 90% of the lodged stalks girdled in Tennessee. Harvest losses of 17.9 bushels/acre resulted from girdling in Mississippi (Douglas 1968).

Predators and Parasites

The southwestern corn borer has several natural enemies occurring throughout its range. Davis et al. (1933) reported Trichogramma minutum Riley and Apanteles diatraea Muesebeck as egg and larvae parasites, respectively. Lady beetle adults and larvae, green and brown lacewing larvae, assassin bugs, flower bugs, and spiders have all been reported (Clymer and Daniels 1975) destroying southwestern corn borer eggs and

young larvae. The yellow shafted flicker, Colaptes auratus (L.), has been reported as a key factor in the reduction of overwintering corn borer populations, removing as much as 63.7-81.8% in Mississippi (Black et al. 1970, Floyd et al. 1969, Wall and Whitcomb 1964, Davis et al. 1973).

Host Plant Resistance and Cultural Control

Corn was first screened for southwestern corn borer resistance in Oklahoma (Walton and Bieberdorf 1948) and Kansas (Wilbur et al. 1950). A hybrid, K228 x K230, showed a reduction in larval infestations and percentage lodging of infested plants over susceptible corn types (Painter 1968). Two synthetic varieties, Ark SWCB Syn, and Ark Leaf Feed Res. Syn, were developed by York and Whitcomb (1966) and exhibited a high degree of resistance to stalk tunneling. Davis et al. (1973) screened corn germplasm for possible resistance to 1st and 2nd brood attack in Mississippi and found two lines from Antigua Gpo 2 (Mp68:576 and Mp:616) which exhibited intermediate resistance to 1st generation.

Control of the southwestern corn borer through various cultural practices has been reported by several workers (Clymer and Daniels 1975). Henderson and Davis (1969) stated that destruction of overwintering habitat by double disking and deep cutting reduced overwintering populations. They hypothesized that large geographical areas must be tilled to prevent reinfestation by migrating adults.

Early planting has been recommended to avoid deadheart and stalk lodging due to southwestern corn borer infestations (Knutson 1975).

Arnold et al. (1970) reported that the most consistent advantage of early planting in Tennessee was the reduction of girdling resulting from earlier harvest. Early planting, however, may not always be feasible because of variations in environmental and climatic conditions. As yet, no known cultural method has consistently controlled the southwestern corn borer population in the United States (Knutson 1975).

Chemical Control

Chemical insecticides have been reported effective in reducing southwestern corn borer populations (Clymer and Daniels 1975, Fairchild 1965, Pless et al. 1972). Many systemic insecticides applied at planting time have shown promising results in controlling larvae. A granular formulation of AC47470 gave effective control for 62 days after application (Hensley et al. 1964). Whitcomb et al. (1966) observed that carbofuran was effective against the southwestern corn borer. Keaster and Fairchild (1968) found that a carbofuran application of 1.5 lb AI/acre at planting and 1.5 lb AI/acre sidedress gave the best control.

Foliar insecticide applications have also shown promise in reducing borer infestations. Endrin, isobenzan, carbaryl, DDT, and diazinon all gave good results when used as sprays and granules in Mississippi (Henderson and Davis 1967).

Keaster (1972) observed that 6 insecticides were most effective for corn borer control in a three-year-test in Missouri: monocrotophos, diazinon, endrin, carbofuran, gardona, and sevimol. In furrow treatments

with carbofuran at planting were as effective for control of 2nd generation borers as timed foliar applications (Davis et al. 1974).

Chemical control can be effective if the insecticide can reach the southwestern corn borer. Therefore, timing insecticide applications is very important (Henderson and Davis 1969). Clymer and Daniels (1975) stated that little control could be obtained after larvae enter the stalk.

METHODS AND MATERIALS

Synthetic Diet vs. Corn as Food Substrates

A laboratory study comparing the effects of a synthetic diet and corn on southwestern corn borer development time and pupal weights at 2 temperatures was conducted. A completely randomized design was used, 2 replications of 4 treatments. Treatments consisted of larvae fed a synthetic wheat-germ diet (Davis 1976), and larvae fed leaf and stalk sections (each section contained meristematic tissue) at 2 temperatures (85° and 90°F). There were no significant diet-temperature interactions.

