Dispersal and Voltinism Adaptation of the European Corn Borer in North America, 1917-1977

D. F. Palmer
T. C. Schenk
H. C. Chiang

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ABSTRACT

Since its introduction and subsequent colonization in the northeastern United States, the European corn borer (ECB), Ostrinia nubilalis (Hübner), has invaded all of the major corn-growing areas on the eastern half of the continent and has shown a phenomenal adaptation to regional climatic and environmental conditions. The insect has dispersed west to the Rockies, south to the Gulf States, and north into southern Canada.

With adaptation to regional conditions, ecotypes of the ECB have developed the ability to produce increasing numbers of generations per year throughout its range in North America. When the ECB came to this continent it produced one to two generations per year; it now produces up to four generations per year in southern areas.

Over the years, voltinism of the borer has changed in some locations, has differed from location to location, and has varied in the same locale from year to year. These changes, which are due to adaptation to different regional climatic conditions, have resulted in the wide distribution of the insect population. This regional adaptation has often produced heterovoltinism in transition zones.

INTRODUCTION

The ECB was accidentally introduced into North America at the beginning of the 20th century (Sailer 1978). It has become one of the most important pest species of corn, a major crop in the United States. The population dynamics and infestations of the ECB have been studied intensively throughout its history, as researchers sought better control methods. For this reason, there is voluminous information on the ECB in published and unpublished reports throughout North America.

Scientists of North Central Regional Research Project NC-105 have studied the feasibility of introducing a laboratory strain selected for low diapausing frequency (Showers 1981) into a high diapausing area as a population suppression strategy. This strategy is based on the theory that a cross of the introduced population and the natural population would produce offspring with a diapause pattern ill-adapted to local ecological conditions.

This approach involves populations with an artificially altered voltinism. Voltinism is related to the ability of borers to enter diapause, which is a physiological condition of suspended development. It is triggered by the action of one or more male sex-linked genes, which in turn is triggered by reduced daylength and temperature (Showers et al. 1983). To assess its potential for success, a knowledge of the natural changes in voltinism of this insect since its introduction into North America is essential.

This report, which is the result of a survey of literature and documents, summarizes the changes in distribution, voltinism, and regional adaptation of this insect over the past 60 years. A basic knowledge of voltinism of the ECB will help to develop management practices. Different management schedules will be required in different areas, depending on how many generations the ECB produces in an area.

D.F. Palmer is entomologist, Dekalb-Pfizer Genetics, Olivia, Minnesota. T.C. Schenk is junior scientist, Department of Entomology. H. C. Chiang, now retired, was professor, Department of Entomology.

HISTORY OF DISPERSAL

There are numerous reviews and reports on the dispersal of the ECB in North America. In the United States, continuous records are available in the Insect Pest Survey Bulletin (1927-1942, 1945-1952), the Cooperative Economic Insect Report (1952-1975), and the Cooperative Plant Pest Report (1976-1980). These publications collate the records on abundance of the insect; new county records are submitted by each state each year. Other papers on the dispersal of ECB include: Anonymous 1952, 1955; Babcock and Vance 1929; Barker and Vance 1938; Beck and Apple 1961a; Brindley and Dicke 1963; Caffrey 1919, 1925, 1929; Caffrey and Worthley 1922, 1927b; Chiang and Hodson 1959a, 1972; Jackson and Peters 1963; Marlatt 1920; Neiswander 1962; and Worthley and Caffrey 1927. Readers should refer to these papers for more details.

Dispersal of the ECB into the Canadian provinces has been similarly documented and reported in the Canada Agriculture Pest Report (unpublished). Synopses of these reports are published in the Annual Reports of the Entomology Society of Ontario under Insect Outbreaks or Important Pests of the Season in a province for a particular year. A more complete history of the ECB in Canada can be found in other papers (Arnott 1941; Crawford 1929; Hudon 1959; and Wressell 1952, 1954, 1958, 1961).

The dispersal of the ECB over the United States from 1917 to 1977 is shown in figure 1. The maps indicate the approximate areas of known maximum distribution of the ECB in 10-year intervals. As of 1977, the ECB had been found in 40 states in the United States and 9 provinces in Canada. The year in which the ECB was discovered in a state or province is shown in table 1. There may be more than one reference for each location, and they sometimes conflict. For example, the ECB probably arrived in Massachusetts about 1910, but it was not discovered until 1917 by Vinal near Boston, when its populations became sizable and its damage on corn became more noticeable. The ECB probably invaded New York about 1912, but it was not identified until 1919 (Smith 1920). This also was the case in Ontario, where farmers knew of its presence for several years before it was officially identified as the ECB in 1920 (Wressell 1961).

ECOTYPES

In all likelihood, different strains of the ECB from various parts of Europe entered North America. They differed in the number of generations produced, developmental times, and number of hosts attacked (Arbuthnot 1944, 1949; Beck and Apple 1961a; Caffrey and Worthley 1927a; Neiswander 1947, 1962). These differences reflected the different conditions of their various origins in Europe. These strains have since changed considerably as they adapted to North American conditions.

More recently, geographical ecotypes have been identified and found to differ in ecological and physiological characteristics such as responses to photo- and thermoperiods, rates of growth, amount of feeding, and diapause (Apple and Beck 1961; Beck and Apple 1961a; Chiang et al. 1968; Showers et al. 1972; Sparks et al. 1966a, 1966b). Ecotypes also have been found to differ in morphometric characteristics (Kim et al. 1967; Mutuura and Munroe 1970), and characteristics of the appendages have been found to vary more than those of the thorax (Chiang et al. 1970). Studies using pheromones have demonstrated that gradations of two different strains exist that respond to different proportions of Z and E isomers of the sex pheromone in the United States and in Europe. This difference suggests that the ECB in the United States may have come from more than one origin in Europe (Klun and Cooperators 1976). The pheromonal strains also differ in their attractiveness and activity periods (Carde et al. 1975; Oloumi-Sadeghi et al. 1975; Showers et al. 1974).

Ecotypes differing in diapause responses are able to mate and produce offspring possessing characteristics intermediate of the parents (Chiang et al. 1968; Sparks et al. 1966b). The same is true of strains differing in pheromone responses (Liebherr and Roelofs 1975).

Currently, three ecotypes with different diapause responses and voltinism are present in North America: northern, central, and southern, which produce, respectively, one, two, and three-four generations per year (Showers et al. 1975). These ecotypes have shown adaptation to regional environmental conditions to which they have not previously been exposed. This adaptation still continues in the southern region (Sparks and Showers 1975).

