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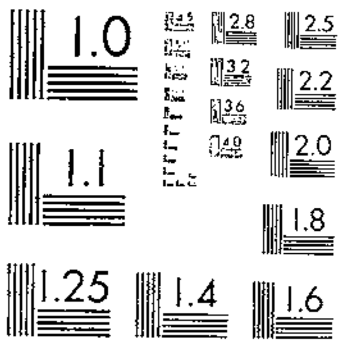

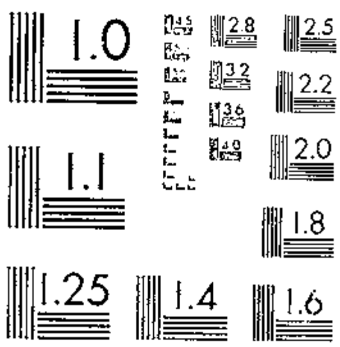

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THE EUROPEAN CORN BORER AND ITS CONTROLLING FACTORS IN THE ORIENT

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HISTORY AND SCOPE OF CORN-BORER PARASITE INVESTIGATIONS IN THE ORIENT[3]

Investigations of parasites of the European corn borer, *Pyrausta nubilalis* (Hbn.), in the Orient were begun in the spring of 1928, when W. B. Cartwright was sent to Japan by the Bureau of Entomology of the United States Department of Agriculture. Corn-borer damage

[1] The writer wishes to express his appreciation of the aid received from D. J. Caffrey, in charge of corn-borer research in the United States, in the preparation of the manuscript. K. W. Babcock, of the Toledo, Ohio, corn-borer laboratory, made many helpful suggestions and his assistance with the preparation of the section on Climate Type and Its Relation to the Number of Generations Annually is gratefully acknowledged. The writer is indebted to Philip Luginbill, of the Monroe, Mich., corn-borer laboratory for assistance in connection with the illustrations. The general outline of this bulletin is similar to that previously used by Thompson and Parker (*12*).[2]

[2] Italic numbers in parentheses refer to Literature Cited, p. 36.

[3] *Official cooperation and contacts.*—Throughout the period during which investigations were conducted in the Orient the Bureau of Entomology of the U.S. Department of Agriculture received the whole-hearted cooperation of many Japanese entomologists, agronomists, and others engaged in studies of the various phases of agriculture. Space does not permit mention by name of all of those with whom contact was made, but it is a pleasure to mention here a number of those who granted many favors. The late I. Kuwana, then in charge of the entomological investigations of the Imperial Government of Japan, was constantly accessible and contributed in many ways to the successful conduct of these investigations. C. Akiyama,

had been recorded in Japanese literature for at least 30 years prior to that time, and some adult specimens of *P. nubilalis* collected in Japan had been received at the Arlington, Mass., laboratory from T. R. Gardner, who was then located in Japan.

During the first 18 months of his stay in the Orient Mr. Cartwright was engaged largely in making official contacts with Japanese entomologists and in travel to investigate the distribution of *P. nubilalis* and the distribution and relative abundance of the parasites of this insect that were discovered. During this period he and his assistants investigated conditions relative to the corn borer in the Japanese archipelago, including southern Hokkaido, Honshu, Shikoku, and Kyushu Islands; and in Taiwan (March 1929), Chosen (Korea), and Manchuria (June and July 1929). In March 1930 Mr. Cartwright visited the Okinawa (Loo Chu or Ryu Kyu) Islands but found no *P. nubilalis*. Mr. Cartwright was in charge of all corn-borer investigations conducted in the Orient by the Bureau of Entomology from the time of his arrival in the spring of 1928 until he returned to the United States in August 1930.[4] During this period of approximately 2 years and 3 months, 572,269 corn-borer larvae containing 5 important species (*Lydella grisescens*, *Cremastus flavoorbitalis*, *Macrocentrus gifuensis*, *Inareolata punctoria*, and *Nemorilla floralis*) of parasites, and 873 adults and cocoons of 6 species (*Microgaster tibialis*, *Eulimneria alkae*, *Cremastus flavoorbitalis*, *Phaeogenes* sp., *Inareolata punctoria*, and *Brachymeria euploeae*) of parasites, including four species not contained in the host larvae, were shipped to the United States.

The writer was sent to Japan in September 1929 and was associated with Mr. Cartwright until his departure for the United States. The writer was in charge of corn-borer investigations in the Orient from September 1, 1930, until the conclusion of the investigations in that area in June 1932. During this latter period much more emphasis was placed on the collection and shipment of parasite material than had previously been possible, with the result that 2,018,875 corn-borer larvae containing 8 species of parasites, and 19,232 parasites in the cocoon or adult stages were shipped to the United States (tables 6 and 7). The increased size of these shipments over those of previous years was made possible by the exploratory investigations previously

in charge of plant-quarantine inspection work at Kobe, kindly offered the use of a large laboratory and office room in the Kobe Plant Quarantine Station and Custom Inspection House from the inception of these investigations until March 1931, when the room was needed for use as a honeybee-inspection laboratory. Mr. Akiyama also made his library available at any time. During the period when studies were being made in Kyushu Island, the men at the Kumamoto Agricultural Experiment Station were of very great assistance. S. Tanji is the director of this experiment station, Y. Koba is the entomologist, and T. Fujimoto is the station agronomist. These three men were always eager to assist in any way possible. During the spring and summer of 1928 a room at the experiment station was made available for corn-borer parasite investigations. In the spring of 1931, and again in 1932, Mr. Fujimoto arranged for the planting and care of a number of fields of hemp for use in connection with corn-borer investigations. Through the kind efforts of G. Okajima a laboratory room at the Imperial College of Agriculture at Kagoshima was made available for the summer of 1931. Mr. Okajima also accompanied the writer on a trip in southern Kagoshima Prefecture. Both he and H. Murata, of the Imperial College of Agriculture, gave valuable aid on a number of occasions. N. Takahashi, director of the agricultural experiment station at Shariin, Chosen, graciously supplied the use of a room at his experiment station during October and November of 1929. Mr. Takahashi and M. Eguchi, the station entomologist, gave all possible assistance on numerous occasions. A. Hamma, director of the experiment station at Lung Ching Tsun, Manchuria, aided materially in the investigations. M. Yanagiwara, an entomologist of the sugarcane experiment station at Shinkwa, Taiwan (Formosa), spent many days assisting in corn-borer studies in southern Taiwan during 1929, 1930, and 1931. Knowledge acquired of the corn borer and its parasites in this region resulted largely from studies conducted or directed by this entomologist. During April and May 1932 he accompanied the writer on an investigational trip and thus enabled him to secure live parasites for introduction into the United States. Finally, grateful acknowledgment is made of the assistance rendered by M. Yoshikawa, Y. Goto, and M. Suzuki, Japanese interpreters and assistants, whose industry and faithfulness contributed largely to the successful conduct of these investigations.

[4] For more detailed information concerning this earlier period, see Cartwright (5).

conducted by Mr. Cartwright. In addition to the foregoing shipments, 12,000 corn-borer larvae, containing the important parasites *Lydella grisescens* R. D. and *Cremastus flavoorbitalis* (Cameron), were shipped to the island of Guam on December 7, 1930. Seventy-seven adults of two species (*Xanthopimpla stemmator* (Thunberg) and *Trichomma cnaphalocrocis* Uchida) of parasites of the borer pupa were successfully brought by the writer to the United States from Taiwan in June 1932.

GEOGRAPHICAL BOUNDARIES, CLIMATE, AND AGRICULTURE OF THE SECTIONS STUDIED

For convenience of reference the areas studied have been designated as sections, each of which is different from any other in some way, either in climate, crops, number of generations of the corn borer, parasites found, or in some combination of these features. These sections, shown on the accompanying maps (figs. 1, 2, and 3), are as follows: In Japan, Kutchan section on Hokkaido Island, Utsunomiya and Hiroshima sections on Honshu Island, Tokushima section on Shikoku Island, Kumamoto, Kokubu, Miyakonojo, and Aso sections on Kyushu Island; in Chosen (Korea), Heijo and Kanko sections; in Manchuria, Chientao section; and in Taiwan (Formosa), Tainan section.

Climatological data for the foregoing sections are given in table 1 and climographs for each are given in figures 4 and 5. Records for Sapporo, Kagoshima, Miyazaki, Lung Ching Tsun, and Genzan are given for Kutchan, Kokubu, Miyakonojo, Chientao, and Kanko sections, respectively, since they were the only records available and are believed to be fairly representative.

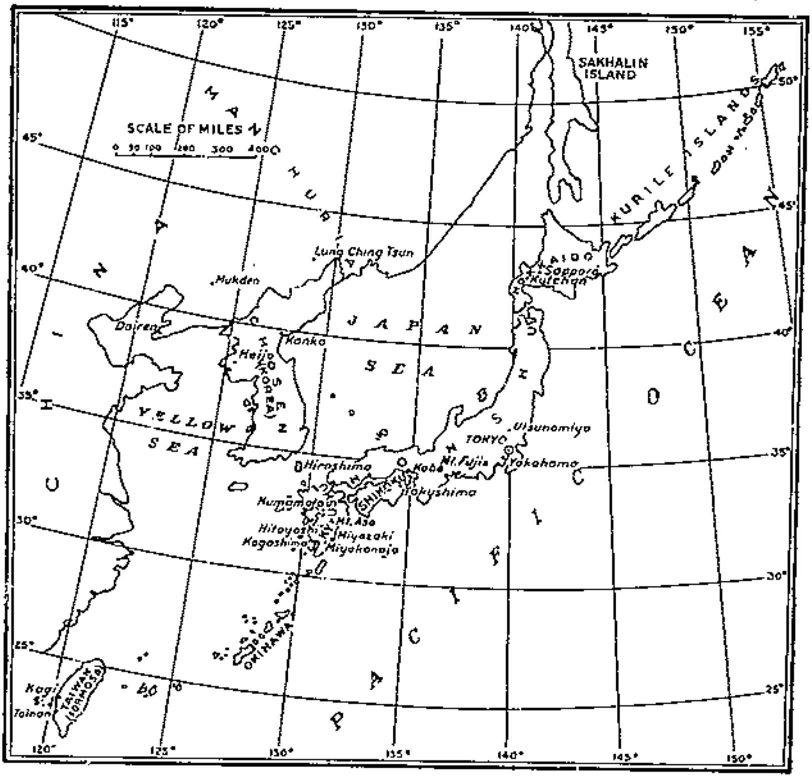

FIGURE 1.—Sketch map showing countries of the Orient in which corn-borer investigations were conducted, 1928-32.

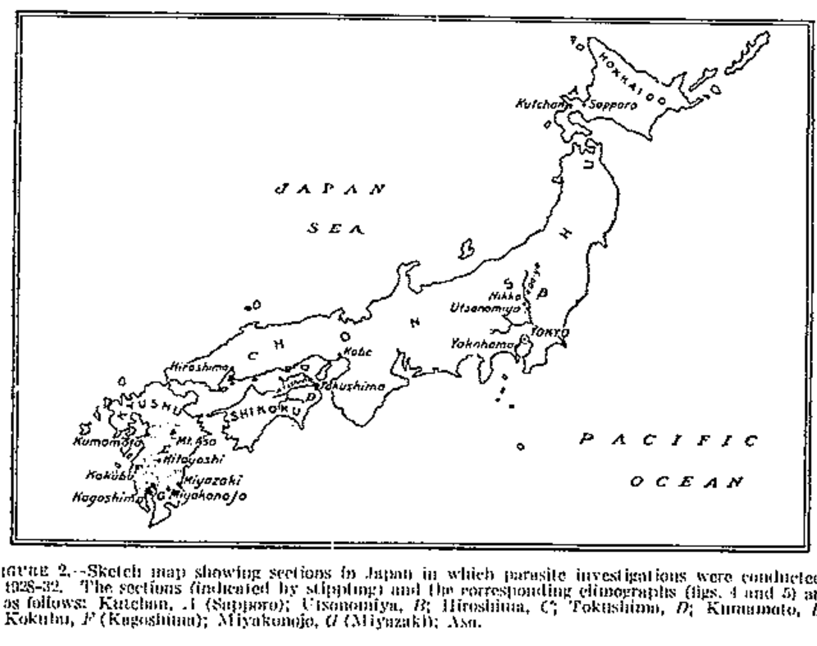

FIGURE 2.—Sketch map showing sections in Japan in which parasite investigations were conducted, 1928-32. The sections (indicated by stippling) and the corresponding climographs (figs. 4 and 5) are as follows: Kutchan, *A* (Sapporo); Utsonomiya, *B*; Hiroshima, *C*; Tokushima, *D*; Kumamoto, *E*; Kokubu, *F* (Kagoshima); Miyakonojo, *G* (Miyazaki); Aso.

