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THE EUROPEAN CORN BORER AND ITS CONTROLLING FACTORS IN EUROPE
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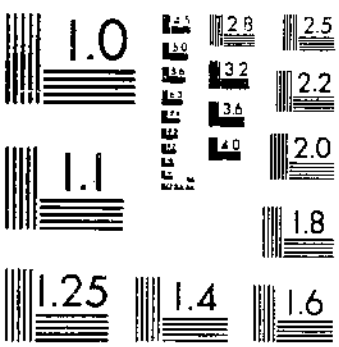

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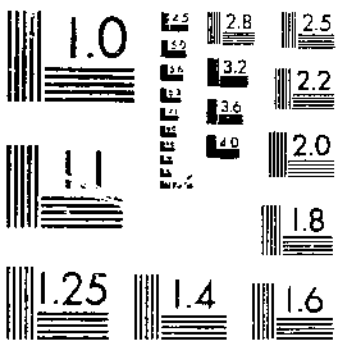

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THE EUROPEAN CORN BORER AND ITS CONTROLLING FACTORS IN EUROPE

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HISTORY AND SCOPE OF THE INVESTIGATIONS IN EUROPE

The investigations of the European corn borer (*Pyrausta nubilalis* Hübner) and its controlling factors in Europe, of which the results are summarized in this bulletin, were initiated in the fall of 1919 under instructions from L. O. Howard, then Chief of the Bureau of Entomology. Little information was then available as to the status and controlling factors of *Pyrausta nubilalis* in Europe, but a preliminary investigation conducted at the request of the Bureau of Entomology by Madame Vuillet of the French entomological service, under the direction of Paul Marchal, revealed the presence of at least two species of parasites attacking the borer in southwestern France. After a consultation with the French entomologists, a temporary laboratory was therefore established on the outskirts of the town of Auch, in the middle of the southwestern corn belt, and collections for the study of parasites and for shipment to the United States were immediately begun. Three species of parasites, *Zenillia roseanae* B. B., *Masicera senilis* Meig., and *Eulimneria crassifemur* Thoms., were discovered associated with the hibernating larvae,

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and an experimental shipment of stalks containing cocoons of *Eulimneria crassifemur* and parasitized caterpillars was made in the spring of 1920. During the summer of that year, which was unusually warm for the region, the seasonal history of the corn borer was of the two-generation type, the majority of the larvae pupating in late July and early August. Numerous collections of the summer-generation larvae were made, resulting in the discovery of three additional species of parasites, *Dioctes punctoria* Rom., *Exeristes roborator Fab.*, and *Microbracon brevicornis* Wesm. During this season Doctor Howard visited Europe, and, as a result of his consultations with entomologists in a number of areas infested by the corn borer, new avenues of investigation were opened up. Several shipments of the stalks of *Artemisia vulgaris* containing cocoons of *Microgaster tibialis* Nees were thus received from Belgium, through the courtesy of G. Severin, of the Musée Royal d'Histoire Naturelle in Brussels, and a large number of hibernating caterpillars and an interesting collection of reared parasites was supplied by F. Silvestri and assistants working under his direction. In the fall of 1920 preliminary investigations were also made in the Mediterranean coastal region in cooperation with M. Poutiers, director of the Insectarium de Menton, and in the valley of the Arno, in central Italy, in cooperation with Professors Berlese and Del Guercio, of the entomological station at Florence.

In the winter of 1920–21 collection and shipment of hibernating larvae of the borer and the cocoons of *Eulimneria crassifemur* were resumed in the vicinity of Auch on a much larger scale than in the previous season. Cornstalks were purchased at a low rate from the farmers of the surrounding country and on their arrival at the laboratory dissected by temporary workers specially trained for this purpose. As a result of previous consultations with Doctor Howard, the method of shipping infested stalks was now abandoned, the corn-borer larvae being shipped in wooden boxes between layers of specially selected corn pith and the parasite cocoons in separate containers. This method was found after a little experiment to be much more economical and efficient than the one previously employed.