Southwestern corn borer larvae were field collected and established as a laboratory colony. The colony was maintained under conditions similar to those outlined by Davis (1976). Laboratory environmental conditions were: photophase - 16 hrs (supplied from auxiliary lighting), temperature - 80°F, humidity - ca. 40% RH. Eggs were collected from oviposition cages in the rearing room 24 hr after deposition and transferred to a plastic dish (6 x 1 1/2 in.). Dishes were placed in a growth chamber (16 hr photophase and 100% RH) until egg hatch. Humidity was

maintained with a 5-gal. room-humidifier. After egg hatch, larvae (20/rep.) were placed either in individual petri dishes (3 7/16 x 3/4 in.) with greenhouse-grown corn (Pioneer 3149) as food or 1-oz plastic cups 1/2-filled with wheat-germ diet. All larvae were examined at 24-hr intervals and the corn changed as needed. Larval instar determinations were based on head-capsule widths (Rolston 1955). Pupal weight was recorded and pupae sexed 48 hr after pupation. Individuals were reared to maturity to obtain pupal-stage duration. Development times and pupal weights of individuals reared on corn were compared with those reared on media.

Development Model

Studies were conducted to develop a phenological growth model for the southwestern corn borer on corn. The same procedures were followed as those outlined for the larvae reared on corn in the preceding diet vs. corn study. A completely randomized design was used, 2 replications of 8 treatments. Temperatures (60°, 65°, 70°, 75°, 80°, 85°, 90°, 95°F) constituted treatments with 20 larvae (experimental units)/replication/treatment fed greenhouse-grown corn (Pioneer 3149). Larvae were examined at 24-hr intervals and development recorded. Larval instar determinations were again based on head-capsule widths. Pupal weight was recorded and pupae sexed 48 hr after pupation. Individuals were reared to maturity to obtain pupal-stage duration.

Seasonal Occurrence

Weekly samples were taken at Sandyland Experiment Field, St. John, Ks. starting June 10, 1976 for comparison to model predictions. The initial sample consisted of 100 plants using a stratified random sampling pattern, 4 strata of 25 consecutive plants each. Subsequent samples consisted of corn plants (20) exhibiting characteristic 1st-generation corn borer damage, viz., shotholing, were dissected and examined for southwestern corn borers. Developmental stages were recorded for all individuals collected. Larval instar determinations were again based on head-capsule measurements.

Daily maximum-minimum temperatures were recorded at Sandyland and thermal units calculated for growth-state development. Developmental observations from the natural population were compared to the data from the laboratory population for model confirmation.

RESULTS AND DISCUSSION

Synthetic Diet vs. Corn as Food Substrates

Mean development times and pupal weights (Table 1) for male and female southwestern corn borers reared on corn were significantly different ($P < 0.05$) from those reared on synthetic diet. Larvae reared on corn required significantly longer to develop than those reared on synthetic diet. Egg and pupal stage development were independent of diet. Pupal weight for males was also independent of diet. However, females reared on synthetic diet were significantly heavier than those

Table 1. Mean development times, pupal weights, and standard errors (S.E.) for male and female southwestern corn borers reared on synthetic diet and corn.^a

Diet	Stage (days)				Pupal wt	
	Larval	S.E.	Pupal	S.E.	Egg-to-adult	S.E.
<u>Male</u>						
Corn	25.1 a	+ 2.1	4.2 a	+ 1.7	34.5 a	+ 2.6
Media	20.8 b	+ 2.8	4.0 a	+ 1.0	29.6 b	+ 2.2
					.156 a	+ .026
					.1544 a	+ .021
<u>Female</u>						
Corn	24.9 a	+ 1.5	4.3 a	+ 1.2	34.2 a	+ 1.7
Media	19.8 b	+ 2.4	4.3 a	+ 1.2	28.6 b	+ 1.4
					.205 a	+ .031
					.2237 b	+ .024

^a Numbers followed by the same letter, within a column, are not significantly different at the 5% level.

reared on corn. These weight differences may indicate differences in female fecundity as Jennings (1974) found for the southwestern pine tip moth, Rhyacionia neomexicana (Dyar).

Synthetic diet may be more suitable for rearing and maintaining a laboratory colony as it is more convenient to work with and requires less daily maintenance. However, as indicated by this study, laboratory-reared southwestern corn borers should be reared on corn for comparisons to the natural population.

Development Model

Mean times required for egg-to-adult development are presented in Table 2. Times ranged from 85.7 days at 65°F to 32.0 days at 90°F. Eggs maintained at 60°F failed to develop. Eggs maintained at 95°F hatched but all larvae died within 12 hrs.

Pupal weights for males and females at different temperatures are presented in Table 3. Females were significantly heavier than males at all temperatures. Pupal weights for both sexes were significantly heavier at 85° and 90°F than the pupal weights at the other temperatures. These weight differences may be attributed to increased feeding at the higher temperatures or a greater expenditure of energy at the lower temperatures.