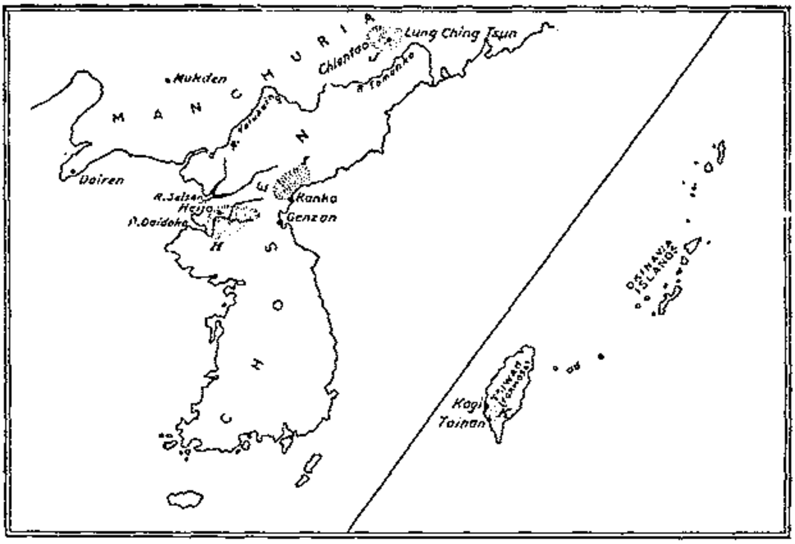

FIGURE 3.—Sketch map showing sections in Manchuria, Chosen, and Taiwan in which parasite investigations were conducted, 1928-32. The sections (indicated by stippling) and the corresponding climographs (fig. 5) are as follows: Heijo, *H*; Kanko, *I* (Genzan); Chientao, *J* (Lung Ching Tsun); Tainan, *K*.

TABLE 1.—*Mean temperatures and precipitation in 11 corn-borer sections in the Orient, also in 1 additional locality in Japan, and 1 locality in the United States* [1]

MEAN TEMPERATURES

Section or locality	Climograph [2]	Years of record	January	February	March	April	May	June	July	August	September	October	November	December	Average
		Number	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
Kutchan	*A*	38	20	22	29	42	51	59	66	69	61	49	37	26	44.25
Utsunomiya	*B*	33	33	35	41	52	60	67	74	76	69	58	47	37	54.08
Hiroshima	*C*		39	40	45	55	63	71	78	80	73	62	52	43	58.42
Kobe		27	40	40	45	56	64	70	78	80	79	63	53	44	59.33
Tokushima	*D*	32	41	41	46	57	64	71	78	80	74	64	54	45	59.58
Kumamoto	*E*	33	40	42	48	58	65	72	79	81	74	63	53	43	59.83
Kokubu	*F*	38	45	46	51	60	66	72	79	80	76	66	57	48	62.17
Miyakonojo	*G*	38	44	46	52	60	66	73	79	80	75	65	56	47	61.92
Heijo	*H*	16	17	23	34	49	60	69	75	76	66	53	37	22	48.42
Kanko	*I*	19	26	28	36	49	58	67	73	74	66	58	42	30	50.42
Chientao	*J*		6	12	27	45	57	67	73	72	61	47	27	12	42.17
Tainan	*K*	27	63	62	67	74	79	81	82	81	80	76	71	65	73.42
Bradenton, Fla			61	62	66	70	76	80	81	81	80	75	67	61	71.67

[1] The data for the places in the Orient, except Chientao, were obtained from the Central Meteorological Observatory, Tokyo.

[2] See figs. 4 and 5.

TABLE 1.—*Mean temperatures and precipitation in 11 corn-borer sections in the Orient, also in 1 additional locality in Japan, and 1 locality in the United States*—Continued

PRECIPITATION

Section or locality	Climograph [7]	Years of record	January	February	March	April	May	June	July	August	September	October	November	December	Average	Total
		Number	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Kutchan	*A*	38	3.3	2.5	2.4	2.2	2.6	2.6	3.4	3.9	5.2	4.1	4.3	3.9	3.36	40.3
Utsunomiya	*B*	33	1.4	2.4	3.7	4.8	6.1	7.6	8.6	8.9	9.5	5.4	2.7	1.5	5.22	62.6
Hiroshima	*C*	-----	2.0	2.5	4.3	6.6	6.1	9.6	8.7	4.1	7.8	4.0	2.6	2.1	5.03	60.4
Kobe	----	27	1.9	2.2	3.6	5.0	4.9	8.2	6.0	4.6	7.7	4.9	2.6	1.9	4.46	53.5
Tokushima	*D*	32	1.9	2.6	3.9	4.9	6.6	7.8	8.0	7.7	12.8	7.6	3.5	2.2	5.74	68.9
Kumamoto	*E*	33	2.4	2.8	5.0	6.3	6.5	13.7	11.5	6.3	6.6	4.3	2.7	2.2	5.86	70.3
Kokubu	*F*	38	3.3	3.9	6.1	8.7	8.5	15.9	11.4	7.2	7.9	5.2	3.7	3.4	7.10	85.2
Miyakonojo	*G*	38	2.8	4.1	7.3	9.2	10.0	15.2	11.3	10.7	13.4	9.1	4.9	3.0	8.42	101.0
Heijo	*H*	16	.6	.5	1.0	1.7	2.5	2.8	9.8	8.1	5.3	1.9	1.6	.6	3.03	36.4
Kanko	*I*	19	1.4	1.5	1.7	2.9	3.5	5.0	11.6	12.5	7.7	3.5	2.8	.9	4.58	55.0
Chientao	*J*	-----	.4	.2	.5	.8	2.1	3.1	3.7	3.8	3.2	1.4	.6	.2	1.67	20.0
Tainan	*K*	27	.9	1.5	1.6	2.5	7.4	13.5	12.7	16.8	6.5	1.5	.7	.5	5.51	66.1
Bradenton, Fla.	----	-----	2.8	3.0	2.3	2.2	3.1	7.8	10.2	9.2	7.3	3.0	2.0	2.5	4.62	55.4

[7] See figs. 4 and 5.

The oriental laboratory for the study of the corn borer was located in Kobe, Japan, and climatological records for that city are included as a matter of interest.

JAPAN

KUTCHAN SECTION

Kutchan section (fig. 2, *A*) extends from Kaributo on the south to Yoichi on the north, and from Kutchan, the most important city in the section, east to Wakikata. The winters are very cold, with an average mean temperature of 24.3° F. for the 4 months of December, January, February, and March. The precipitation averages 40.3 inches, which is well distributed throughout the year (fig. 4, *A*). Usually from 3 to 5 feet of snow falls during the winter months.

Pole beans, the principal summer host of the borer in this section, are grown throughout the Kutchan section, bamboo poles being used for supports. In various localities many young apple orchards are being set out and beans are planted between the trees. When these trees reach full growth there will undoubtedly be a decrease in the production of beans with a consequent reduction in numbers of the corn borer. Bean land is gradually being turned into rice fields, although 5,000 acres are still planted to pole beans.

A total of 5,200 larvae, obtained at Kutchan, were sent to the United States during November 1928.

UTSUNOMIYA SECTION

The territory drained by the River Daiya in the center of Tochigi Prefecture has been designated Utsunomiya section (fig. 2, *B*). This extends from Nikko to Utsunomiya and is in the center of the hemp-producing area. The annual mean temperature is 54.08° F. and the precipitation averages 62.6 inches per year (fig. 4, *B*). Hemp (*Cannabis sativa* L.) is the principal host plant in this section from which collections of *P. nubilalis* and its parasites were made.

A total of 195 specimens of *Phaeogenes* sp. in the adult or pupal stage were shipped to the United States from this section.

HIROSHIMA SECTION

Hiroshima section (fig. 2, *C*) is located in the southern part of Honshu Island, the main island of Japan; it extends inland from the city of Hiroshima to the border of Shimane Prefecture and includes the towns of Miyoshi, Iimuro, and Kake. This is also a hemp-growing

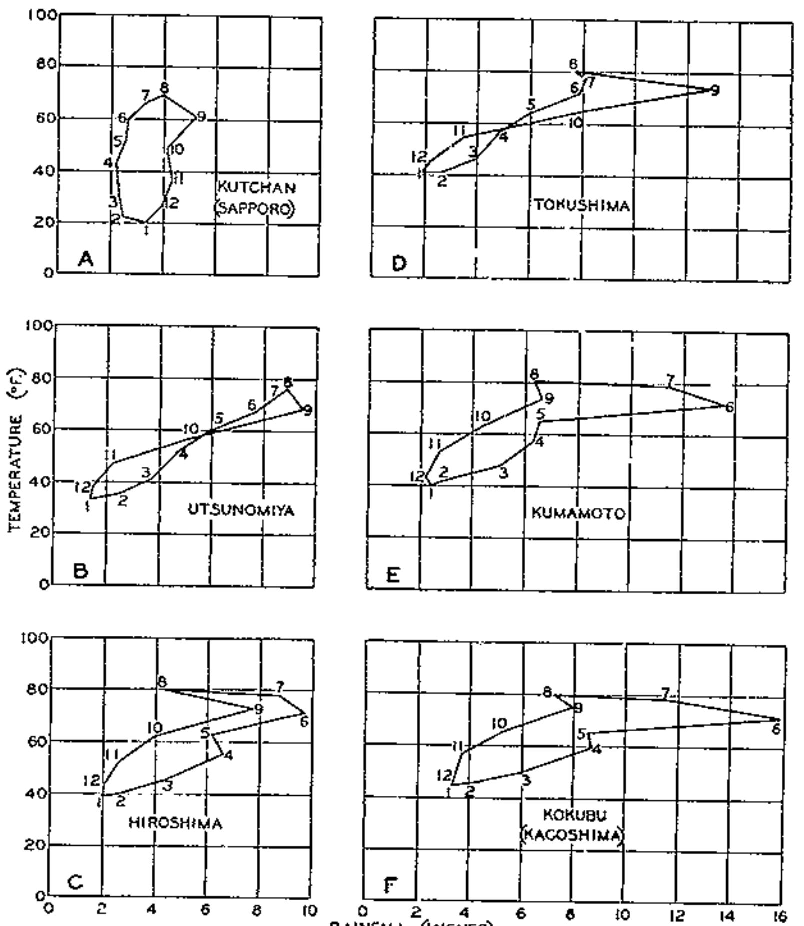

FIGURE 4. Climographs for various sections of Japan: *A*, Kutchan (records for Sapporo); *B*, Utsunomiya; *C*, Hiroshima; *D*, Tokushima; *E*, Kumamoto; *F*, Kokubu (records for Kagoshima). Numbers in the graphs indicate the months of the year.

section, although it is said that the production of this crop is decreasing. In the Iimuro locality of this section the nematode *Hexamermis meridionalis* Steiner parasitized 31 percent of the corn-borer larvae in the summer of 1930. The climate is mild, with June and July the wettest months (fig. 4, *C*). No live parasites obtained in this section were sent to the United States.

TOKUSHIMA SECTION

Tokushima section (fig. 2, *D*), in Tokushima Prefecture, on Shikoku Island, lies along the River Yoshino, north and west of the city of Tokushima. The climate is mild and the rainfall is well distributed throughout the growing season (fig. 4, *D*). This is the main indigo (*Polygonum tinctorium* Ait.) section of Japan, although a small acreage is planted to the crop in some other sections.

No parasites obtained in Tokushima section were shipped to the United States.