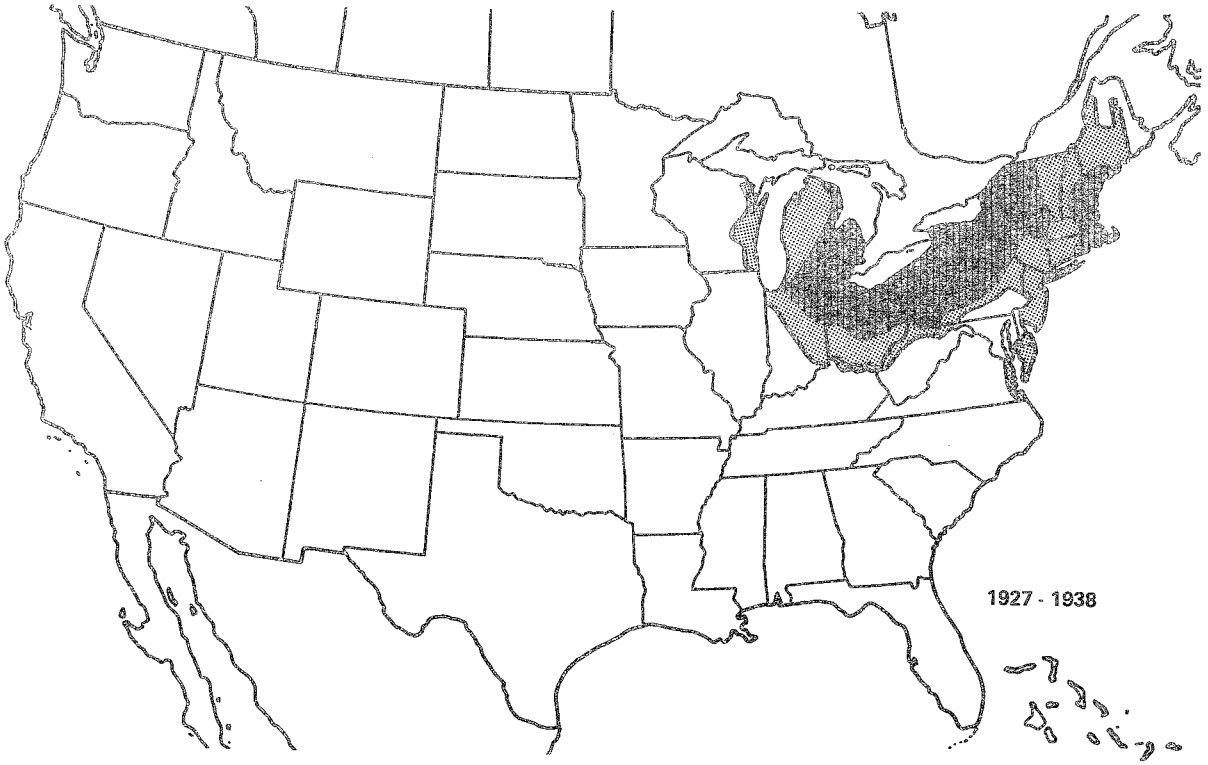
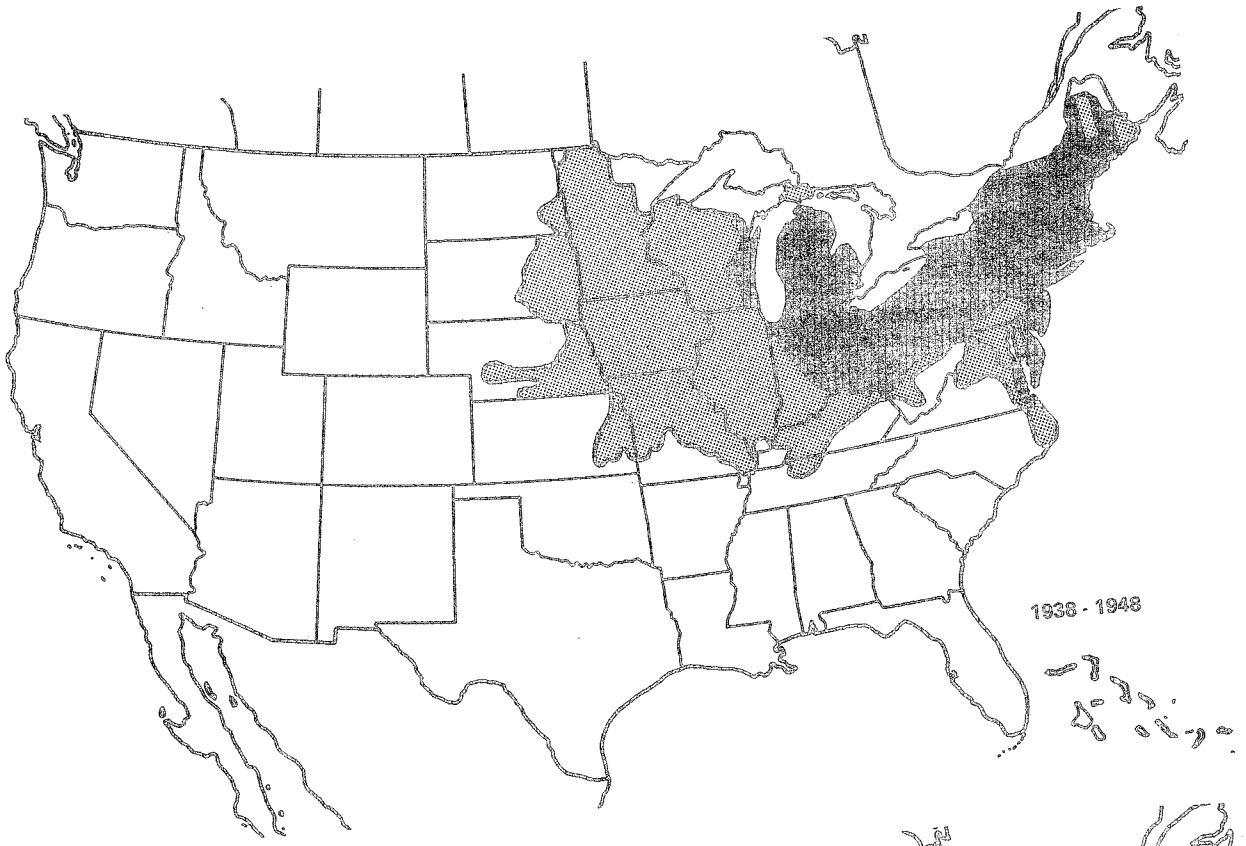
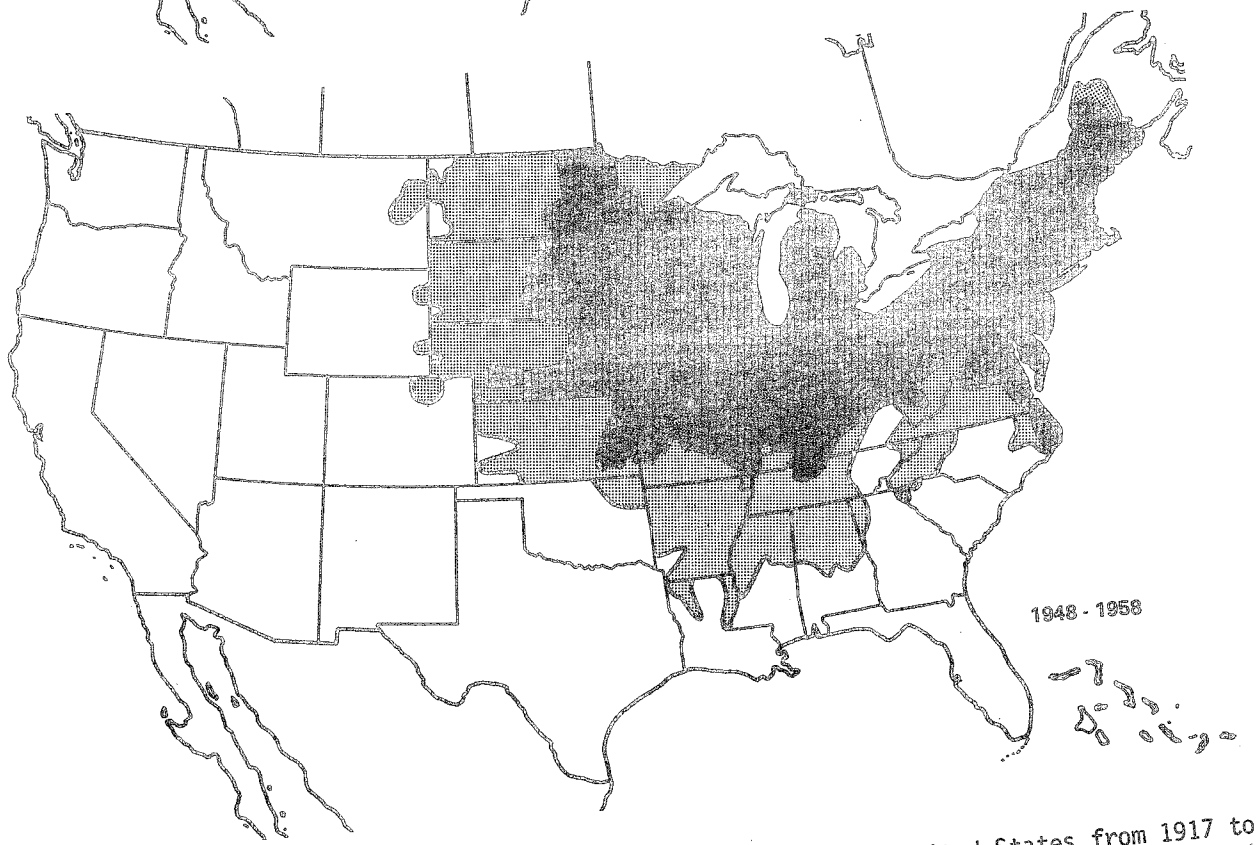