In the summer of 1921, in order to obtain a more central location for the work, within reasonable range of the principal corn-borer areas of Europe, the laboratory was transferred to Hyeres, on the French Riviera. The investigations undertaken in this area soon revealed the presence of several parasites hitherto rare or unknown, notably *Dioctes punctoria*, *Microbracon brevicornis*, *Exeristes roborator*, and *Phaeogenes planifrons* Wesm. After a number of preliminary experiments, a method was developed for the rearing in confinement of *M. brevicornis*, of which 1,300 cocoons were shipped in the fall to the laboratory in Arlington, Mass., together with instructions for breeding this species, which was subsequently reared and liberated in large numbers in the infested areas.

The absence of parasites in the winter stalks collected in the Mediterranean region made it necessary to return to the southwest of France in order to obtain material of the hibernating species. Two carloads of cornstalks therefore were purchased for this purpose in the Department of the Aude and shipped to Hyeres, where

the hibernating caterpillars were taken out for shipment. Lack of assistance prevented the establishment of a collecting station in the southwest until the middle of the hibernating season, but after that time a considerable quantity of material was obtained. During the summer months an experimental shipment of cocoons of *Dioctes punctoria* was also made in cold storage from the region of Hyeres.

In the winter of 1922–23 the parasitism in the hibernating caterpillars of *Pyrausta nubilalis* was so low that it was considered useless to collect them for parasite rearing, though a shipment of parasite cocoons was made from the stalks examined. In the spring of 1923 the search for parasite material was extended to the weed areas of northern France, and a small preliminary shipment of Microgaster cocoons was made for experimental purposes.

During the summer months an additional shipment of *Dioctes punctoria* was made. After some careful laboratory studies a practical method of rearing *Exeristes roborator* was developed, and later in the season over a thousand cocoons of this species were shipped to the Arlington (Mass.) laboratory in cold storage and used there for breeding on an extensive scale in the following seasons.

In the fall of 1923 the winter work in southwestern France was temporarily abandoned in favor of the collection of hibernating larvae and parasite cocoons in the weed areas near Paris, and although the lack of funds prevented the organization of this work on a large scale, enough material was obtained for satisfactory shipments of hibernating caterpillars of Pyrausta and cocoons of Eulimneria and Microgaster.

In the summer of 1924, after a preliminary scouting trip in northern Italy, collection of the parasites attacking the summer generation was begun in the region of Bergamo. The courteous assistance of Doctor Zapparoli of the Stazione di Maiscoltura and the directors of the regional agricultural offices greatly facilitated the organization of this work. During the following winter centers for the collection of hibernating parasites and caterpillars were established at Bergamo, in Italy, at Auch, in southwestern France, and in the region of Paris, and provided a considerable quantity of material for shipment.

In 1925 summer collections were again organized at Bergamo. But as few parasites were present in the winter stalks, the collection of hibernating parasites and caterpillars was abandoned in Italy, and the work in southwestern France and in northern France was organized on a somewhat larger scale.

Careful scouting operations and test dissections during the spring and summer of 1925 revealed the presence in considerable numbers of two parasite species, of which one, a species of Apanteles, had been previously found upon two occasions, and the other, *Macrocentrus abdominalis* Fab., was new as a parasite of *Pyrausta nubilalis*. In order to obtain a supply of these parasites, two new substations were organized in northern France, at Lille and Angers. The operations in southwestern France were also extended during this season.

The increased appropriations available for the fiscal year 1926–27 made it possible to organize the work on a larger scale than ever before. Large-scale operations were conducted in Bergamo, where about 150 collectors were employed. In the southwest of France

eight collecting centers were established with 135 collectors, and in the north of France stations were organized at Paris, Lille, Le Mans, Tours, Arras, and Douai, with 26 collectors.

During the period of years covered by the work, 3,899,813 caterpillars were collected and shipped to the United States for the rearing of parasites. Ten species of parasites, represented by 690,388 individuals, have been obtained from the material sent. This group of parasites includes all the important natural enemies of the corn borer in the regions studied up to the present.

The results obtained in this phase of the work have been due in large measure to the energy and efficiency of the temporary field superintendents, among whom W. Gamkrelidze deserves special mention. The organization of the large-scale collecting operations in France and the conduct of the collecting stations in the southwestern corn area have been for several years in charge of this entomologist, who has discharged his very difficult duties in a most satisfactory manner and has also furnished some of the technical data embodied in this bulletin.