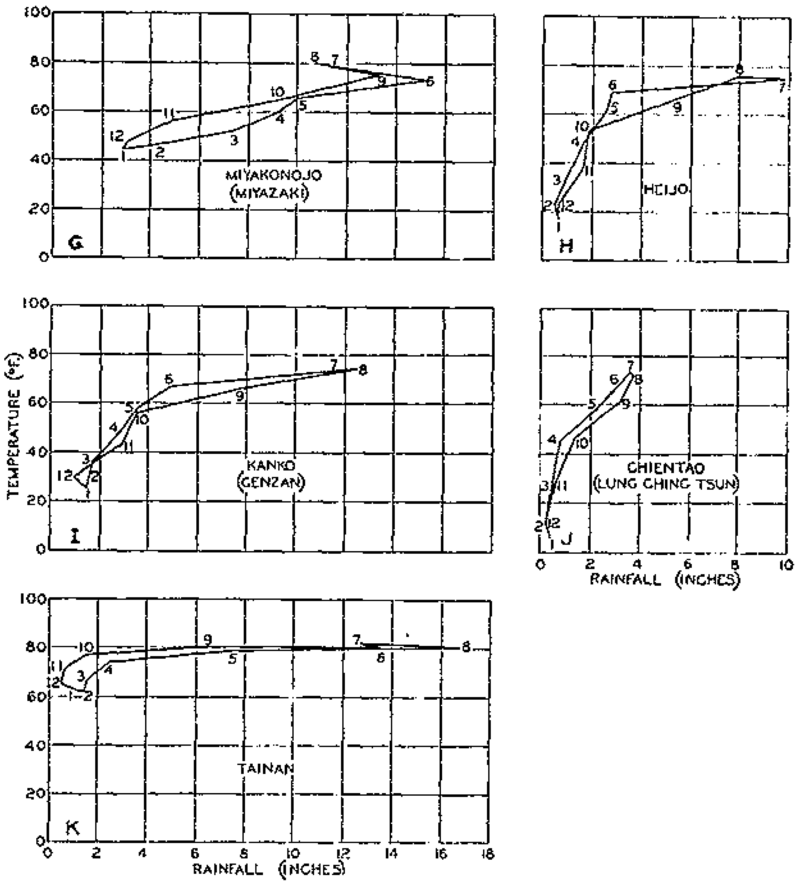

FIGURE 5. Climographs for various sections of the Orient: *G*, Miyakonojo (records for Miyazaki); *H*, Heijo; *I*, Kanko (records for Genzan); *J*, Chientao (records for Lung Ching Tsun); *K*, Tainan. Numbers in the graphs indicate the months of the year.

KUMAMOTO SECTION

Kumamoto section (fig. 2, *E*) embraces a strip along the western shore of Kyushu Island from Omuta to Hitoyoshi and extends about 20 miles inland. This is a lowland district and the precipitation is less than in the more southerly Kokubu and Miyakonojo sections, but the summer temperatures are as high as those of Kokubu or Miyakonojo. The average mean temperature for the year is 59.8° F. (fig. 4, *E*).

Millet and hemp are grown in this section, the hemp being especially abundant in the southern part of the section around Hitoyoshi.

A total of 1,062 cocoons of *Cremastus flavoorbitalis* (Cameron), 10 adults of *Brachymeria euploeae* (Westwood), and 2,500 host larvae containing *C. flavoorbitalis*, *Lydella grisescens* R. D., and *Macrocentrus gifuensis* Ashmead were obtained in Kumamoto section and shipped to the United States.

KOKUBU SECTION

Fifteen miles north of the city of Kagoshima there is a narrow valley extending 20 miles inland, with Kokubu as the principal village (fig. 2, *F*). The soil in this valley is well fitted for growing tobacco, and this is the important cash crop grown in the early spring and summer. Tobacco is usually followed by millet, a favorite host plant of the corn borer. No figures are available to show corn-borer infestation in millet in this valley, but 534,400 corn-borer larvae were collected from millet grown in this section during the winter of 1931–32. The climate is warm, the mean temperature averaging 62.2° F., and the precipitation 85.2 inches per year (fig. 4, *F*). The southern part of Kyushu Island which includes Kokubu section is often visited by very heavy windstorms in the late summer months. These storms sometimes seriously damage crops and may destroy corn-borer larvae, although no information was obtained on this subject.

A total of 536,400 larvae (including 2,000 from Kagoshima), containing *Inareolata punctoria* (Roman), *Lydella grisescens*, *Cremastus flavoorbitalis*, *Macrocentrus gifuensis*, *Nemorilla floralis* Fallén, and *Phorocera erecta* Coq., were shipped from Kokubu section to the United States, as shown in table 6.

MIYAKONOJO SECTION

Miyakonojo section (fig. 2, *G*) is quite similar to Kokubu section, except that average yearly precipitation (101 inches) in the former exceeds that in the latter by 15.8 inches. Miyakonojo section has a greater annual precipitation than any other section studied. January is the coldest month, with a mean temperature of 44° F., and June is the month of greatest rainfall, with an average of 15.2 inches (fig. 5, *G*, and table 1). Almost all the corn-borer studies and parasite collections have been made on a cultivated tableland about 25 miles in diameter, situated west of the city of Miyakonojo. Miyakonojo section extends from the interior border of Miyazaki Prefecture to the seacoast, and comprises the territory drained by the River Oyodo and its tributaries in Miyazaki Prefecture (fig. 2). Approximately 75 percent of the arable land of this section is given over to millet production in the fall of the year, and it is from this host plant that overwintering *P. nubilalis* larvae were collected from 1928 to 1932.

A total of 1,065,869 corn-borer larvae containing *Lydella grisescens*, *Bracon atricornis* Smith, *Macrocentrus gifuensis*, *Cremastus flavoorbitalis*, and *Nemorilla floralis*, were collected in Miyakonojo section and sent to the United States (table 6). Twelve thousand larvae shipped to the island of Guam in December 1930 were also obtained in this section.

ASO SECTION

The Aso section consists of the hilly country around Mount Aso, in Kumamoto Prefecture. This section has an elevation of 2,000 to 4,000 feet, whereas Kumamoto section in the same prefecture is only 50 to 500 feet above sea level. Consequently at the elevations prevailing in Aso section, crops are grown which are not cultivated in the lowland. Ten thousand acres are annually planted to field corn in Aso section, but corn-borer infestation averages 10 percent or less and associated borers are also present.

Lydella grisescens is the most important parasite of *P. nubilalis* in this section. No parasites were obtained in Aso section for shipment to the United States.

CHOSEN (KOREA)

HEIJO SECTION

Heijo section constitutes that portion of northwestern Chosen, in Heian Nan Do Province, between the River Seisen on the north and the River Daidoku on the south, and extends inland from the shore of the Yellow Sea to the town of Tokusen (fig. 3, *H*).

The rainy season in this section occurs in July and August, with an average precipitation of 17.9 inches for these 2 months. There are 18.5 inches of rain during the other months, making the total rainfall 36.4 inches per year. The winter months are cold, with an average mean temperature for December, January, and February of 20.7° F. (fig. 5, *H*, and table 1). Grain sorghum is the crop from which corn-borer larvae and parasites were principally obtained. A total of 358,400 host larvae, containing principally *Macrocentrus gifuensis*, were collected in Heijo section and sent to the United States (table 6).

KANKO SECTION

Kanko section is on the opposite coast from Heijo section (fig. 3, *I*) and borders upon the Japan Sea, extending from Genzan along the coast to Jokko. Winters are warmer and summers slightly cooler than those of the Heijo section, although the average mean temperatures for the two sections are approximately the same—between 48° and 51° F. The precipitation here is 55 inches per year (fig. 5, *I*, and tables 1 and 2). As in the Heijo section, grain sorghum is the most important host source for larvae of *P. nubilalis*. A total of 1,600 larvae were collected in Kanko section and shipped to the United States (table 6).

MANCHURIA

CHIENTAO SECTION

Chientao section (fig. 3, *J*) is located in southeastern Manchuria, just north of the Chosen-Manchuria boundary, and includes the cities of Lung Ching Tsun (Ryusaisan), Yen Chi (Chutzukai), and Nan Yang Ping. The territory investigated includes a strip only 10 or 15 miles wide on each side of the railroad between the above-named three cities. Chientao section is characterized by very cold, dry winters and comparatively warm summers (fig. 5, *J*, and table 1). The total annual precipitation is only 20.0 inches in normal years. Soybeans, millet, and grain sorghum (kaoliang) are the most important crops.

A total of 621,175 corn-borer larvae, with from 8 to 18 percent parasitized by *Inareolata punctoria* (Roman), and 18,795 cocoons and adults of *Eulimneria alkae* (Ell. and Sacht.) and *Microgaster tibialis* Nees obtained in Chientao section were shipped to the United States (tables 6 and 7).

TAIWAN (FORMOSA)

TAINAN SECTION

The Tainan section (fig. 3, *K*) is considered to be that part of the coastal plain of southwestern Taiwan extending from the vicinity of Kagi on the north to Keishu (south of Heito) on the south, and from the seacost on the west to the foot of the mountains of the great central range on the east.

Conditions in Tainan section are very different in every way from conditions in the other sections studied.[5] The climate here borders on the tropical, for the section lies below the Tropic of Cancer. The average mean temperature at Tainan, near the center of the section, is 73.4° F., and for the 6 hottest months, May to October, the average is 79.8° F. (table 1). Precipitation is high, averaging 66.1 inches per year (fig. 5, *K*, and table 1). The 5 summer months from May to September receive 86 percent of the total rainfall, and the 6 months from October to March receive 6.7 inches. Thunderstorms are characteristic of this region during the summer season and are accompanied by very heavy tropical downpours. The section is situated in the typhoon region and each year is visited by one or more of these heavy windstorms which often cause tremendous damage to crops. Typhoons occur only in the summer months, particularly during August and September. Climatic conditions in Tainan section closely resemble those existing in certain portions of Florida, and the climographs for Tainan, Taiwan, and Bradenton, Fla., are very similar, although Tainan is slightly drier in winter and wetter in summer.

Agriculture in this section is conducted by Chinese (who constitute the greater proportion of the population), and the principal crops grown are rice, sugarcane, bananas, and sweetpotatoes. Corn is grown in small fields near the houses, chiefly for domestic consumption, and most of it is grown during the period February to June, although small acreages of corn are present at almost any other time of the year. Coconuts, papayas, and other tropical fruits are well adapted to this region.

A total of 77 adults of two parasite species (73 *Xanthopimpla stemmator* (Thunberg) and 4 *Trichomma cnaphalocrocis* Uchida) were successfully transported alive from the Tainan section of Taiwan to the eastern part of the United States.

[5] The habits of the corn borer in Tainan section seem to differ from those exhibited in the other sections in the Orient and in the United States. M. Yanagiwara, an entomologist of the sugarcane experiment station, stated that corn-borer eggs were laid on the upper side of the corn leaves as often as on the underside. Young larvae apparently first attack the tassels and then migrate down the stalk as in other sections, since the tassel was broken over but usually uninfested when examinations were made. Late in April 1932 many fourth- and fifth-instar larvae were found outside the plant at the base of the leaf blade or between the leaf sheath and the stalk. Pupae were found in the same location. Although this phenomenon has been noted during investigations in the United States, it seemed to be much more evident in Taiwan. The larvae which were found in the stalks usually had not tunneled more than 2 inches, while larvae in sorghum in Heijo, Kanko, and Chientao sections usually made tunnels at least 6 inches long.

DISTRIBUTION, NUMBER OF GENERATIONS, AND HOST PLANTS OF PYRAUSTA NUBILALIS IN THE ORIENT

DISTRIBUTION OF THE CORN BORER IN THE ORIENT

Pyrausta nubilalis has been found widely distributed throughout the territory scouted in the Orient. This includes Taiwan, Japan (Kyushu, Honshu, Shikoku, and Hokkaido Islands), Chosen, and Manchuria, and embraces the area extending north and south from the 43d to the 22d parallel of latitude and east and west from the 120th to the 143d meridian. No corn borers were collected or received in shipments of insect collections from the Okinawa Islands, which lie about half-way between Taiwan and southern Japan proper. Corn in the Okinawas is said to be very severely damaged by borers, but apparently this injury is not by *P. nubilalis*. The corn borer also exists in the island of Guam and in the Philippines, and has been found in Java.[6]

NUMBER OF GENERATIONS OF THE CORN BORER IN THE ORIENT

Because the corn-borer investigations in the Orient covered such a large area (larger than the entire infested area of the United States in 1932), travel facilities in some sections were slow, the number of trained workers was small, and the number of seasons spent in securing data was limited, and since it was necessary to place emphasis upon other phases of the project, no sustained effort was made to obtain seasonal-history data on the corn borer under field conditions in any one section. For this reason the contained information on the number of generations is subject to revision when more detailed studies are made. The information obtained, however, will give a reasonably correct idea of the number of generations of the corn borer ordinarily occurring in all but one of the sections studied.

In Kutchan section of Hokkaido there is usually but one generation each year, with a few individuals developing two generations during favorable years.

Chientao section of Manchuria (about on the same parallel with Kutchan section) is undoubtedly a one-generation area, although in 1932 a few pupae were found as early as April 24.

Heijo and Kanko sections in Chosen should properly be termed "transition zones" between the one-generation and two-generation climates, with a tendency toward the two-generation type.

Utsunomiya section, in the central part of the main island of Japan, is a two-generation area, with perhaps a partial third generation in favorable years. It is important to note that in this section moths of the first summer generation emerge late in July. This will be discussed later under Agricultural and Other Practices Affecting the Corn Borer (p. 32).

Hiroshima section and Tokushima section are three-generation areas, although in the former there may be only two complete generations and a partial third in some years. Pupation of the first summer-generation larvae in Hiroshima Ken takes place about mid-July. On July 16, 1931, it had reached 55 percent at Imuro in this Prefecture. In Tokushima the peaks of moth emergence are late in May, in mid-July, and late in September.