Figure 1. Distribution of the European corn borer in the United States from 1917 to 1977 at approximate 10-year intervals. (Canada was not included due to our inability to procure distribution maps for the years between 1917 and 1977.)





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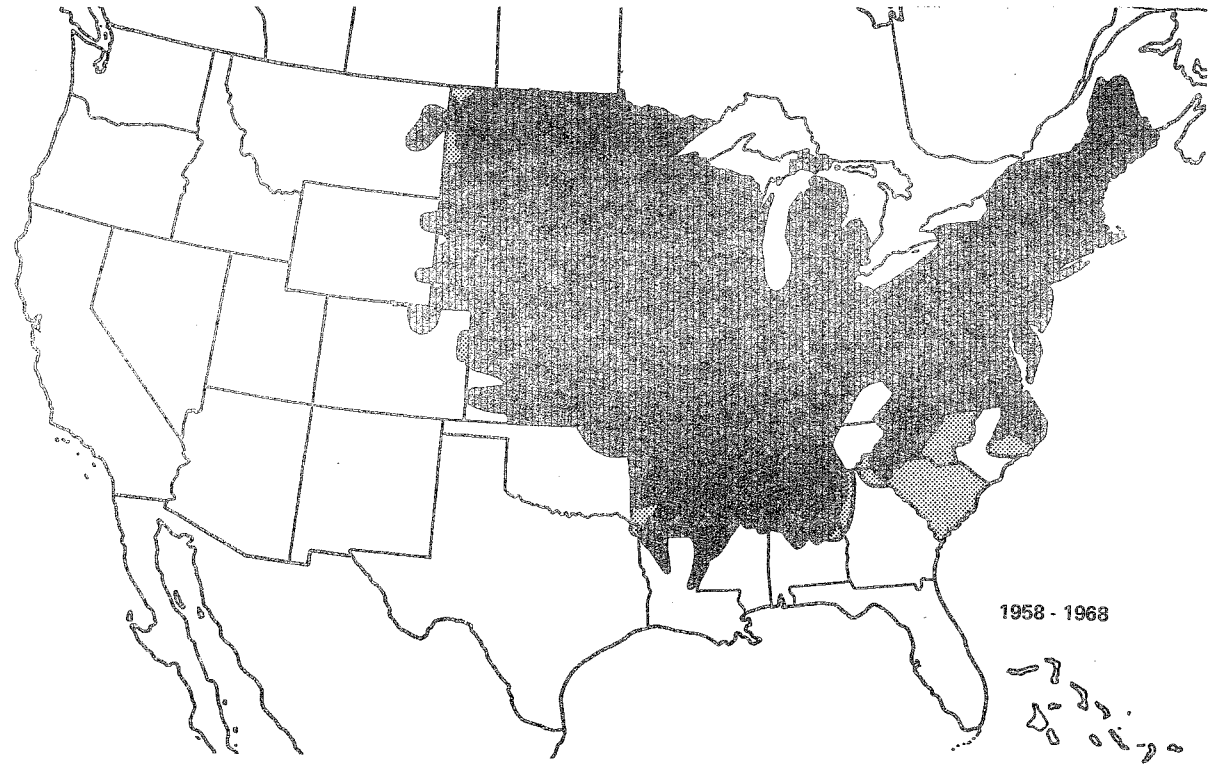