Table 1, enumerating the yearly shipments of *Pyrausta nubilalis* larvae and parasites, will give an idea of the progress of the parasite work from its inception to the present time.

TABLE 1.—*Parasites of Pyrausta nubilalis shipped to the United States from France and Italy to January 31, 1928*

Fiscal year (ended June 30)	Number of host larvae	Number of parasites									
		Eulimneria	Dioctes	Exeristes	Phaeogenes	Microgaster	Apanteles	Macrocentrus	Microbracon	Zenillia	Masicera
1920	20,207	60								120	88
1921	76,258	7,620	10							784	290
1922	75,645	350	450						1,300	63	87
1923		1,000	168	1,061		100					
1924	8,165	583				2,160					
1925	154,408	2,037	2,043		1,601	9,226				689	185
1926	562,000	14,615	2,157	250	5,440	34,741	5,935	3,885		3,865	2,277
1927	1,601,500	34,804	11,296		17,017	166,722	33,175	11,447		42,704	8,336
1928	1,400,000	25,191	7,500		30,205	120,600	29,250	16,200		31,500	14,600
Total	3,903,813	86,860	23,024	1,411	54,263	333,549	68,360	25,532	1,300	79,725	15,764

[1] Estimated as contained within the 1,400,000 host larvae.

The operations the results of which are summarized in Table 1 represent only a single phase of the work carried on in connection with the corn borer. Before collections could be made or shipments of parasites undertaken, careful studies of the biology of the various species involved were necessary in order to eliminate the risk of introducing secondary parasites and in order to determine the developmental stages best adapted for shipment. Numerous experiments were conducted with the object of deciding what species could be reared under laboratory conditions and in order to determine the most practical methods of rearing.

The majority of the important parasites (Eulimneria, Dioctes, Masicera, Zenillia, Microgaster, Exeristes, and Microbracon) were thus reared successfully, although on account of the care required to secure good results with most of the species it was usually found more practical to rely on direct collection in the field.

To permit the establishment of the collecting stations at the points most favorable for the purpose, extensive preliminary investigations were required. Collections of larvae were made from many points in the areas studied, and the parasitism was determined by laboratory dissections, the collecting stations being established in the places where both the host and its parasites were abundant.

An attempt also has been made, by the collection of data on infestation and parasitism from generation to generation, to gather a comprehensive idea of the status of the European corn borer and of the principal controlling factors acting upon it in all the clearly differentiated sections of its European habitat. The work of collecting, breeding, and shipping parasites has necessarily limited the scope of these studies, which really require the continuous attention of several trained investigators. Nevertheless, although much no doubt remains to be discovered, it is believed that the data already accumulated give a fair general idea as to the position of *Pyrausta nubilalis* and the nature and action of its principal controlling factors in most parts of Europe. In view of the importance which the corn-borer problem has now assumed in the United States, it has seemed desirable to publish the general survey of the situation embodied in this bulletin.

THE GEOGRAPHICAL BOUNDARIES, TOPOGRAPHY, CLIMATE, AND AGRICULTURE OF THE AREAS STUDIED

Before considering the controlling factors of *Pyrausta nubilalis* in Europe it seems desirable to describe the principal biogeographical areas in which observations have been made. These areas, the position of which is shown on the accompanying map (fig. 1), are as follows: France—the Mediterranean, Aquitainian, Rhodanian, Vosgian, Sequanian, and Armorican zones; Spain—the Galician zone; Italy—the Campanian and Padovian zones; Central Europe—the Danubian zone.

FRANCE

THE MEDITERRANEAN ZONE

The Mediterranean zone, or zone of the olive, comprises the narrow coastal area of southern France lying between Spain and Italy, bounded on the west by the Pyrenees, on the east by the Ligurian Alps, and on the northwest and northeast by the foothills of the Cevennes and the Alps, separated by the valley of the Rhone, which broadens southward into an extensive low-lying delta. This zone includes also the Rhone Valley itself as far as Valence and Privas.

The Mediterranean climate is characterized in general by its warmth, but owing to the topography of the region the local variations are considerable.