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[6] For world distribution of *P. nubilalis*, see Caffrey and Worthley (4).

The corn borer develops three complete generations and a partial fourth in Kumamoto, Kokubu, and Miyakonojo sections. These sections should be considered as three-generation areas, as the partial fourth is usually unimportant. A number of small larvae are present in the fields during the winter months, and some of these are undoubtedly immature individuals of the partial fourth generation, but some of them are undersized as a result of parasitization by *Cremastus flavoorbitalis*. In 1931 the first pupa found in Miyakonojo section was collected on March 28. A number were found in April, but pupae did not become abundant until May, with the peak of pupation occurring approximately May 20. Probably this record was a little earlier than during the average season.

In the mountainous area near Mount Aso there are probably only two generations each year, although data from this section are not sufficiently comprehensive to warrant a definite statement.

The number of generations of the corn borer in the Tainan section of southwestern Taiwan is unknown and no reasonably accurate estimate can be given. From superficial observation it appears that several generations develop each year. All stages of the borer can be found late in April, although at this time the majority of the individuals are in the last larval or in the pupal stage. There is probably no true hibernation of the borer in this area, for the mean temperature of the coldest month, February, is 62° F., which is approximately the same as the June mean temperature in Massachusetts.

CLIMATE TYPE AND ITS RELATION TO THE NUMBER OF GENERATIONS ANNUALLY

The different types of corn-borer seasonal history, ranging from one generation annually to a multi-generation cycle of development, are associated with marked diversity in climate. Certain climatic characteristics of different annual-cycle zones are presented in table 2. The association between the number of months with a normal mean temperature of 60° F., or above, and the number of generations annually is evident. The range in both these features is clearly shown in table 2, from Kutchan with one generation to Tainan with several generations annually.

TABLE 2.—*Climatic indices of different seasonal cycles of the European corn borer in the Orient*

Section	Climograph (figs. 4 and 5)	Generations annually	Months with normal mean temperature of 60° F. or above	Normal mean temperature of March	Precipitation, October to March, inclusive
		Number	*Number*	*° F.*	*Inches*
1. Kutchan	*A*	1	3	29	20.5
2. Chientao	*J*	1	4	27	3.3
3. Kanko	*I*	−2	4	30	11.8
4. Heijo	*H*	−2	5	34	8.2
5. Utsunomiya	*B*	2	5	41	17.1
6. Hiroshima	*C*	−3	6	45	17.5
7. Tokushima	*D*	3	6	46	21.7
8. Kumamoto	*E*	3	6	48	19.4
9. Kokubu	*F*	+3	7	51	26.6
10. Miyakonojo	*G*	+3	7	52	31.2
11. Tainan	*K*	[1]	12	67	6.7

[1] Exact number not known; possibly 4 or more.

The data in column 5 of table 2 substantiate the importance of the use of the mean temperature of March as an index to climates inducing a given number of generations annually.

The average precipitation during the dormant period for the 1-generation and 2-generation types of climate (sections 1 to 5, inclusive) is 11.8 inches, while an average precipitation of 23.1 inches (almost twice as much) is available during the dormant period in sections with three or more generations (sections 6 to 10, inclusive). This contact moisture during the dormant period may be of importance in meeting the physiological requirements of the larvae (*1*).

As might be expected, precipitation during the dormant period is not always the most important activating influence. A comparison of the climatic data for Miyakonojo and Tainan (table 1) indicates the lessening in importance, under these conditions, of total precipitation as an index of the number of generations annually. Somewhere within the range of climates between these two, as illustrated in climographs *G* and *K* (fig. 5), the temperature would be sufficient throughout the year to foster the development of several overlapping generations. Where this condition of continuous development occurred, the lack of precipitation during any series of months would probably be reflected in a lowered rate of larval survival.

In order to visualize easily the association between climate type and developmental cycle, comparisons have been made between the normal climates of important sections in the Orient and the "standard" normal one-generation climate type as used by Babcock (*2*) for the central European corn belt. These data, as presented in table 3, have been compiled from the meteorological data contained in table 1.

TABLE 3.—*Climatological data on corn-borer sections in the Orient compared with the one-generation area of the central-European corn belt used as a standard*

Months	"Standard" 1-generation climate type		Deviation from "standard"					
			Kutchan (1 generation)		Utsunomiya (2 generations)		Kumamoto (3 generations)	
	Temperature	Precipitation	Temperature	Precipitation	Temperature	Precipitation	Temperature	Precipitation
	° F.	*Inches*	*° F.*	*Inches*	*° F.*	*Inches*	*° F.*	*Inches*
October, November, and December	41.2	1.89	−3.9	+2.21	+6.1	+1.31	+11.8	+1.18
January, February, and March	33.5	1.32	−9.8	+1.41	+2.8	+1.18	+0.8	+2.08
April and May	57.4	2.48	−10.9	−.13	−1.4	+2.97	+4.1	+3.92
June, July, and August	70.8	2.47	−6.1	+.83	+1.5	+5.90	+6.5	+8.03
September	62.9	2.04	−1.9	+3.16	+6.1	+7.40	+11.1	+4.56

Months	Deviation from "standard"					
	Hiroshima (3 generations or less)		Tokushima (3 generations)		Heijo (2 generations or less)	
	Temperature	Precipitation	Temperature	Precipitation	Temperature	Precipitation
	° F.	*Inches*	*° F.*	*Inches*	*° F.*	*Inches*
October, November, and December	+11.1	+1.01	+13.1	+2.54	−3.9	−.52
January, February, and March	+7.8	+1.61	+9.2	+1.48	−8.8	−.62
April and May	+1.6	+3.87	+3.1	+2.97	−2.9	−.38
June, July, and August	+5.5	+5.00	+5.5	+5.36	+2.5	+4.43
September	+10.1	+5.76	+11.1	+10.76	+3.1	+3.20

The most marked climatic separation between distinct zones of 1-generation and 2-generation habitats, viz, Kutchan and Utsunomiya, lies in the increase of both warmth and available moisture during the dormant period as compared with the "standard." The change from a 2-generation to a 3-generation annual cycle is associated with higher temperatures throughout the year.

The production of a transition or borderland habit of 1 generation or 2 generations seasonally, as the weather fluctuates, is aptly illustrated by the normal climate of Heijo. In this climate the dormant period is distinctly of the 1-generation type, while the growing-season climate is distinctly warmer and wetter than the 1-generation "standard" type.

PRINCIPAL HOST PLANTS OF THE CORN BORER IN THE ORIENT

Hemp, corn, millet, and grain sorghum are the most important host plants of the corn borer in the Orient, although there are a number of others, notably beans and indigo. A complete list of the host plants found infested during these investigations is given in table 4. No single species of host plant is of importance over the entire area studied, although millet is found in all except one of them. Some host plants, such as zinnia and barnyard grass, were found infested only a few times. Cotton plants were examined on a number of occasions in northwestern Chosen, but no corn-borer infestation was found, though larvae of the pink bollworm (*Pectinophora gossypiella* Saund.) were common.

TABLE 4.—*Plants found infested by the European corn borer in the Orient, 1928–32*

Scientific name	Common name	Japanese common name
Cannabis sativa L.	Hemp	Asa.
Humulus japonicus Sieb. and Zucc	Japanese hop	Hoppu.
Chrysanthemum morifolium Ram	Chrysanthemum.	Kiku.
Dahlia variabilis Desf	Dahlia.	Dariya.
Zinnia elegans Jacq.	Zinnia	Hyakuni chi-so.
Polygonum blumei Meisn		Inutade.
Polygonum lapathifolium nodosum (Pers.) Weinm.		
Polygonum thunbergii Sieb. and Zucc		Mizosoba.
Rumex japonicus Meisn.	Dock	Gishigishi.
Fagopyrum vulgare Hill	Buckwheat	Soba.
Polygonum viscosum verrucosum Meisn		
Soja max (L.) Piper	Soybean	Daizu.
Phaseolus spp.	Bean	Saito.
Zea mays L.	Corn	Tomorokoshi.
Sorghum vulgare Pers. var	Sorghum	Habakimorokoshi.
Do	do	Morokoshi.
Coix lacryma-jobi L.	Jobs-tears.	Zyuzudama.
Setaria italica (L.) Beauv	Italian millet	Awa.
Setaria italica (L.) Beauv. var	German millet	Koawa.
Panicum miliaceum L.	Broomcorn millet.	Kibi.
Echinochloa crusgalli edulis Hitchc	Barnyard grass.	Hie.
Polygonum tinctorium Ait	Indigo	Ai.

Hemp (*Cannabis sativa* L.) is grown in a number of localities throughout the majority of the islands of Japan proper. This plant is a very important host of *P. nubilalis* in the most important hemp-growing Prefecture, Tochigi (Utsunomiya section), in Hiroshima section, and in the southern part of Kumamoto section. Babcock and Vance (*8*) state that corn-borer infestation in hemp could rarely be found in central Europe; that region, however, is a typical corn-growing belt, and the borer offers no hindrance to hemp cultivation, since it is concentrated on other plants, mainly corn, in preference to hemp. In Japan the corn borer is of decided economic importance to hemp cultivation and in some areas has been responsible for drastic reductions in the acreage planted to this crop. Clausen (*6*), in a compilation from Japanese sources, records *P. nubilalis* as one of the insects of lesser importance on the hemp crop, but the writer's observations reveal the corn borer as a major, if not the most important, pest of this particular plant during the period 1929–31.

The corn borer usually injures from 10 to 20 percent of the hemp plants in Utsunomiya section, but often 50 percent of the plants in individual fields are damaged. In Hiroshima section infestation and resulting injury are as high as in Utsunomiya section, and in Kyushu Island (Hitoyoshi) damage as high as 90 percent has been recorded. Infestations ranging from 10 to 50 percent in fields of hemp only 200 yards apart were observed each year in both Utsunomiya and Kumamoto sections, and although the causes of these variations were not determined during the course of these investigations, it is probable that the explanation is to be found in different planting dates and rates of growth.

Beans (*Phaseolus*) constitute a very important host of the corn borer in the Kutchan section of Hokkaido. Damage occurs yearly and is sometimes severe. String beans on the Kobe market were found to be infested, although no examinations were made to determine the intensity of infestation.

Corn (*Zea mays* L.) is a host of the corn borer wherever it is found in the oriental regions studied. Infestation varies greatly, from very light to severe. Corn is not an important crop in any part of Japan proper, with the possible exception of an area in midwestern Hokkaido and around the lower elevations of Mount Fuji on Honshu Island and Mount Aso on Kyushu Island. Corn-borer infestation is usually light, but in a few scattered fields it may affect 50 percent of the plants during some seasons. Corn is infested throughout the districts where it is grown in Chosen, but infestation is usually light. The extensive corn-growing section near the western end of the Chosen-Manchuria border has not been studied intensively. Infestations as high as 100 percent were recorded from the corn in Manchuria just across the border from northeastern Chosen. In the small cornfields of southern Taiwan infestation by *P. nubilalis* often is as high as 100 percent, with 3 to 10 or more borers per stalk. High infestations are especially prevalent in the fall months in Takao Shu Province, possibly owing to corn-borer concentration, for at this time the corn acreage is not so extensive as in the spring months.

An examination of 7,800 plants at Heito in May revealed a 100-percent infestation, with an average of 1.57 borers per stalk and a maximum of 28 larvae in one stalk. Infestation of corn slightly farther north in the vicinity of Tainan rarely exceeds 50 percent. This difference in infestation in these two localities may be the result of the abundance of the pupal parasite *Xanthopimpla stemmator* in the latter locality as contrasted with its apparent scarcity in the former.

Grain sorghum (*Sorghum vulgare* Pers.) is grown throughout Manchuria and in northern Chosen. It is the plant from which 981,175 borer larvae and 18,836 parasite cocoons were obtained in the Heijo.

Kanko, and Chientao sections. Corn-borer infestation in this plant in these sections usually ranges from 15 to 30 percent, with an average of approximately 20 percent. The stem of this plant is strong enough to escape breakage even when infested by 3 to 5 borers per plant.

Millet, principally *Setaria italica* (L.) Beauv., is grown generally throughout the Orient, where it is often an important article of human food, especially in Chosen and Manchuria. Throughout many regions of the Orient millet is a favorite host of *P. nubilalis* (referred to by the Japanese as "awa-no-mushi" or "awa-no-zuimushi", meaning millet borer). Millet found on Kyushu Island during the late fall and early winter months is occasionally seriously damaged by *P. nubilalis*, but part of the damage must be attributed to another borer, apparently a species of *Sesamia*, which is commonly found associated with the corn borer in infested plants.