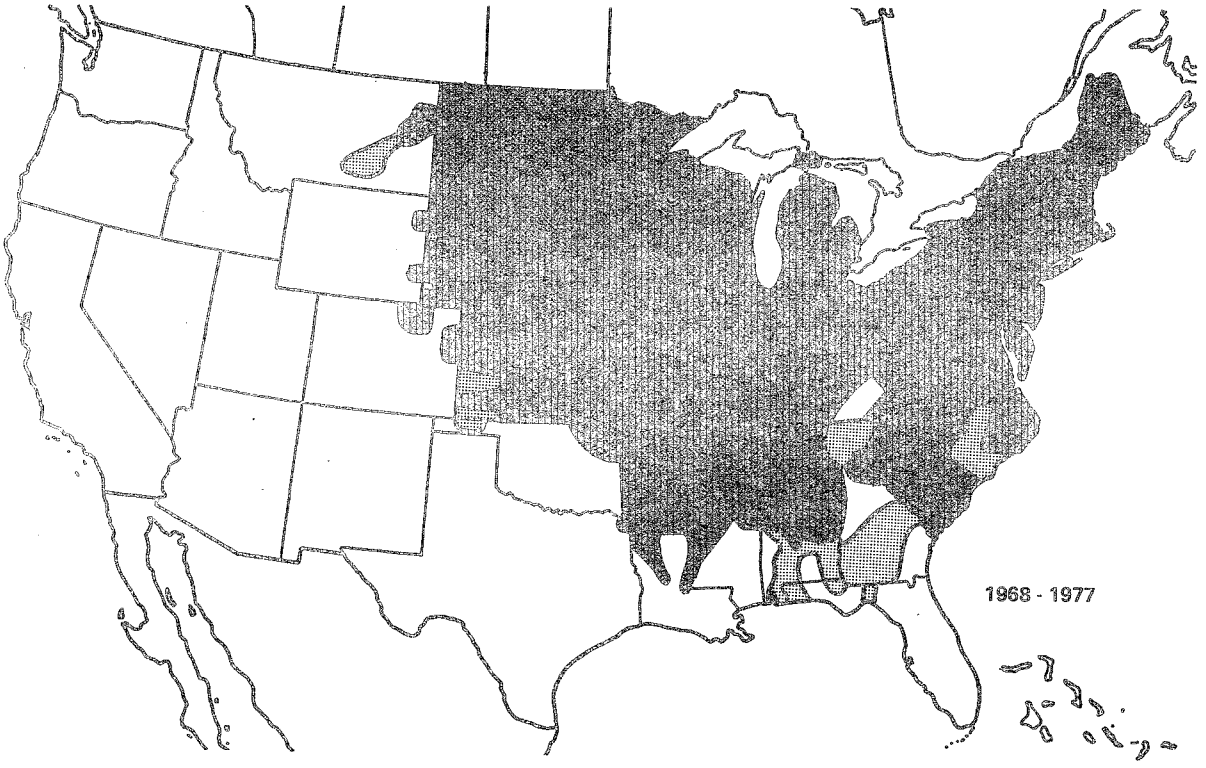

Figure 1 (continued). Distribution of the European corn borer in the United States from 1917 to 1977 at approximate 10-year intervals. (Canada was not included due to our inability to procure distribution maps for the years between 1917 and 1977.)

NUMBER OF GENERATIONS

By using climatographs, Babcock (1924) made the earliest predictions of number of generations. He predicted one generation at Des Moines, Iowa, and one generation at Highmore, South Dakota. Haseman (1938) said the insect would produce a single generation under Missouri conditions, but this prediction was incorrect.

In an extensive report, Arbuthnot (1949) predicted the zones of ECB generations across the United States. He assembled and correlated average yearly temperature and precipitation data from around the world with data on the distribution and known number of generations of the ECB at that time in the United States and other parts of the world. The number of generations increased as annual temperature and length of growing season increased. Some of the generation zones he predicted in the United States have held but others have not. The ECB has dispersed to areas well to the north of where Arbuthnot had predicted it could survive, and in some areas the number of generations is now higher than he predicted. Several more recent papers on this subject point out these differences (Beck and Apple 1961a; Jackson and Peters 1963; McLeod 1976; Showers et al. 1971; Showers et al. 1975; Showers and Reed 1971; Sparks et al. 1966a, 1966b; Sparks and Showers 1975; Wressell 1952).

Information on the number of generations produced by the ECB in North America during its dispersal and adaptation since 1917 are collated and presented in table 1. The table is arranged in the approximate order of the year in which a state or province became infested. Progression down the table shows the spread of the ECB into new areas. There is at least one reference for each number of generations in a year within a state or province.

Type of generation and voltinism as defined by Jackson and Peters (1963) are used in this paper. These definitions are:

A complete generation: generation in which all members complete all stages of development. A population may have one, two, or three complete generations per year. A complete generation is indicated as 1, 2, or 3.

An incomplete generation: generation in which the members do not complete all stages of development. A population may have one complete generation and an incomplete second generation, or two complete generations and an incomplete third generation. An incomplete generation is indicated as 1+ or 2+.

A partial generation: generation in which some individuals complete development and others do not. A population may have one complete generation and a partial second generation, or two complete generations and a partial third generation. A partial generation is indicated as 1-2 or 2-3.

Homovoltine: the developmental pattern whereby members of a population undergo the same number of complete generations.

Heterovoltine: the developmental pattern whereby members of a population undergo an unequal number of generations.

Possible combinations of generations used in Table 1 can be further clarified as follows:

1 : one complete generation/year (homovoltine)

1+ : all individuals go through one complete generation/year and some individuals go through an incomplete second generation (heterovoltine)

1,2: one or two complete generations/year (homovoltine)

1-2: one complete and a partial second generation/year (heterovoltine)

2 : two complete generations/year (homovoltine)

2+ : two complete generations/year and an incomplete third generation (heterovoltine)

2-3: two complete generations/year and a partial third generation (heterovoltine)

2-4: two and three complete generations/year and a partial fourth generation (heterovoltine)

3 : three complete generations/year (homovoltine)

3+ : three complete generations/year and an incomplete fourth generation (heterovoltine)

3-4: three complete generations/year and a partial fourth generation (heterovoltine)

4 : four complete generations/year (homovoltine)

4+ : four complete generations/year and an incomplete fifth generation (heterovoltine)

The ECB is typically heterovoltine in North America, especially between areas separating zones of complete (homovoltine) generations. This heterovoltinism could be due to either a partial generation or an incomplete generation. In central Minnesota, for example, a partial second generation could occur if summer temperatures are so low that some members could not reach diapausing state when frost occurred (Chiang and Hodson 1959b). An incomplete second generation could be due to a very early frost that could kill all members before they reached winter hardiness (Chiang and Hodson 1972). Such occurrences represent exactly the same effect desired in the population-suppressing strategy of releasing a low diapausing strain into a high diapausing area.