A thermal unit accumulation system was calculated for the southwestern corn borer. Reciprocals of days needed for egg, larval, pupal, and egg-to-adult development were regressed on temperature to establish respective developmental thresholds. Regression equations and coefficients

Table 2. Mean development times (days) of southwestern corn borers reared at different temperatures.

Temp. (°F)	N	Egg stage	1st	2nd	3rd	4th	5th	Larval stage	Pupal stage	Egg to adult
60	40	ND ^a								
65	40	11.0	15.5	14.2	11.9	11.9	11.3	64.8	9.9	85.7
70	35	10.4	9.9	9.1	9.1	7.3	12.4	47.7	7.4	66.2
75	40	8.0	5.3	5.4	5.9	7.0	12.2	35.9	8.0	52.0
80	36	6.4	4.8	5.9	6.8	7.2	6.9	31.7	6.4	44.1
85	36	5.0	4.4	4.9	5.6	5.9	8.3	29.0	4.7	36.6
90	38	5.0	4.1	3.8	4.4	5.3	7.1	24.8	3.9	32.0
95	40	5.0	ND							

^aNo development.

Table 3. Mean pupal weights (mg) for male and female southwestern corn borers reared at different temperatures.^a

Temp. (°F)	Male	Female
65	.1179 a	.1584 ab
70	.137 b	.1538 a
75	.1268 ab	.2009 c
80	.1362 b	.1736 b
85	.1504 c	.2096 c
90	.1602 c	.2016 c

^a Numbers followed by the same letter, within a column, are not significantly different at the 5% level using Duncan's Multiple Range Test.

of determination for each stage were: egg, $y = 0.24865 + 0.00508 x$ ($R^2 = 0.948$); larval, $y = -0.05524 + 0.00109 x$ ($R^2 = 0.993$); pupal, $y = -0.30768 + 0.00610 x$ ($R^2 = 0.872$); egg-to-adult, $y = -0.03968 + 0.00079 x$ ($R^2 = 0.997$). Based on regression analysis, development was significantly linear ($P < 0.05$) between 65° and 90°F . Development thresholds for egg, larval, pupal, and egg-to-adult stages, calculated from regression equations, were 48.9 , 50.7 , 50.4 , and 50.2°F , respectively. The 95% confidence limit, using Fieller's theorem, for egg-to-adult development was 55.1 - 45.7°F .

Thermal units were calculated for each temperature by the following formula:

$$Tu = \sum (\bar{x} - mc), \text{ where}$$

$\bar{x}$ = mean daily temperature

mc = minimum cardinal temperature (50°F)

The minimum cardinal temperature for egg-to-adult development (50°F) was used as the developmental threshold for all stages. Thermal units required for development at all temperatures were averaged to obtain the thermal unit system (Table 4). Completion of egg, larval, pupal, and egg-to-adult development required 190, 964, 168, and 1,321 thermal units, respectively.

Seasonal Occurrence

Weekly samples were taken from June 10 to November 12, 1976. On June 10, 100 plants were sampled revealing a total of 27 white southwestern corn borer eggs. On June 17, 3,000 plants were sampled yielding a total of 27 eggs. No more eggs were found in subsequent samples. The

Table 4. Means ($\bar{x}$) and standard errors (S.E.) of the cumulative thermal units required for development of the southwestern corn borer.

Stage	$\bar{x}$	S.E.
Egg	190	± 6.8
<u>Larval stadia</u>		
1st	361	± 15.3
2nd	533	± 10.9
3rd	713	± 7.9
4th	902	± 11.3
5th	1153	± 21.7
Pupal	1321	± 9.2

proportion of the population in each developmental state, other than the egg, is presented in Table 5. The 1st and 2nd generation overlapped from ca. July 22 to August 4. During this period, 4th and 5th-instar larvae from the 1st generation and 1st and 2nd-instar larvae from the 2nd generation were collected. From September 25 to November 12, sampling revealed ca. 1 larvae/plant. This probably resulted from bird predation (Davis et al. 1973) and the cannibalistic behavior (Rolston 1955) of the species.

Validation of Model

Freshly laid southwestern corn borer eggs were found on June 10 and June 17, 1976. A maximum-minimum equation was used to calculate the available thermal units for southwestern corn borer development throughout the growing season. The equation was as follows (Poston et al. 1977):

$$Tu = \sum [(ma + mb) \div 2] - mc, \text{ where}$$

ma = maximum daily temperature

mb = minimum daily temperature $\geq 50^{\circ}\text{F}$

mc = minimum cardinal temperature (50°F)

If the minimum daily temperature was less than 50°F it was adjusted to equal 50°F . If the maximum daily temperature exceeded 90°F it was adjusted to equal 90°F . According to model predictions, eggs laid during the period June 9-16 should have hatched June 16-24 and larvae should have pupated July 21-26. First generation adults should have emerged July 26-31. These predictions do not account for natural variations in development times between individuals.