Indigo (*Polygonum tinctorium* Ait.) is grown principally in Tokushima section, on Shikoku Island, and only about 100 acres are to be found in the few places where the plant is grown on Honshu Island. Cultivation of this crop is rapidly decreasing owing to the competition of dyes from other sources. Thus, in Tokushima Prefecture the acreage planted to this crop in 1927 was 1,600 acres, whereas by 1930 the area planted to indigo in the same prefecture was only 700 to 800 acres. The "Ai-no-meichu" (indigo borer), as the Japanese farmers in the indigo section refer to *P. nubilalis*, infests indigo from year to year. One hundred percent infestation of the plants is not uncommon, but because of the branched habit of growth, and the ability of the plant to send out new branches in place of injured ones, the intensity of infestation may not cause serious injury unless the number of larvae per plant is very large.

Infestation is easily detected when the infested branches die and become bluish black in color. Local entomologists reported that infestation by the borer and resultant severe damage occurred in 1930, but in 1931 the infestation and damage were found to be very low in the Tokushima indigo section.

Other crops and plants, such as chrysanthemum, dahlia, zinnia, dock, and barnyard grass, were found infested by *P. nubilalis* on one or more occasions, but they are not of much importance as host plants of the corn borer. During 1929 and 1930 several examinations of ramie failed to disclose the presence of *P. nubilalis* in this plant.

BIOLOGICAL CONTROLLING FACTORS OF PYRAUSTA NUBILALIS IN THE ORIENT

The only controlling factors to be considered in this discussion are those of a biological nature, including the parasitic and predacious enemies of the corn borer in its various stages. Other phases of the natural control (as distinguished from "biological control" in its restricted sense) of *P. nubilalis* are treated elsewhere in this bulletin. The climates of the sections in which studies were made have been treated in an earlier part of this bulletin, and the cultural control of the borer, or the agricultural practices affecting its abundance, will be discussed in a later section.

The insect parasites and predators are important biological controlling factors of the corn borer in the Orient. Many of the parasites of the corn borer in the oriental area are similar taxonomically to those found in the European area, although there is always the possibility of a different biological reaction in the same parasite species collected from different regions. Nevertheless certain important parasites of *P. nubilalis* are found in the oriental sections studied that apparently do not exist in the European fauna. A complete investigation of the corn-borer parasite association must include these species. A list of the natural enemies of the corn borer recorded in the Orient during the course of these investigations is given below. None of the parasites found on the islands of Japan proper or on the Asiatic mainland have been found on the island of Taiwan, which seems to present an entirely different parasite association.

Insect parasites and other natural enemies of Pyrausta nubilalis in the Orient

Parasites of the larva:
- Diptera—
  - *Lydella grisescens* R. D.
  - *Nemorilla floralis* Fallén
  - *Phorocera erecta* Coq.
- Hymenoptera—
  - *Eulimneria alkae* (Ell. and Sacht.)
  - *Inareolata punctoria* (Roman)
  - *Campoplex*, new sp.
  - *Cremastus flavoorbitalis* (Cameron)
  - *Microbracon* sp.
  - *Microgaster tibialis* Nees
  - *Apanteles thompsoni* Lyle
  - *Apanteles* sp.
  - *Macrocentrus gifuensis* Ashmead
  - *Bracon atricornis* (Smith)
- Moniliales—
  - *Beauveria bassiana* (Bals.) Vuilleman
- Nematoda—
  - *Hexamermis meridionalis* Steiner

Parasites of the pupa:
- Hymenoptera—
  - *Phaeogenes* sp.
  - *Xanthopimpla stemmator* (Thunberg)
  - *Xanthopimpla punctata* (Fab.)
  - *Trichomma cnaphalocrocis* Uchida
  - *Labrorychus tenuicornis* (Grav.)
  - *Brachymeria euploeae* (Westwood)

Predators:
- Coleoptera—
  - One carabid, probably *Plochionus* sp.
- Birds, probably woodpeckers

In addition to the 19 species of insect parasites listed above, 3 additional parasite species were collected, but their specific determination is not known. These additional species, if actual parasites of the corn borer, are not of great importance since they have been infrequently observed and it is possible that one or more of them are parasitic on borers closely associated with *P. nubilalis*.

As stated previously, several species of corn-borer parasites found in the Orient were also found in Europe and have been imported to the United States from the latter area. Parker (*9*) has published on *Macrocentrus gifuensis*, and Thompson and Parker (*13*) have studied and published on *Eulimneria alkae*, formerly called *E. crassifemur*, while Vance has studied *Apanteles thompsoni* (*14*) and *Microgaster tibialis* (*15*). Jones (*7*) and Jones and Caffrey (*8*) have reported upon the status of these parasites in the United States. Some of the parasite species found in the Orient are treated separately in the following pages, but no biological information is available about others (*Campoplex*, new sp., *Microbracon* sp., and *Labrorychus tenuicornis*) which were very rare, only a few specimens having been obtained.

TRICHOGRAMMA SP.

Egg parasites of the corn borer in the Orient have not been thoroughly investigated, but probably some exist. A species of *Trichogramma* reported to be *australicum* was secured and placed on eggs of the corn borer, which it parasitized. Adults of the parasite failed to emerge; however, the host eggs turned black, thus indicating effective parasitization.

LYDELLA GRISESCENS R. D.

The tachinid *Lydella grisescens* is the most important dipterous parasite of the corn borer observed in the Orient. It is one of the most widely distributed parasites of the pest in that region, ranging from at least Peiping (Peking) on the north, eastward throughout Manchuria, Chosen, and Japan. The parasite was obtained from all sections studied, with the exception of Taiwan (in which island *L. grisescens* apparently does not occur) and Tokushima section. More extensive collections probably would reveal its presence in the latter section, for it has been found in Kochi Prefecture, which is not far distant from Tokushima section. Although this parasite has been found throughout the range of the corn borer in the oriental areas studied, with the exception of the island of Taiwan, it is not found abundantly in Chientao section and is certainly not of much importance there. It is found in quite large numbers in Heijo and Kanko sections in Chosen, in Utsunomiya and Hiroshima sections of Honshu Island, and in all sections of Kyushu Island (Kumamoto, Kokubu, Miyakonojo, and Aso). It probably reaches maximum abundance in the latter sections. The study of this species was made in Miyakonojo and Kumamoto sections, and the following information applies to these sections only.

The winter is passed as an immature larva inside the host larva. Emergence from the host larvae begins late in January, and puparia are very numerous in the field during February. In 1931 approximately 1,000 puparia were collected during the first 10 days of February in Miyakonojo section. Puparia are found inside the tunnels made by the host larvae in the host plants. The puparium stage lasts from 1 to 2 months, and adults emerge in April and May.

Second- and third-instar borer larvae of the first summer generation become available for this parasite early in June, and one complete summer generation of *Lydella grisescens* is passed on the borer by July 1. Host larvae in all stages are present in the field in Kumamoto and Miyakonojo sections for the remainder of the summer and, similarly, puparia of this parasite may be found at almost any time during the season. There is so much overlapping of the generations of *L. grisescens* that it is not possible, from present information, to state definitely the number of generations produced by the parasite each year, although probably four generations develop in the presence of average or normal weather conditions. A summer generation of the parasite requires approximately 20 to 25 days. This parasite appears to reach its greatest effectiveness in the late summer and overwintering generations. It is not so effective as certain other parasites on the spring and early summer generations of the borer in Kyushu Island. *L. grisescens* has been collected from *P. nubilalis* feeding on corn, hemp, sorghum, and millet.

A total of 71,995 adults of this parasite have been obtained from shipments of larvae from the oriental areas. The parasite has been liberated in the United States and has been recovered, indicating establishment.

NEMORILLA FLORALIS FALL. AND PHOROCERA ERECTA COQ.

Not a great deal is known about these two tachinids in the areas studied. Both species were obtained from host larvae collected during the winter months in Chientao, Heijo, and the Kyushu Island sections. A total of 1,807 *Nemorilla floralis* and 835 *Phorocera erecta* were collected in Heijo and Kokubu sections, respectively, in 1932. During 1932 a total of 2,184 *N. floralis* and 1,828 *P. erecta* were obtained in the United States from oriental material.

The three dipterous parasites given above are the only species of this group found parasitizing the corn borer in the Orient, with the exception of one undetermined and malformed specimen reared from a corn-borer pupa collected in southern Taiwan.

EULIMNERIA ALKAE (ELL. AND SACHT.)

This ichneumonid is limited to the more northern sections in which *Pyrausta nubilalis* has been studied in the Orient. During 1930, 1931, and 1932 a total of 16,032 cocoons of this species were secured in Chientao section, Manchuria. Parasitization of the borer of the fall generation averages between 7 and 12 percent in normal years. In the Heijo and Kanko sections less than 500 cocoons of this parasite were obtained, and this seems to be the southern limit of the occurrence of *Eulimneria alkae* in the Orient. This parasite has not been found on Honshu, Shikoku, or Kyushu Islands of Japan. In Chientao section *E. alkae* is parasitized by what appears to be a species of *Eupteromalus*. A total of 16,045 specimens of the primary parasite have been shipped from the Orient to the United States.

INAREOLATA PUNCTORIA (ROMAN)

The ichneumonid *Inareolata punctoria* is more widely distributed than *Eulimneria alkae*, but like the latter species it is of importance only in the colder sections. It is the most important parasite in the Chientao section of Manchuria. Parasitization by *I. punctoria* in this section ranges between 10 and 20 percent and in the winter of 1931–32 it averaged 17 percent. The parasite is also found in Kutchan section in Hokkaido, Japan, and in Heijo and Kanko sections of Chosen, but in the latter two sections it is not so important as are other parasites.

Specimens of *I. punctoria* have been obtained in Utsunomiya, Hiroshima, and Miyakonojo sections, and in the Ijuin locality of Kagoshima. In the latter locality the distribution of this species was very restricted, as practically all specimens were collected from two isolated fields.

From 1929 to 1932, inclusive, a total of 30,167 adults of *I. punctoria* were successfully obtained in the United States from borer larvae received from the Orient.

CREMASTUS FLAVOORBITALIS (CAMERON)

The ichneumonid *Cremastus flavoorbitalis* (formerly known as *C. hymeniae* Vier.) reaches its maximum abundance in Kumamoto, Kokubu, and Miyakonojo sections, but is also found in Utsunomiya and Hiroshima sections, where it is of some value as a parasite of *P. nubilalis*. It seems to be of particular importance in Kumamoto section, where parasitization of 30 percent has been recorded, although the average rate of parasitization in the sections studied was lower than this. The parasite normally passes the winter as an immature larva inside the dormant borer larva, but apparently a small number overwinter in the cocoon stage. An examination of 40 cocoons in the field in Kokubu section in February 1932 brought out the fact that not all of the individuals of this species were in the host larvae at this time of the year. Two of the cocoons each contained a live *C. flavoorbitalis* larva, one contained a live pupa of the parasite, and two cocoons each contained a number of live hyperparasites (Feb. 18, 1932). The remaining parasite cocoons contained dead parasites in various stages or were empty, the adults from the empty cocoons probably having emerged during the late fall months.

During field examinations made in 1931 the first spring cocoons of this parasite were found on May 3 in Miyakonojo section, and by the middle of May cocoons were numerous in the fields in that territory. In Kumamoto section a full spring generation of the parasite developed on *P. nubilalis* larvae before the end of June. Parasites of *C. flavoorbitalis* in the cocoon stage reduce its effectiveness. Superparasitization also reduces the biotic potential of the parasite, since from 1 to 3 parasites of this species have been dissected from a single host larva collected in the field, and apparently only 1 parasite per host can mature and successfully emerge. Under field conditions only 1 cocoon of this species is found with the remains of each host. Starvation rather than cannibalism appears to be responsible for the elimination of surplus individuals, as judged by dissections of superparasitized larvae, which usually revealed one or more dead parasites within each host.

On Kyushu Island *C. flavoorbitalis* was recovered from overwintering borers collected from millet, and also from summer-generation borers obtained from hemp. On this island this parasite seems to reach its maximum effectiveness during the spring months, but other species (*Macrocentrus gifuensis* and *Lydella griscscens*) apparently supplant it later in the summer. *C. flavoorbitalis* has been found in Tokushima section on Shikoku Island, but investigations in this territory were not extensive enough to yield a reliable estimate of its value as a parasite of the corn borer when infesting indigo plants.

This parasite is quite hardy under favorable conditions. Adults were kept alive for a period exceeding 2 months during the summer of 1931, even under the handicap of high room temperatures.

C. flavoorbitalis has been imported into the United States in increasing numbers; thus, 439 adults were obtained in 1929, 1,471 in 1930, 2,759 in 1931, and 12,582 in 1932, bringing the total number of adults secured during this 4-year period to 17,251.