Early in the history of the ECB there were two main areas of infestation (See table 1 and figure 1). One was in New England, where the eastern multiple-generation population with one-two generations per year (bivoltine) occurred. The other area is the Lake Erie region, where the western single generation population occurred. During the 1930s, dispersal in the New England area turned southward when the population apparently was stopped first by the Atlantic Ocean along the East Coast and later by the Great lakes. The population along the East Coast began its southern dispersal and adaptation sooner than did the west-central population.

These two populations expanded and eventually intermingled in western New England and eastern New York about 1935. The degree of mixing between these populations is unknown. The dispersal had a northward component when the population passed the southern edge of the Great Lakes. Dispersal north of the Great Lakes probably was limited by patchy, sparse, and unsuitable habitats.

After becoming a contiguous population and after the transition of the one-generation population to two generations in the north-central states, dispersal was primarily westward throughout the Corn Belt and, secondarily, southward. In the 1930s dispersal averaged about 12 miles per year; in the 1940s, it was about 71 miles per year, indicating that the two-generation population dispersed faster than the one-generation population. During the 1940s the dispersal westward was rapid and steady, possibly because the photo- and thermoperiod changes along the same latitude are negligible. Also, the host habitat is vast and nearly continuous throughout the Corn Belt. Therefore, the borer met the least resistance to dispersal and required little adaptation while moving westward. The dispersal south, where the borer was not yet adapted, was slower because of the need to adapt to different photo- and thermoperiods in southern latitudes. It also was erratic because of patchy habitat.

During some periods of ECB adaptation, voltinism of the populations changed. The tendency of the one-generation populations in the eastern Corn Belt and southwestern Ontario to develop two generations in the late thirties and forties is well-documented (see table 1 for references). Possible reasons for this change include climatic change, natural selection or adaptation to regional conditions, and gene flow from the multiple generation area throughout the entire population, which resulted in equilibrium of alleles (Showers 1979). The ECB has developed three generations in the South along the East Coast, and four generations in the areas farthest south (Showers 1979). In the northern areas, the populations appear to have changed from two to one generation per year. As the two-generation populations dispersed north in New England and Minnesota and into Canada, the populations were limited to only one generation by environmental conditions. The phenotypes we now see are the result of genotype by environment interactions and natural selection over many years.

Environmental conditions affected the rate of dispersal and adaptation to the north and south. The northward dispersal involved adaptation of the population to shorter seasons, longer days, and low thermoperiods, which resulted in a gradual decrease in the number of generations, such as the previously mentioned decrease from two to one. The fact that the northward dispersal was faster than the southward dispersal suggests that it was easier to reduce the number of generations than to increase it. The number of generations in a given state or locale also can vary from year to year, depending on weather conditions. In Minnesota, detailed records on the proportion of one and two generations for several decades demonstrate this relation (see table 1) (Chiang and Hodson 1959a, 1959b, 1972, and unpublished data). Seasonal variation in weather affects the voltinism of ECB in a north-south direction. It is especially variable if the location is in a transition zone such as in Minnesota. Weather is the main factor infuencing the transition zones to shift up or down or to vary in width from year to year. Climate and latitude, however, determine the actual limits of the ecotypes that evolve (Babcock 1927).

Transition zones often are created by variation in the phenology of the life cycle of the borer. Eggs laid early in the season can produce larvae that begin the next generation, but eggs laid later produce larvae that diapause (O'Kane and Lowry 1927).

Resistant corn varieties may delay borer development. Because of delayed development, larvae will be exposed to shorter photoperiods, which in turn will reduce voltinism (Chiang 1968). Conversely, susceptible corn varieties may result in increased voltinism (Showers and Reed 1971). This host factor can thus vary larval phenology and the proportion of diapausing individuals in the population.

The current zones of voltinism of the ECB in North America are shown in figure 2. The latest numbers of generations from table 1 have been put on the map and lines separating isoclines of different numbers of generations have been drawn. Gradations between areas of one, two, or three complete generations are the transition zones (clines) of intermediate numbers of partial generations or incomplete generations. Transition zones have been recognized by several researchers (Arbuthnot 1949; Babcock 1927; Beck and Apple 1961b; Beck and Hanec 1960; Chiang et al. 1968; O'Kane and Lowry 1927). These zones generally are the areas between the three ecotypes. Although the southern ecotype contains a transition zone on the map, at present this zone is not the same as the zone between ecotypes, suggesting that it is still in the process of adaptation and may become two distinct ecotypes in the future.

The diapause response shows a cyclic or wave phenomenon over latitude (Showers et al. 1975), and the ECB is more heterovoltine in the south than in the north. Climatic, topographic, biotic, artificial, and actively moving fringe populations have been described by Chiang (1961). He has shown that there are as many types of fringe populations as there are barriers delimiting the population of a species. The ECB populations reviewed here have exhibited all types of fringe populations through their dispersal and adaptation in North America. The result suggests that several ecotypes have evolved in response to regional conditions and that voltinism of the ecotypes varies as a function of environmental gradients interacting with genotypes of the different populations within the range and distribution of the ECB.

More detailed studies on population genetics are needed to fully understand the mechanism involved in voltinism adaptation in this species.