Table 5. Proportion (%) of southwestern corn borers in larval and pupal stage at Sandyland Experiment Field, St. John, KS, 1976.

Date	Larval instars					Pupae	Total
	1st	2nd	3rd	4th	5th		
June 17	45.7	30.8	23.5				276
24		2.1	52.1	45.8			48
30		13.2	34.2	34.2	18.4		38
July 8		11.1	27.8	22.2	33.3		18
13			2.5	25.0	37.5	35.0	40
22				5.9	11.8	82.4	17
Aug 3	12.0	12.0	28.0	46.0	2.0		50
12		8.7	30.4	43.5	17.4		23
20		6.7	50.0	36.7	6.7		30
28			2.6	44.7	52.6		38
Sept 4				10.5	89.5		19
11				17.0	83.0		35
20			3.6	14.3	82.1		28
25				8.3	91.7		24
Oct 1				7.1	92.9		14
15				9.5	90.5		21
27				22.2	77.8		27
Nov 12				17.7	82.4		17

Weekly samples for eggs and pupae from a naturally infested field at Sandyland Experiment Field seem to support these calculations. Eggs were collected only on June 10 and 17. On July 22, 82.4% of the population samples were pupae. At that time, calculating from June 10, 1,108 thermal units had accumulated. Adults were collected on July 15 using a standard black-light trap. Peak numbers were collected on the nights of July 26 to August 2, with peak catch on July 31. From July 22, when the majority of the population were pupae, until July 31, 265 thermal units had accrued (cumulative total = 1,373). Peak adult emergence apparently occurred later than the model predicted. However, dissection of borer females and classification of the bursa copulatrix (Showers et al. 1974) indicated that females collected in light traps had laid most of their eggs. Therefore, peak emergence probably occurred 2-4 days before peak catch (Schenck and Poston, unpublished data).

Weekly samples from June 24 through July 13, when the population was in the larval stage, indicated no 1st-instar larvae. Only plants containing predominantly 3rd, 4th, and 5th-instars were sampled. This probably resulted from bias in the sampling technique, viz., only plants displaying larval damage were sampled. Early instar larvae (1st and 2nd instars) feed predominantly in the whorl. Several days are required before feeding damage is apparent. Thus, the probability of selecting a plant with early instar larvae is decreased.

Peak oviposition by 1st generation females probably occurred July 25 to July 31. Thus, 2nd generation larvae should have hatched August 1-8. On August 3, 12% of the population sampled were 1st-instar

larvae which was the only sample period in which 1st-instars were collected. Samples of 2nd generation southwestern corn borers from August 28 revealed the majority of the population in the 5th-instar. From July 25 to August 28, 958 thermal units had accumulated. Therefore, the model appears valid for 2nd generation borers through the 4th larval instar. The 4th larval instar is the last stage completed before larval diapause.

Therefore, developmental observations, from the natural population of southwestern corn borers, agreed with the calculated thermal unit system for 1st generation egg-to-adult development and 2nd generation larval development through the 4th instar. It is felt that the relative precision of the model will be increased by future studies.

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ACKNOWLEDGMENTS

I express my gratitude to Dr. Fred L. Poston for his many corrective suggestions and criticism of this study and manuscript preparation.

To my guidance committee, Dr. Theodore L. Hopkins and Dr. George A. Milliken, I wish to express my gratitude for reviewing the manuscript and making helpful suggestions.

Acknowledgment is made to Helyn Marshall for patiently typing the manuscript.

I also wish to express my greatest appreciation to Peggy and Amy Whitworth for their support and encouragement.

Financial support and facilities for this study were provided by the Kansas Agricultural Experiment Station through the Department of Entomology, Kansas State University.

GROWTH AND DEVELOPMENT OF THE SOUTHWESTERN CORN BORER
ON CORN (LEPIDOPTERA: PYRALIDAE)

by

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B. A., Kansas Wesleyan University, 1971

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Entomology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1977

Laboratory tests were conducted to establish a developmental model for the southwestern corn borer, Diatraea grandiosella (Dyar) on corn. Insects reared on corn required significantly ($P < 0.05$) longer to develop than those on synthetic diet. Insects reared at 65 and 90°F required ca. 86 and 32 days, respectively, for egg-to-adult development. A thermal-unit accumulation system was established for southwestern corn borer development. An accumulation of 1,321 thermal units was required for egg-to-adult development.