This parasite is also present in the Hawaiian Islands, where it is an important parasite of the coconut leaf roller, *Omiodes blackburni* (Butler), and attacks 28 other species of insects (*11*). Undoubtedly it will find other hosts than the corn borer in the United States, which may aid in its establishment and maintenance if synchronization with the seasonal development of *P. nubilalis* is not established.

MICROGASTER TIBIALIS NEES

The braconid *Microgaster tibialis*, in common with *Eulimneria alkae* and *Inareolata punctoria*, is limited in effectiveness to the colder regions of the Orient. It has been obtained in the field from practically all sections, but only in the Chientao section does it appear to be an effective aid in the control of *P. nubilalis*. Parasitization of the overwintering borers averaged approximately 1.5 percent during the 3-year period 1930–32. A total of 2,750 cocoons of this species have been imported into the United States from the Orient.

APANTELES SPP.

Two species of *Apanteles*, one of which has been determined to be the same as the European species *A. thompsoni* Lyle, are found in the Asiatic regions. Males of the other species are present. These braconids do not seem to be of much importance in any section in the oriental areas studied. They are found in largest numbers in Chientao section but have also been found on Hokkaido, Honshu, Shikoku, and Kyushu Islands. A total of 288 adults of *Apanteles* sp. were obtained prior to 1932 and 277 adults of *A. thompsoni* were obtained from borer larvae received from the Orient during 1932.

MACROCENTRUS GIFUENSIS ASHMEAD

The braconid *Macrocentrus gifuensis* is one of the most important parasites of the corn borer in the Orient. It has approximately the same distribution as *Lydella grisescens* and is important in the same regions, particularly in the sections of Kyushu Island, Japan, and in Heijo section of Chosen. In the former sections the peak of its effectiveness seems to come during midsummer. Consequently it follows *Cremastus flavoorbitalis* and precedes *L. grisescens* in seasonal sequence, although individuals of these three species are present at the same time. As shown by Parker (*9*), this polyembryonic insect passes the winter in the egg stage inside the overwintering host larva.

It is important to note that this species seems to be an important parasite in sections where it is apparently too cold for the warm-climate species *Cremastus flavoorbitalis*, and still not suitable for those parasites, such as *Inareolata punctoria*, *Eulimneria alkae*, and *Microgaster tibialis*, that appear to be better adapted to the cooler regions.

A total of 140,240 adults of *Macrocentrus gifuensis* were obtained from material received from oriental regions during 1929, 1930, 1931, and 1932. Of the above total, 133,155 adults were obtained during 1932.

BRACON ATRICORNIS (SMITH)

Bracon atricornis is a rather large species which, so far as known, is not an important parasite of *P. nubilalis* in any locality in the Orient. A total of 221 adults of this parasite, however, have been reared from borer larvae received from the Orient, particularly from larvae collected in Miyakonojo section. It may be interesting to note that

B. atricornis, or a very similar species, is obtained in very small numbers from larvae of *P. nubilalis* collected in Europe.

BEAUVERIA BASSIANA (BALS.) VUILLEMAN

The fungus *Beauveria bassiana* was recorded from all portions of the Asiatic area studied, except Taiwan. However, only larvae collected in Hokkaido, Manchuria, or Chosen seemed to be seriously infected with this disease. In the winter of 1929–30 the larvae in a collection of 10,000 were so seriously infected that they were of no value as a source of insect parasite material. A total of 204,000 larvae of those collected during the earlier seasons became infected and a mortality exceeding 90 percent resulted. Later, as a result of increased experience and improved technic, the collection and shipment of parasite material was not seriously interfered with by infections of this disease. Less than 5 percent of overwintering borer larvae in eastern Manchuria were infected by this disease, as determined by careful field examinations made in the early winter months of 1931, and usually the mortality from this factor was much less than the above-mentioned figure. Only 1 larva killed by this disease was found in an examination of 288 larvae obtained from sorghum stalks at Lung Ching Tsun, Manchuria, in March 1932.

HEXAMERMIS MERIDIONALIS STEINER

The mermithid worm *Hexamermis meridionalis* was first obtained from corn-borer larvae collected from hemp plants growing in the vicinity of Iimuro, Hiroshima section, in 1930. In that year parasitization by this species attained 30.91 percent in the above locality. The following year (1931), in the same locality, a parasitization of 28.89 percent was recorded, yet collections 10 miles away exhibited little or no parasitization by *H. meridionalis*. Maximum parasitization by this nematode, or a closely allied species, appears to be restricted to the Iimuro locality, for, although this worm has been found in Utsunomiya, Kumamoto, Heijo, and Tainan sections, no more than 10 specimens of the parasite were obtained from any of these sections.

Usually only 1 to 3 nemas were obtained from a single host larva, although on one occasion 22 specimens of this nematode emerged from a single corn-borer larva under observation. These ranged from 4 to 6 centimeters in length. No live specimens of this parasite have been sent to the United States.

H. meridionalis has been reported by Plank (*10*) as infesting larvae of the sugarcane borer (*Diatraea saccharalis* (Fab.)) in Cuba. This nematode has been collected in South America (Paraguay) and in many localities in the United States.

PHAEOGENES SP.

During the period 1929–31 the summer collections of corn-borer pupae were confined to the sections on Honshu and Kyushu Islands. The ichneumonid *Phaeogenes* sp. was obtained in a number of these collections, but the majority were obtained from collections made on Honshu Island in Utsunomiya and Hiroshima sections, particularly in the former. The host pupae from which this parasite was reared were collected from hemp. The maximum parasitization recorded was 11.9 percent in a collection made at Kanuma, Utsunomiya section, during July 1930. It is estimated that 195 specimens of this parasite were sent to the United States, some in the adult stage and some as pupae inside the host pupae, with provision for adult parasite emergence en route.

XANTHOPIMPLA STEMMATOR THUNBERG

The ichneumonid *Xanthopimpla stemmator* is an important parasite in certain parts of Tainan section, Taiwan. It has been collected at Shinkwa, Shin-ei, Eiko, and Heito. It has not been found on *P. nubilalis* in any other section investigated. This parasite emerges from pupae of the corn borer, but nothing is known of its immature stages. The stage of the borer attacked by this parasite is not positively known but is believed to be the pupa. If this assumption is true, the parasite probably has a life cycle of approximately 23 days in Tainan section. This assumption is based upon records made in 1932. In the field at Shinkwa only 2.6 percent of the borers had pupated on April 27, but when collections were made May 1 to 5 the pupae had become abundant. Weighted averages of emergence records gave 23 days as the approximate duration of the life cycle. Males of the parasite emerge 1 day earlier than the females, on an average.

Xanthopimpla stemmator does not require a specific host; it has been recorded from the sugarcane borers (*Grapholitha*) *Olethreutes schistaceana* Snell., *Diatraea infuscatellus* Snell., and *Diatraea venosata* Walk., and the sweetpotato vine borer *Omphisa anastamosalis* Guen. ("satsumaimo-no-meiga" of the Japanese). It is particularly interesting to note the latter host, for sweetpotatoes are interplanted commonly with sweet corn, the two crops being planted in alternate rows in the same field. The parasitization of *P. nubilalis* by this species in the vicinity of Tainan reached 39.35 percent in 1931, but examinations of corn-borer pupae collected in the fields in the vicinity of Heito indicated that this parasite is not important in that locality. There is at least one species of hyperparasite, but it does not seem to be important. Table 5 is a summary of data recorded for *X. stemmator* in 1931 and 1932.

TABLE 5.—*Data on parasitization of pupae of the European corn borer by Xanthopimpla stemmator in Tainan section, Taiwan, 1931 and 1932*

Locality	Dates of collection	*Pyrausta nubilalis* pupae collected	Pupae parasitized by *X. stemmator*		*X. stemmator* parasitized (hyperparasites)	
		Number	*Number*	*Percent*	*Number*	*Percent*
Shinkwa	Apr. 17–May 20, 1931	681	268	39.35	10	3.73
	Apr. 27–May 5, 1932	473	73	15.43	0	0
Heito	May 11, 1931	8,671	2	.02	0	0
	Apr. 29, 1932	18	0	.00	0	0
Eiko	May 2, 3, 1932	156	25	16.03	0	0

The maximum parasitization found was 80.95 percent and 22.14 percent at Shinkwa in 1931 and 1932, respectively. The records show more females than males reared from field-collected host pupae. In the 1931 and 1932 collections the females composed approximately 62 percent of the total adults obtained.

Mating is easily obtained in laboratory cages soon after the adults emerge. The mating usually takes from 30 to 60 seconds.

The information given above is of somewhat doubtful value owing to the later discovery that two species, *X. stemmator* Thunb. and *X. punctata* (Fab.), are involved in the records, although *stemmator* is the predominating species.

Fifty-seven female and 16 male *Xanthopimpla* were brought alive from Taiwan to the United States in June 1932.

TRICHOMMA CNAPHALOCROCIS UCHIDA

Trichomma cnaphalocrocis is a very large parasite that has been reared from pupae of *P. nubilalis* only in Taiwan. Even in that location it is not nearly so important a parasite as *Xanthopimpla stemmator*, yet it occurs in some numbers each year. A total of 619 pupae collected from 5 fields at Shinkwa and Eiko during the spring of 1932 revealed a parasitization of 2.91 percent by *T. cnaphalocrocis*, on an average, with a maximum parasitization of 7 percent of the pupae from one field. Nothing is known of the early stages or biology of this parasite.

In June 1932 an attempt was made to transport live adults of *T. cnaphalocrocis* from Shinkwa, Taiwan, to the Arlington, Mass., laboratory in the United States, but only 1 male and 3 females were alive when the destination was reached.

BRACHYMERIA EUPLOEAE (WESTWOOD)

The pupal parasite *Brachymeria euploeae* was first found at Kumamoto in June 1930. Later it was found in Utsunomiya section, but only a few specimens were obtained. At Kumamoto, however, this parasite is commonly secured in rearings from host pupae in June. There is some doubt as to whether this parasite attacks the pupa or an earlier stage of the borer. Nothing is known of its earlier stages. A test shipment of 10 adults was made to the United States in 1930, but they died en route.

PLOCHIONUS SP.

Larvae of a carabid beetle, probably a species of *Plochionus*, were often found in the tunnels made by corn-borer larvae. These beetle larvae were usually eating corn-borer larvae but were also observed to eat into the cocoons of *Cremastus flavoorbitalis* in hemp plants in Kumamoto section. The *Plochionus* larvae were found throughout Japan proper. In Kutchan section they were observed during the spring months feeding on the overwintering *P. nubilalis* larvae hibernating in bamboo bean poles. No attempt was made to ship this beetle to the United States.

BIRDS

The beneficial activities of birds in relation to overwintering borer larvae were observed in Kutchan section of Hokkaido, Japan. In this section the bamboo poles commonly sheltering the borers during the winter often contained holes made by birds, probably woodpeckers (order Pici). The holes were located mainly along the upper internode, indicating that the birds could determine the location of the larvae or that they had learned by experience where the larvae might be found. Judging by the number of holes in the bamboo stems, the number of borers destroyed by birds in this section must have been very large indeed. No bird activities having any relation to *P. nubilalis* were observed in any other part of the Orient.

COLLECTION AND SHIPMENT OF CORN-BORER PARASITES

During the time the distribution of *Pyrausta nubilalis* and the principal host plants attacked by it in the Orient were being investigated, small collections of *P. nubilalis* were made from various localities, and information regarding the parasites present, their relative importance, and approximate distribution, was obtained. This information, supplemented by additional information derived from later rearings of parasites and dissections of host larvae, served as a basis for collections of parasites and parasite material (host larvae and pupae). This procedure was similar to that practiced and found satisfactory in the work in Europe (*8*).

The method followed in securing parasites for shipment to the United States varied according to the local conditions existing in the various sections, the particular species of parasites to be obtained, their biology, the plants from which the parasites or parasite hosts were obtained, and many other factors of importance.

Parasites of *P. nubilalis* pupae (*Phaeogenes* sp. and *Brachymeria euploeae*) were obtained in relatively small numbers only, and were collected in host pupae, by permanent, trained assistants, directly from the infested host plants.

The 1,064 cocoons of *Cremastus flavoorbitalis* shipped to the United States in June 1930 and June 1931 (table 7) were obtained by cutting up all the hemp, piece by piece, in three small, but heavily infested fields.