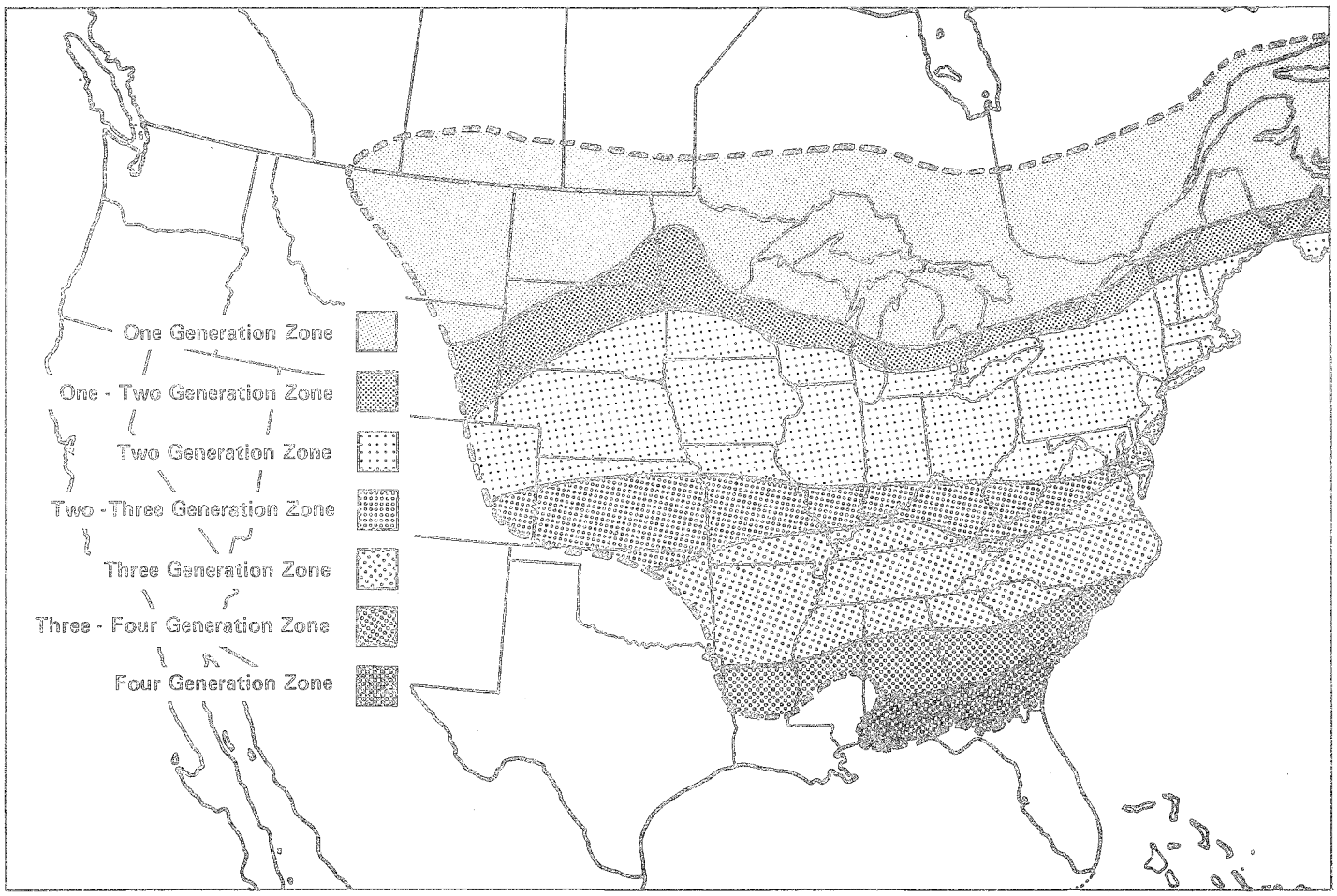

Figure 2. Approximate areas of current generation zones of the European corn borer in the United States and Canada. Distribution in Canada, which is approximate, is based on information by Hudon et al. (1982). The broken line represents the outer limit of distibution.

Table 1. Number of generations of the European corn borer found in the United States since the discovery of the insect in North America in 1917.*

Year of Discovery	State	Year								
		1917	1918	1919	1920	1921	1922	1923	1924	1925
1917 233	MA	F2 230	2-3 2	2 231	2 69	2-3 87	1-2 88	1-2 58	1-2 58	2 192
1919 157	NH			F 157	1-2 87	1-2 58	1-2 58	1+ 179	1+ 179	1+ 179
1920-21 110	ME				F1-2 87	1-2 58	1-2 58	1-2 58	1-2 58	2 192
1920-21 110	RI				F1-2 87	2-3 87	1-2 88	1-2 88	1-2 88	2 192
1923 77	CT							F 77	1-2 77	2 192
1923 110	VT							F 110	1-2 88	2 88
1919 235	NY			F1 87	1+ 119	1-2 88	1-2 120	1,2 88	1 58	1,2 88
1919 129	PA			F 129	1 88	1-2 87	1 88	1 88	1 88	1 192
1921 182	OH					F1-2 87	1 177	1 177	1 177	1 177
1921 167	MI					F1-2 87	1 116	1 116	1 116	1 116
1926 106	NJ									
1926 86	IN									
1926 235	WV									
1930 110	KY									
1931 94	WI									
1931 155	VA									
1932 110	MD									
1934 110	DE									
1939 15	IL									
1939 15	NC									
1942 131	IA									
1942 69	MO									
1943 1	MN									
1944 217	NB									
1944 69	TN									
1944 69	KS									
1946 62	SD									
1946 174	ND									
1950 74	AR									
1950 74	OK									
1950 69	CO									
1950 66	AL									
1950 74	MS									
1950 23	GA									
1950 74	SC									
1951 67	MT									
1953 196	WY									
1957 125	LA									
1959 29	TX									
1974 46	FL									

* Light type indicates references. Footnotes a, b, c, etc., indicate personal correspondence. In many instances, more than one reference was found for a given state, year, and generation; only the reference that appeared to be the most accurate was used. F indicates the first record for the state. ME, RI, CT, and VT are out of sequence because several references refer to New England specifically as a separate population.

Table 1 (continued). Number of generations of the European corn borer found in the United States since the discovery of the insect in North America in 1917.*

State	Year										
	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936
MA	2 192	2 237	2 79	2 135	2 236	2 90	2 91	2 220	2 10	2 220	
NH	1+179	2 237			2 6		2 91	2 220	2 220	2 220	2 221
ME	2 192	2 237	2 85		2 6	2 90	2 91	2 220	2 220	2 220	2 221
RI	2 192	2 237	2 243	2 135	2 6	2 90	2 91	2 220	2 10	2 220	
CT	2 192	2 237	1-2 79	2 135	2 236	2 90	2 91	2 220	2 76	2 220	2 221
VT	2 88	2 237	2 85		2 6		2 91	1 220	1 220	1 220	1 221
NY	1,2 88	1,2 112	1,2 136	1,2 136	1,2 136	1,2 136	1,2 8	1,2 220	1,2 10	1,2 220	1-2 195
PA	1 192	1 237		1 135		1 90	1 91	1 220	1 220	1 220	
OH	1 177	1-2 69	1 177	1 177	1-2 158	1 177	1 177	1 177	1 177	1 177	1-2 176
MI	1 192	1-2 69	1 116	1 116	1-2 73	1 116	1 8	1 116	1 10	1 220	1-2 222
NJ	F 86			2 135		2 90	1-2 91	2 220	2 171	1-2 185	1,2 186
IN	F1 192	1-2 69	1 111	1 111	1 111	1 111	1 111	1 111	1+ 121	1+ 121	1-2 122
WV	F1 235	1 237		1 135	1 236				1 171		
KY					F 110				1 171		
WI						F1 69	1 116	1 116	1 116	1 116	
VA						F2 52	2 220	2 220	2 171	2-3 220	2-3 232
MD							F 110	2 220	2-3 232	2 220	
DE									F 110		
IL											
NC											
IA											
MO											
MN											
NB											
TN											
KS											
SD											
ND											
AR											
OK											
CO											
AL											
MS											
GA											
SC											
MT											
WY											
LA											
TX											
FL											