On the coast the mean annual temperature varies between 55° and 59° F., the yearly amplitude being only about 27° to 28°. The mean summer temperature is about 70°, with an average maximum of 90°; that of the winter is above 43°, with an average minimum of 28°. Frosts are uncommon. Although snow falls occasionally, it does not last, except in the mountains. The eastern extremity of the coast (Department of the Alpes-Maritimes), with a southern exposure

and a mountain barrier protecting it from the northern winds, is particularly favored in regard to temperature. West of the Rhone Valley the climate is more severe. The cloudiness is low, and the rainfall, though fairly abundant (27.5 to 31.5 inches) at certain points east of the Rhone, occurs in the form of heavy downpours of short duration, after which the ground dries up very rapidly, owing to the low cloudiness and the strong northerly winds. Little rain falls in the summer months, during which the country takes on a very arid aspect, irrigation being generally essential wherever market gardening is practiced.

In the Rhone Valley conditions are somewhat different. In the delta area (Bouches-du-Rhone) the rainfall is considerably less than on the coast. Farther up the valley the precipitation is about the

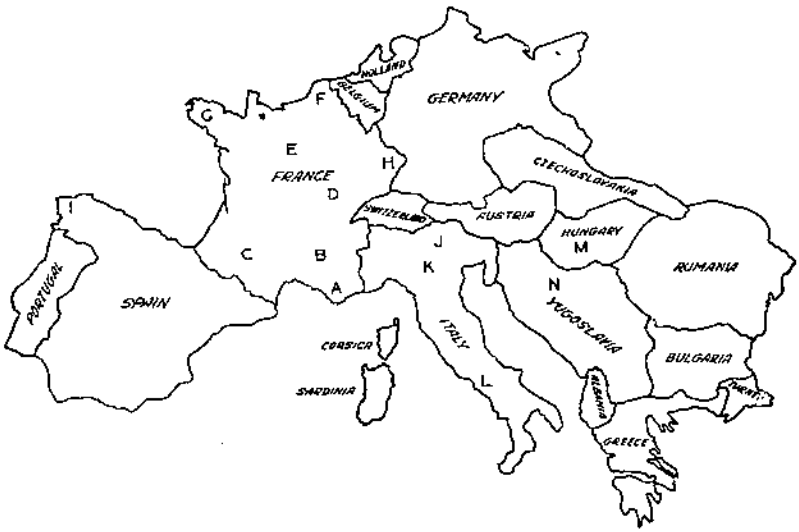

FIG. 1.—Map showing principal biogeographical zones in which investigations of *Pyrausta nubilalis* and parasites have been made in Europe, 1919–1927. A, Mediterranean zone (coast); B, Mediterranean zone (Rhone Valley); C, Aquitainian zone; D, Rhodanian zone; E, Sequanian or Parisian zone (south); F, Sequanian or Parisian zone (north); G, Armorican zone; H, Vosgian zone; I, Galician zone; J, Padovian zone (north); K, Padovian zone (south); L, Campanian or Neapolitan zone; M, Danubian zone (Hungarian); N, Danubian zone (Yugoslavian)

same as on the coast, but is more evenly distributed throughout the year, the fall rains being less abundant and the summer wetter than on the littoral. The climate is also considerably colder, especially in the upper part of the valley. An important characteristic of the Rhone Valley is the cold northwest wind, known locally as the mistral, which blows very frequently, being especially violent toward the mouth of the Rhone.

The accompanying climographs (fig. 2, A and B) for Toulon and Valence will make clear the general character of the climate in the two districts in which most of the investigations have been carried on.

The agricultural features of the various parts of this region differ considerably. The most characteristic plant is probably the olive, which is cultivated along the lower slopes of the hills, ordinarily cut into terraces, and is found as far north as Lyons. In the

irrigated bottom lands are found fruit trees, vegetables, and flowers; and palm, aloe, agave, prickly pear, mimosa, and eucalyptus give a subtropical note to the flora. The coastal area west of the Rhone comprises the vinelands of Languedoc, while the delta itself is de-