In Chientao, Kanko, and Heijo sections parasite material was obtained from grain-sorghum plants. The procedure found most satisfactory in actual practice in these sections was to purchase infested sorghum stems immediately following the harvesting of the crop in the fall and before the advent of cold weather. The price to be paid for infested stems was determined by a plant-infestation survey conducted just previous to and during the harvesting season. An attempt was made to so fix the price that anyone of average industry would receive approximately the prevailing wage of the locality for a full day's work. Infested sorghum stems were cut in approximately 18-inch lengths and packed in bundles of 100 stems each. Five of these small bundles were then tied in larger bundles or bales, and in this condition they were brought from the various farms to a central place previously designated. When sufficient infested stems had accumulated at the central location, laborers were hired to remove the corn-borer larvae and parasites from the stems. The number of laborers hired, usually between 25 and 200, depended upon the quantity of material and the time available in which to do the work. In Chientao section the laborers found most available and most satisfactory were Korean women (fig. 6), while in Heijo section it was possible to engage high-school students, with their teachers acting as foremen. At one time grade-school children were engaged, at piecework rate, to collect larvae directly from the fields, but this method proved unsatisfactory because many of the larvae obtained in this way were injured and a heavy mortality resulted (see shipments for 1929–30, table 6).

The laborers hired to obtain the larvae and cocoons from infested sorghum stems were usually seated in one or more large circles or in long rows on straw matting on the ground. Each person was given a can containing folded newspaper in which to put all corn-borer larvae as rapidly as they were obtained from the sorghum stems. All stems found to contain parasite cocoons, which the workers learned to recognize quite readily, were placed in a separate pile at the side of each "cutter." Each group of approximately 25 cutters was supervised by a foreman whose duty it was to see that the laborers of his group were continuously supplied with infested stems, at intervals to collect the stems which had been found to contain cocoons, and to replace collecting cans as often as necessary. Each cutter had bundles

FIGURE 6.—Women removing corn-borer larvae and parasites from sorghum stems, Lung Ching Tsun, Manchuria.

of infested stems within easy reach, and after examination the empty and cut stems were thrown back of the ring of cutters, where they were out of the way and could be collected at intervals and disposed of. Collecting cans containing larvae and stems containing parasite cocoons were taken by the foreman to a table situated at one section in the row or circle of cutters. Here an assistant, usually one of the permanent men well trained in the work, and his helpers would sort the larvae to remove all dead or injured individuals or any insects of species other than *Pyrausta nubilalis*. These men would also carefully remove the cocoons of parasites from the stems containing them and sort the various species (principally *Microgaster tibialis* and *Eulimneria alkae*) into separate groups.

The corn-borer larvae obtained were packed in practically the same manner as those sent to the United States from Europe by H. L. Parker and his assistants at the European parasite laboratory. The larvae were placed in strips of corrugated cardboard tied into packets or "cores",[7] 400 larvae being placed in each core (fig. 7, *A*). Each core containing larvae was placed in a metal shipping can, and each can was packed in an individual corrugated cardboard box (fig. 7, *B* and *C*).

Parasite cocoons were placed in pill boxes, 25 cocoons to each box, and the pill boxes containing the cocoons were packed tightly in wooden boxes. Cocoons of different species of parasites were packed separately.

In southern Japan (Miyakonojo and Kokubu sections), where larvae were obtained from millet, a somewhat different procedure was followed. Here farmers and their families collected the insects direct from millet stems and crop debris in their own and neighboring fields and brought them to a designated place. The collectors were paid at a piecework rate depending on the abundance of the borers in the field as determined by a previous survey made by trained assistants.

Borer larvae and parasite cocoons, which had been placed in shipping cans and boxes at the locations where collected, were shipped by fast express to Kobe,[8] Japan, where they were given a very careful final examination and packed in cartons and crates [9] (fig. 8) preparatory to shipment. When necessary, these crates of material ready for shipment were placed in commercial cold-storage warehouses under proper conditions of temperature and moisture until the arrival of a suitable ship upon which they could be shipped. Larvae and parasite cocoons were stowed in the vegetable or fruit cold-storage rooms of large ships sailing from Kobe direct to Boston via the Suez Canal. The number of larvae shipped from the Orient to the United States during the period 1928–32 is given in table 6.

The success of the shipments listed in table 6 may be judged by the fact that, unless otherwise noted (see shipments from Chosen and Manchuria, season of 1929–30), approximately 95 percent of the larvae contained therein were received at Arlington, Mass., alive and in good condition.

Parasites shipped in the cocoon or adult stages consisted of six species: *Phaeogenes* sp., *Brachymeria euploeae*, *Cremastus flavoorbitalis*, *Eulimneria alkae*, *Microgaster tibialis*, and *Inareolata punctoria* (table 7).

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[7] Cores impregnated with hot beeswax were used during the 1930–31 and 1931–32 seasons. The wax-impregnation process was developed by W. G. Bradley of the Arlington, Mass., laboratory, and was found to be an improvement, as it strengthened the cores and made them waterproof. The increased strength of the cores made it possible to dispense with the practice of tying them with wire, and small rubber bands were substituted. This saved considerable time in core preparation and had other advantages as well.

[8] One of the major changes in collection technic was the shipment to Kobe, by fast express (although the time necessary was 4 days in some cases), of all corn-borer larvae and parasite cocoons as rapidly as they could be packed and shipped. No refrigeration was available on the train trip, but, as shipments were made during cold weather, this was not an important factor. This procedure was begun in the fall of 1930. The previous year the larvae and parasites had been allowed to accumulate in the collection areas and were not taken to Kobe until the end of the collecting season in the field.

[9] The heavy wooden crates were first used for the shipments of larvae made during the 1930–31 season. These crates were prepared, and addresses and other marks were put on with the aid of stencils, before the busy collecting season began, which greatly speeded up the final packing.

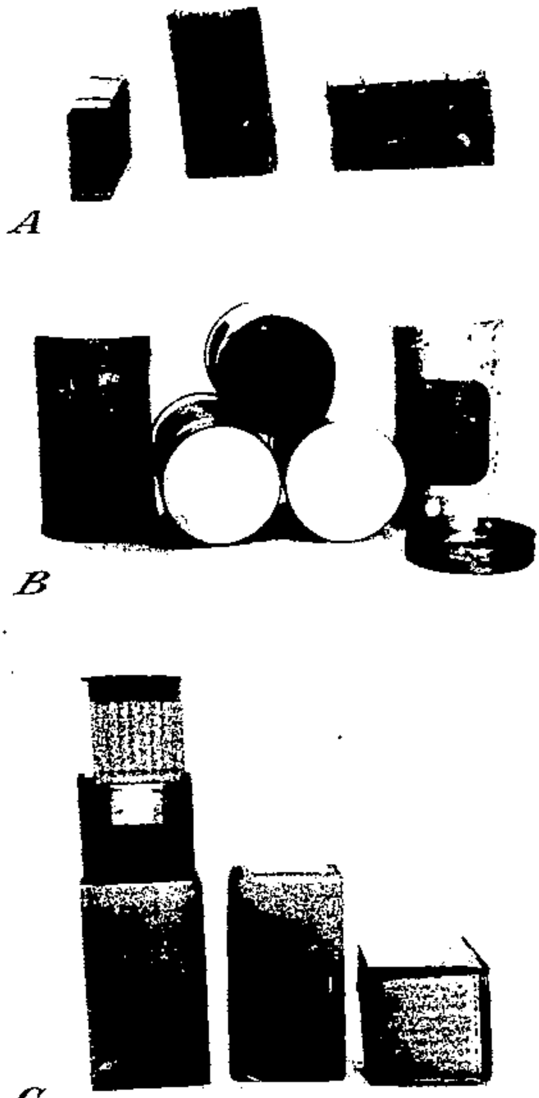

FIGURE 7.—Method of packing corn-borer larvae for shipment: *A*, Cores used for packing larvae; *B*, shipping cans; *C*, cans packed in separate boxes.

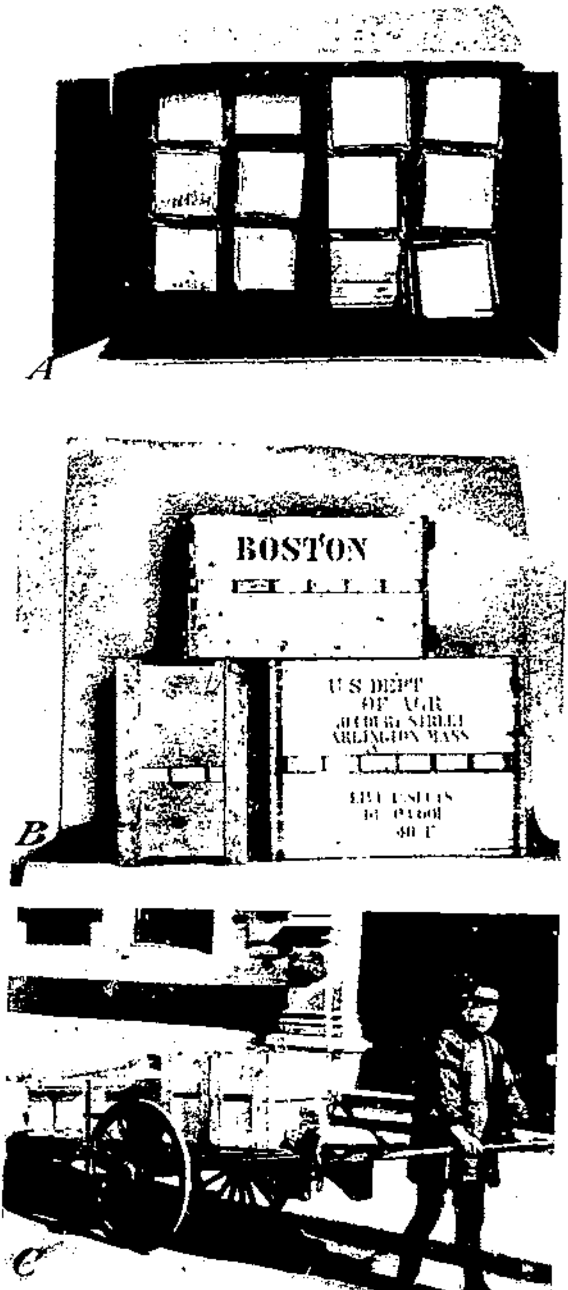

FIGURE 8.—Method of packing larvae for shipment: *A*, Boxes of larvae; *B*, crates of larvae ready for shipment; *C*, transporting shipment to wharf.

TABLE 6.—*Larvae of the European corn borer shipped to the United States[1] from the Orient during 4 seasons*

Section	Place collected[2]	Larvae shipped					Principal parasites in host larvae
		1928-29	1929-30	1930-31	1931-32	Total	
Kutchan	Kutchan, Japan	5,200				5,200	*Lydella grisescens* and *Apanteles thompsoni*.
Miyakonojo	Miyakonojo, Japan.	122,069	183,000	602,400	158,400	1,065,869	*L. grisescens*, *Cremastus flavoorbitalis*, and *Bracon atricornis*.
Kumamoto	Kumamoto, Japan			2,500		2,500	*L. grisescens* and *C. flavoorbitalis*.
Kokubu	Kagoshima, Japan.			2,000		2,000	*C. flavoorbitalis*, *Nemorilla floralis*, *L. grisescens*, and *Phorocera erecta*.
Kokubu	Kokubu, Japan				534,400	534,400	*C. flavoorbitalis* and *N. floralis*.
Chientao	Long Ching Tsun, Manchuria.		[3]140,000	72,900	[4]131,875 [5]276,400	621,175	*Inareolata punctoria*.
Heijo	Sharin, Chosen	[6]20,000	[7]38,000			58,000	*Macrocentrus gifuensis* and *L. grisescens*.
Heijo	Anshu, Chosen		[7]64,000		236,400	300,400	*M. gifuensis* and *L. grisescens*.
Kanko	Kanko, Chosen			1,600		1,600	*M. gifuensis* and *L. grisescens*.
Total		147,269	425,000	681,400	1,337,475	2,591,144	

[1] In addition to the total given, 12,000 larvae were sent to the Island of Guam in the 1930-31 season. These were obtained at Miyakonojo.
[2] The name of the place given as the collecting point refers to a locality with the town given as the center.
[3] 112,000 were infected with a fungus disease and 90 percent of them died.
[4] Spring collection, 1932.
[5] Fall collection, 1931.
[6] Collection from both Sharin and Anshu, Chosen.
[7] These larvae were infected with a fungus disease and 90 percent of them died.

TABLE 7.—*Parasites of the European corn borer shipped to the United States from the Orient in the adult and cocoon stages*

Parasite species	Place collected	Section	Stage shipped	1930	1931	1932	Total
Eulimneria alkae	Long Ching Tsun, Manchuria	Chientao	Adult	13			16,045
			Cocoon	[1]2,430	6,477	[3]7,125	
Inareolata punctoria	do	do	do	41			41
Cremastus flavoorbitalis	Kumamoto, Japan	Kumamoto	do	744	320		1,064
Brachymeria euploeae	do	do	Adult	10			10
Phaerogenes sp.	Utsunomiya, Japan	Utsunomiya	Pupal		120		195
			do		[2]40		
			Adult	35			
Microgaster tibialis	Long Ching Tsun, Manchuria.	Chientao	Cocoon	600	800	[3]1,350	2,750
Total				3,873	7,757	8,475	20,105

[1] 50 additional cocoons were sent to Guam in 1930.
[2] Estimate; 400 field-collected pupae were shipped.
[3] March 1932.