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Table 1 (continued). Number of generations of the European corn borer found in the United States since the discovery of the insect in North America in 1917.*

State	Year										
	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947
MA			2 15	2 224	2 225			2 17		2 19	2 20
NH			2 15								
ME			2 15		1 225			1 17			1-2 20
RI			2 15								
CT	2+ 227	2 80	2 15	1-2 61	1-2 225	2 219	2 219	2 17	2 219		
VT			1-2 15								
NY	1-2 51	1-2 51	1-2 15	1-2 51	2 114	2 114	2 114	2 17	2 114	2 114	2 114
PA	1-2 51	1-2 51	1-2 15	1-2 51			2 17			2 19	
OH	1-2 176	1-2 51	1-2 51	1-2 51	1-2 177	1-2 177	1-2 177	1-2 177	2 178	2 178	2 178
MI	1-2 222	1-2 51	1-2 15	1-2 51							
NJ	1,2 186	2+ 106	2-3 15					2+ 17	1-2 18	2 19	2 20
IN	1-2 122	1-2 122	1 2 15	1-2 123	1-2 225		1 145	2 184		2 19	2 20
WV											
KY								2+190	2 190	2 190	2+ 20
WI	1-2 51	1-2 51	1-2 15	1-2 51	1-2 225	1-2 16	2 16		2 18	2 19	2 20
VA	2-3 155	2-3 155	3 199				2 154				
MD					2 225			2+ 17			
DE			2 213	2 213			2 16	2 17			
IL			F1-2 69		2 225	2 146	2 145	1-2 93	2 18	2 48	2 48
NC			F 15								
IA						F2 131	2 16	1-2 93	2 18	2 19	2 20
MO						F 69	2 16	1-2 93			2 20
MN							F1-2 173				1-2 20
NB								F 69			
TN								F 69			
KS								F 69			
SD										F 26	
ND										F1 174	1 174
AR											
OK											
CO											
AL											
MS											
GA											
SC											
MT											
WY											
LA											
TX											
FL											

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Table 1 (continued). Number of generations of the European corn borer found in the United States since the discovery of the insect in North America in 1917.*

State	Year										
	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
MA		2 22		2 24	2 25						
NH											
ME	1-2 134	1-2 133	1-2 133	1-2 133							
RI		2 22									
CT		2 59									
VT											
NY	2 114	2 114	2 114	2 114	2 114	2 114	2 114	2 114	2 114	2 114	2 114
PA											
OH	2 178	2 178	2 178	2 178	2 178	2 178	2 178	2 178	2 178	2 178	2 178
MI		1-2 22									
NJ	2 21	2 22			2 25					2 170	
IN	1-2 21	2 22			2 25						1-2 71
WV											
KY	2-3 21	2-3 22			2 25						
WI		2 25	2 25	2 25	2 25					1-2 71	1-2 71
VA											
MD	2+ 21		2 23	1-2 24							
DE				2 25							
IL	2 48	2+ 147	2 23	1-2 24	2+ 25						
NC											
IA	1-2 21	2 22	2 152	2 152	2 152	2 152	2 152	2 152	2 152	2 152	2 210
MO	2 21	2 23	2 24						3 81	2-3 187	2-3 151
MN	1-2 173	2 100	2 100	2 100	2 100	2 116	2 100	2 99	2 99	1-2 95	1-2 99
NB				2 24	2 25						
TN					2-3 212	2-3 212					
KS		2 105	2 183		2+ 25						
SD	1-2 20										
ND	1 174	1-2 174			2 25						
AR			F 74								
OK			F 74								
CO			F 69								
AL			F 66						3 199	3 115	3 115
MS			F 74								
GA			F 23								
SC			F 74								
MT				F 67							
WY						F 196					
LA										F 125	
TX											
FL											

* Light type indicates references. Footnotes a, b, c, etc., indicate personal correspondence. In many instances, more than one reference was found for a given state, year, and generation; only the reference that appeared to be the most accurate was used. F indicates the first record for the state. ME, RI, CT, and VT are out of sequence because several references refer to New England specifically as a separate population.

Table 1 (continued). Number of generations of the European corn borer found in the United States since the discovery of the insect in North America in 1917.*

State	Year										
	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
MA											
NH											
ME											
RI											
CT											
VT											
NY	2 114	2 114	2 114	2 114	2 114	2 114	2 114	2 114	2 114		
PA											
OH	2 178	2 178	2 210	2 210						2 203	2 203
MI											
NJ											
IN											
WV											
KY											
WI		1-2 107	1-2 107	1-2 107	1-2 107	1-2 107	1-2 107	1-2 107	1-2 107	1-2 107	1-2 107
VA	3 139										
MD										2-3 203	2-3 203
DE											
IL	1-2 71										
NC											
IA	2 210	2 210	2 210	2 210	2 180	2 180	2 138	2 138	2 138	2 138	2 138
MO	2-3 103	2-3 156	2-3 156	2-3 156	3 156	3+ 208	2 138	2 138	2 138	3-4 203	3-4 203
MN	1-2 99	1-2 99	1-2 99	1-2 99	2 99	1-2 99	2 138	2 138	1 99	1 99	1 99
NB							2 138	2 138	2 138	2 138	2 138
TN											
KS											
SD											
ND					1 124	1+ 124	1 124	1 124	1 124		
AR									2-3 c		
OK											
CO											
AL	3 115				3 75				3 201	3-4 203	3-4 203
MS									3 201		
GA									3 201	3-4 203	3-4 203
SC									3 113	3-4 113	4 199
MT											
WY											
LA									3 201		
TX	F 29										
FL											

* Light type indicates references. Footnotes a, b, c, etc., indicate personal correspondence. In many instances, more than one reference was found for a given state, year, and generation; only the reference that appeared to be the most accurate was used. F indicates the first record for the state. ME, RI, CT, and VT are out of sequence because several references refer to New England specifically as a separate population.