All of the parasites shipped in the cocoon stage reached Arlington in good condition. Considering the great distance traversed, those parasite shipments in the pupal or adult stage, or so packed and shipped as to allow adults to emerge en route, should be considered successful, since in the majority of instances at least 50 percent arrived at their destination alive.

AGRICULTURAL AND OTHER PRACTICES AFFECTING THE CORN BORER

There are a number of agricultural and other practices that affect the abundance of the corn borer in the Orient. These practices, although having a very direct effect on the corn borer, are not used primarily for this reason but constitute the custom of the people of the sections studied or are due to the prevailing economic conditions.

HARVESTING AND PROCESSING HEMP

As was mentioned in a previous paragraph, the corn-borer moths of the first summer generation, in Utsunomiya section, emerge late in July, thus coinciding with the harvesting season of hemp, the most important host plant in the section for this generation of the borer. At the time of harvest many pupae and full-grown larvae are present in the stems. Some of the moths have emerged and deposited eggs on the hemp leaves and a small number of immature borers are present on or in the plant. Soon after the plants are harvested by the customary method of grasping a handful at a time and pulling up the plants, the leaves and roots are cut off with a long, thin-bladed knife. The leaves fall to the ground and soon dry out, thus killing any eggs present. The stripped stems are then placed in large barrellike containers and boiled. This changes the color of the plants from a bright fresh green to a brown and serves to kill all borers and pupae in the plant at the time of treatment. Thus every stage of the corn borer on or in the hemp plant at the time of harvest is killed. (Incidentally this procedure also results in the death of any parasites present in the treated hemp stems.) However, there are still numerous moths in flight which furnish a nucleus for another generation, although the normal processing of hemp in this area must reduce the borer population tremendously. The above practice is not followed as a control measure for the insect, but if the condition of the crop will allow a slight deviation from the existing practice, harvesting a week or so earlier should very nearly eliminate the insect in this section.

HARVESTING AND THE USES OF GRAIN SORGHUM OR KAOLIANG

Grain sorghum, a member of the grass family, is harvested in practically the same manner throughout the Heijo, Kanko, and Chientao sections. In the fall, when the plants are fully mature, they are cut by hand with a sickle and left in shocks in the field to dry for a short period. The grain, which grows in a compact head at the top of the stalk, is harvested by pushing over the shocks and cutting off each head of grain with a sickle. A stem from 6 to 12 inches in length is left projecting below the grain head, and this stem is used for a handle or as a place to tie the heads into a bundle. Thousands of acres of grain sorghum are harvested in this primitive manner. The reaction of the corn borer in sorghum differs from its normal habits when infesting corn. In sorghum there seems to be less migration of partly grown larvae from the upper to the lower portions of the stalk, with the result that the large majority of the full-grown larvae are found in the upper 3 feet of stalk when the crop is cut in the fall. Therefore stubble becomes of small importance and the disposal of the remainder of the plant, particularly the upper third of the stalk, assumes greater interest.

The uses of sorghum stalks are many. In these rather primitive communities everything, including crop remnants, has an economic value. Sorghum stalks are sold as a commodity in the country markets, although the quantity disposed of in this manner is small. Large pottery vessels are made in certain places in Chosen and Manchuria, which are used by the natives to carry water from the wells or rivers to the houses or as containers for storing grain. When these jugs are shipped from the place of manufacture to the various markets, sorghum stems are often used for wrapping material. These stems are sometimes infested with the borer.

Sorghum stems often function as laths in the construction of the mud walls of farmhouses. The stems are placed vertically and horizontally and woven in and out, usually being tied with rope made of rice straw. After the framework of the house is completed and the side walls are covered with the sorghum-stem lath work, a thick covering of mud is put on. This forms the side walls of the completed house, and it is improbable that any borers inside the sorghum stems could emerge, since the wall becomes very hard. Therefore the use of sorghum stems for laths is a very good practice from the standpoint of corn-borer control.

The greatest use for sorghum stems in each of the three sections under consideration (Heijo, Kanko, and Chientao), however, is for fuel during the cold winter months. The greater proportion of all crop refuse is used in this manner, and it is practically the only fuel available to keep the houses, with their paper-covered doors and windows, warm and comfortable. Practically no wood or coal is used, since all the hills have been denuded of trees (with the exception of certain remote parts of Chientao section which still have forests, and parts of Chosen which have been reforested under Japanese supervision in an attempt to reduce the severe erosion caused by river overflows in the spring, and from these areas no trees may be cut without permission), and coal is far too expensive for an area where the daily wage is less than the equivalent of 20 cents of United States currency for a long day's work.

Sorghum stems are used commonly in Kanko section and to a lesser extent in Heijo section to build fences around the houses and yards. These fences are made of very tightly woven sorghum stalks, and their principal purpose is to prevent the cold winter winds from penetrating to the houses. These sorghum-stem fences are renewed each year and they are often heavily infested with overwintering corn-borer larvae. It is the writer's opinion that the fences in Kanko section are the main source of moths for infestation in the spring, and that if they were burned before moth emergence the corn borer would be reduced to negligible numbers. It is difficult to account for any other source of infestation each year, since, before spring, all loose sorghum plants have been burned as fuel, including portions of stems attached to the sorghum heads when harvested. The same disposition is made of any possible weed hosts, leaves, grass, and other plant material collected in the general scramble for fuel directly after the crops have been harvested in the fall. This collection includes the stubble of crops which have been dug or pulled up and taken to the farmhouses in the fall. Even hills, upon which there are few trees, and the graveyards on the side hills, are raked carefully for dead grass or other possible fuel. It is impossible to visualize a more intensive farm clean-up than actually takes place over northern Chosen and Chientao section of Manchuria. It should be remembered, of course, that these farm clean-up practices which diminish the corn-borer population also have a similar effect upon the parasite population. It is possible that the parasites emerge in the spring before the emergence of the borer moths and that there is a period during which the pest could be destroyed without greatly reducing the numerical abundance of the parasites. This possibility should be investigated.

In such sections as those under discussion, where there is a great centralization of authority, a regulation covering the destruction of the sorghum-stem fences, after the principal use for a fence as a windbreak had been fulfilled, should be easily put into effect to the benefit of the farming community.

Although the foregoing may be a digression, it will perhaps serve to give a better idea of the territory in which corn-borer studies have been conducted.

HARVESTING INDIGO

Two crops of indigo are harvested each year in the indigo-producing area of Shikoku Island (Tokushima section). The first crop is cut about 6 inches from the ground, and new shoots from old stems furnish the second crop. Harvesting of the first crop begins normally about July 10, at which time the moths of the first spring generation (as distinguished from the moths derived from the overwintering borers) are emerging. A considerable number of larvae and pupae are killed when the harvested crop is processed, as well as any eggs deposited on the leaves before harvesting, a situation analogous to that existing in Utsunomiya section on hemp plants. Nevertheless, the moths that are not killed are able to find abundant host material upon which to deposit their eggs on the parts of the indigo plant remaining in the field directly after harvest. Young shoots soon develop on the host plant, producing ample food for the young larvae, with the result that the second crop of indigo is also damaged by the borer.

BAMBOO POLES AS BEAN SUPPORTS

As mentioned previously, in Kutchan section bamboo poles are used to support the bean vines, and it is in these bamboo poles that the borer larvae pass the winter. In new poles the overwintering larvae are found above the top node, as they are unable to make their way into the other parts of the pole, but in old poles the bamboo often splits as it becomes dry and softer, thus allowing the borers to enter the various internodes. The bamboo supports are used for about 7 years before being discarded. They are usually stacked around the farmhouse or in a corner of the field during the winter months. It seemed quite evident that the main source of infestation in the spring must originate from borers that overwintered in the bamboo canes.

FARM DISPOSAL OF CROP DEBRIS

Certain other agricultural practices have their effect upon the borer. Thus, in Hitoyoshi, in southern Kumamoto section, millet stems and stubble are usually plowed under soon after the crop is harvested early in December, while in Miyakonojo section, which is also on Kyushu Island, the stems and stubble are allowed to remain on the fields until spring.

In general, it may be stated that the usual farm disposal of crop debris, or clean-up between crops, is much more thorough in the Orient than that generally practiced on the farms of the corn-borer infested territory in the United States. This contrast is to be expected between agricultural areas in one of which farm operations are extensive and handled by machinery whereas in the other the farm practices are intensive, primitive, and principally performed by hand labor. The contrast should be kept in mind when comparing oriental and American agriculture. Many recommendations have been made for corn-borer control in Japan which may be of practical value in that country but could not be adopted in countries where labor is higher priced. Even the extreme measure of collecting eggs from the plants and borers from the stems by hand has been recommended by Japanese entomologists as a practical control measure for *Pyrausta nubilalis*.

SUMMARY AND CONCLUSIONS

This bulletin is based upon the results of investigations of the European corn borer and its parasites in Japan, Manchuria, Chosen, and Taiwan.

The areas studied differ greatly with respect to temperatures and precipitation. Consequently they differ also with respect to the leading crops and agricultural practices.

The principal host plants of the corn borer in the region as a whole are hemp, corn, millet, grain sorghum, indigo, and beans.

The corn borer has 1 generation annually in the northern sections studied, 2 generations in the intermediate sections, and 3 or more generations in the southern sections.

Early studies soon made it apparent that no one parasite, or any one group of parasites, attacks *P. nubilalis* throughout the various sections in which investigations were being conducted. For example, in the warm, southern Japan sections (Kumamoto, Miyakonojo, and Kokubu) *Eulimneria alkae* is not found, and *Inareolata punctoria* is rare, but *Cremastus flavoorbitalis* and *Lydella grisescens* annually parasitize a considerable, although variable, percentage of the corn-borer larvae present. Conversely, in the colder sections (Kutchan and Chientao) *C. flavoorbitalis* and *L. grisescens* are unimportant, but *E. alkae* and *I. punctoria* are valuable as parasites.

In areas such as the Heijo section of Chosen, with an intermediate climate, certain parasites typical of the warm or cold types of climate coexist. Thus *Lydella grisescens* (a southern species) and *Inareolata punctoria* (a northern species) both exist in Heijo section. This is undoubtedly a fortunate provision of nature, since, with the fluctuations in weather conditions away from the normal, the climate in this transitional region would become increasingly similar to either the cold or warm type of climate, and either the southern (warm region) or northern (cold region) species of parasites would be expected to assume increasing or decreasing importance, depending on whether the fluctuation in climatic conditions is toward the warm or cold climate type.

The foregoing considerations with regard to these intermediate sections are not altered by the fact that one or more additional parasite species, not found in one or both the extreme climates, may be present and perhaps dominant in the transitional section. In Heijo section *Macrocentrus gifuensis* is the parasite species dominant on *Pyrausta* *nubilalis*, although this parasite is not found, except in rare instances, in Chientao section.

Considering the above factors, as well as the extent of the corn-borer infested territory in the United States, and especially the probable future geographical distribution of the pest in its new environment, it was evident that the proper policy to follow with regard to parasite introductions against *Pyrausta nubilalis* was to collect and ship all the primary parasite species obtainable without regard to the stage of the host which they attacked. Under the conditions present in the corn-borer problem, the theory of parasite competition was believed to be of academic rather than of practical interest.

Some valuable primary parasites of the corn borer exist in the Orient that are not present in other areas in which parasite investigations have been carried on. *Cremastus flavoorbitalis* and *Xanthopimpla stemmator* are included in this category. In addition to the parasites obtainable only from the Orient, such as the two species mentioned above, there are a number of other entomophagous insects, such as *Bracon atricornis* and *Nemorilla floralis*, which, although present and obtainable in Europe in limited numbers, are much more readily obtained from the Orient.

There are indications that certain parasites found in the Orient, particularly *Macrocentrus gifuensis* and *Inareolata punctoria*, although morphologically indistinguishable from similar species found in Europe, nevertheless exhibit biological differences when liberated in North America.

Intensive investigations in the oriental areas would undoubtedly lead to the discovery of additional parasites of the corn borer, particularly of the egg stage (which would be especially valuable in the establishment of a parasite "sequence"), and would possibly indicate locations where known parasites, now difficult to obtain, might be secured in large numbers.

Owing to the low cost of labor, the collection of insects in the Orient tends to show greater return for expenditure of funds than could be expected from a similar expenditure in almost any other part of the world.

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