Table 1 (continued). Number of generations of the European corn borer found in the United States since the discovery of the insect in North America in 1917.*

State	Year									To Date (1982)
	1970	1971	1972	1973	1974	1975	1976	1977	1978	
MA										2
NH										1-2
ME										1-2
RI										2
CT										2
VT										1-2
NY	2 191			2 216	2 216	2 216				1-2
PA					2 160		2 g			2
OH	2 203	2 128		2 160				2 181	2 j	2
MI		2 109	2 h	2 h		2 h			2 j	2
NJ					2 160					2+
IN	2+ 117	2 128		2 193				2 181		2+
WV										-
KY		2 a	2 a	2 a	2 a	2 a			2 j	2-3
WI	2+ 49		1-2 i	1-2 i	1-2 i	1-2 i			2 j	1-2
VA										2-3
MD	2-3 203									2
DE										2
IL	2 c	2 128	2 c	2 c	2 c	2-3 c		2 181		2-3
NC					3 f	3 f				3
IA	3 138	2 128		2 160	2 160			2 181		2+
MO	3-4 203	2 128			2 160			2 181		3
MN	2 99	2 128		2 160	2 160	2 e		2 181	2 j	1-2
NB	2 137	2 128			2 160			2 181		2
TN		2 d	2 d	2 d						3
KS		2 128			2 193			2 181		2
SD	1-2 l	1-2 l	1-2 l	1-2 l	1-2 l	1-2 l				1-2
ND	1+ k	1+ k	1+ k	1+ k	1+ k	1+ k				1-2
AR						2-3 b				2-3
OK										-
CO										-
AL	3-4 203									3
MS										3
GA	3-4 203			3 160		3-4 207				3-4
SC										3-4
MT										-
WY										-
LA										3
TX										-
FL				F 46						-

* Light type indicates references. Footnotes a, b, c, etc., indicate personal correspondence. In many instances, more than one reference was found for a given state, year, and generation; only the reference that appeared to be the most accurate was used. F indicates the first record for the state. ME, RI, CT, and VT are out of sequence because several references refer to New England specifically as a separate population.

Table 1 (continued). Number of generations of the European corn borer found in the provinces of Canada since the discovery of the insect in North America in 1917.*

Year of Discovery	Province	Year 1917	1918	1919	1920	1921	1922	1923	1924	1925
1920 241	**ON**				F 168	1+ 53	1 211	1 215	1 215	1 192
1926 142	**QU**									
1928 127	**NB**									
1945 240	Rediscovered in **NB**									
1929 126	**NS**									
1949 165	**MN**									
1949 239	**SS**									
1949 165	**PEI**									
1956 130	**AL**									

Province	Year 1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936
ON	1 192	1 214	1 214	1 215	1 216	1-2 82	1-2 53	1-2 53	1-2 53	1-2 53	1-2 53
QU	F1 143	1 143	1 143	1 143	1 143	1 143	1 143	1 143	1 143	1 143	1 143
NB			F2 188	2 240							
NS				F2 240							
MN											
SS											
PEI											
AL											

Province	Year 1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947
ON	1-2 53	1-2 53	1-2 53	1-2 53	1-2 53	1-2 60	1-2 60	1-2 218	1-2 242	1-2 242	1-2 242
QU	1 143	1 143	1 143	1 143	1 143	1 143	1-2 16	1 143	1 143	1 143	1 143
NB									RD 188		
NS											
MN											
SS											
PEI											
AL											

* Light type indicates references. In many instances, more than one reference was found for a given province, year, and generation; only the reference that appeared to be the most accurate was used. F indicates the first record for the province.

Table 1 (continued). Number of generations of the European corn borer in the provinces of Canada since the discovery of the insect in North America in 1917.*

Province	Year 1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
ON	1-2 242	1-2 242	1-2 242	1-2 242	1-2 242	1-2 242	1-2 242	1-2 242	1-2 242	1-2 242	1-2 242
QU	1 143	1 143	1 143	1 143	1 143	1+ 239	1 143	1 143	1 143	1 163	1 163
NB											
NS						1 239					
MN		F2 205						1+ 72			
SS		F 239									
PEI		F 165									
AL									F 130		

Province	Year 1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
ON	1-2 242	1-2 242	1-2 242	1-2 242	1-2 242	1-2 242	1-2 242	1-2 242	1-2 242	1-2 242	
QU	1 141	1 163	1 163	1 163	1 143	1 143	1 143	1 142		1 203	1 203
NB											
NS											
MN											
SS											
PEI											
AL											

Province	Year 1970	1971	1972	1973	1974	To Date (1982)
ON		1-2 169	1-2 169	1-2 169	1-2 169	1-2
QU	1 203			1 104		1
NB						1
NS						1
MN						1+
SS						-
PEI						1
AL						-

* Light type indicates references. In many instances, more than one reference was found for a given province, year, and generation; only the reference that appeared to be the most accurate was used. F indicates the first record for the province.

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* Asterisks denote references not used in the text or tables but for preparing the distribution maps.

PERSONAL CORRESPONDENCE

a) Douglas E. Barnett
Extension Survey Entomologist
University of Kentucky
College of Agriculture
Lexington, Kentucky 40506

b) W. P. Boyer
Extension Survey Entomologist
Cooperative Extension Service
University of Arkansas
Fayetteville, Arkansas 72701

c) Tim A. Cooley
Survey Entomologist
Illinois Natural History Survey
169 Natural Resources Building
Urbana, Illinois 60801

d) Chester Gordon
Department of Agriculture
Ellington Agricultural Center
Box 40627 Melrose Station
Nashville, Tennessee 37204

e) Bert Hoger
Crop Pest Control
Division of Plant Industry
Department of Agriculture
State Office Building
St. Paul, Minnesota 55155

f) Thomas N. Hunt
Survey Entomologist
North Carolina State University
Entomology Box 5215
Raleigh, North Carolina 27607

g) Ke Chung Kim
State Survey Coordinator and Entomologist
Pennsylvania State University
106 Patterson Building
University Park, Pennsylvania 16802

h) Jim Liebherr
Cooperative Extension Service
Michigan State University
East Lansing, Michigan 48824

i) Orville L. Lovett
Survey Entomologist
Plant Industry Division
Department of Agriculture
State of Wisconsin
801 West Badger Road
Madison, Wisconsin 53712

j) Minutes for NC-105 1978 Work Year for North Central States Regional Technical Committee, "Genetics and Ecology of European corn borer." January 9-10, 1979, Des Moines, Iowa

k) Cal Scholl
Assistant State Entomologist
State of North Dakota
Department of Agriculture
Bismark, North Dakota 58501

l) David D. Walgenbach
Professor
College of Agriculture and Biological Sciences
South Dakota State University
Brookings, South Dakota 57006

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