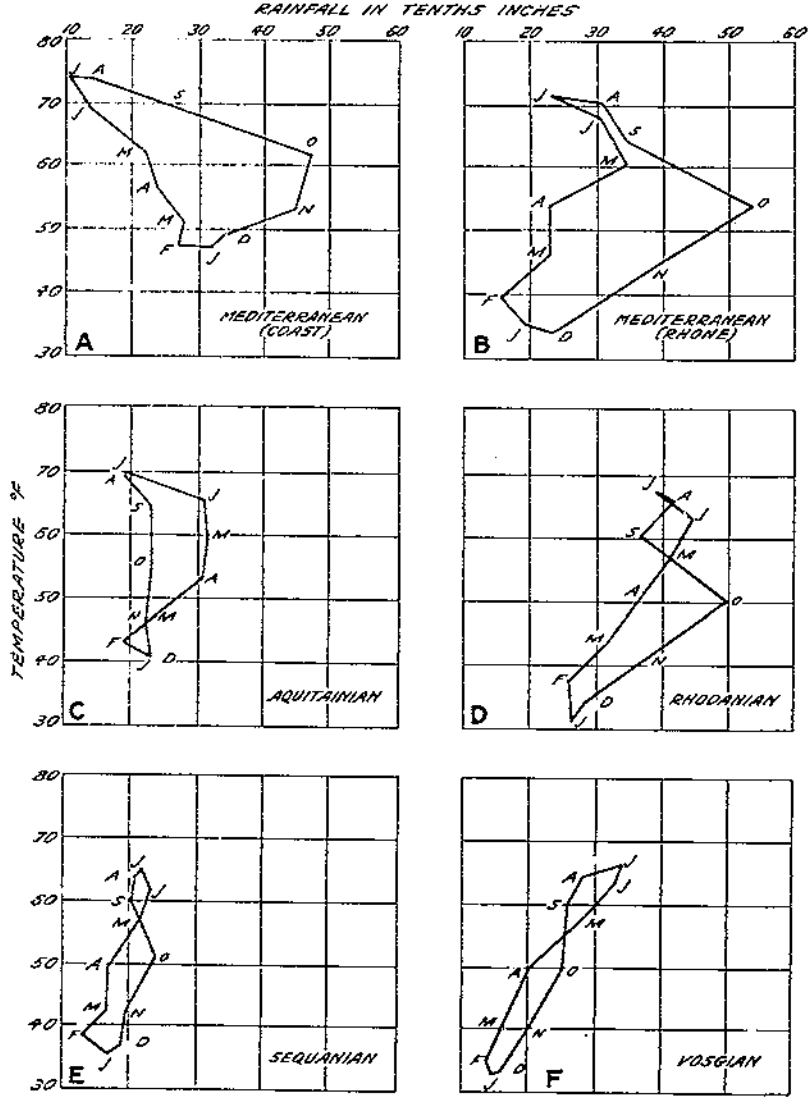

FIG. 2.—Climographs of selected biogeographic zones in Europe. A, Mediterranean (coast); B, Mediterranean (Rhone); C, Aquitainian; D, Rhodanian; E, Sequanian; F, Vosgian. Letters in the graphs stand for the months of the year

voted mainly to stock raising. There is little corn west of the Rhone, but corn is grown to some extent for grain on the eastern littoral and in the Rhone Valley, where broomcorn also is cultivated extensively at certain points.

THE AQUITAINIAN ZONE

The Aquitainian zone comprises the southwestern corner of France. It is bounded on the south by the Pyrenees and on the north and northeast by the foothills of the central plateau. This region has a roughly triangular outline, its base being formed by the Atlantic seaboard, and its apex being directed toward the Gulf of Lions, from which it is cut off by the mountains lying between the Corbieres and the Cevennes.

The climate of this region is in general mild, except in the higher parts of the Pyrenees, but the yearly range is greater than in the Mediterranean zone, the maximum summer temperature being somewhat higher and the minimum winter temperature distinctly lower. The mean annual temperature is about 53° to 57° F., that of the winter above 40°, and that of the summer in the neighborhood of 68°, the average annual variation being about 30°. The average maximum for Toulouse is about 96°, and the average minimum about 17°. The rainfall is heaviest in the mountainous Departments of Basses-Pyrenees and Hautes-Pyrenees, where it averages about 50 inches. It is lowest in the Departments of Gers, Lot, Lot-et-Garonne, and Tarn-et-Garonne, which form the plain of the Garonne River, and in which the average rainfall is only about 30 inches. In the other Departments the average precipitation is a little over 35 inches. The distribution of the rainfall tends to the maritime type toward the Atlantic seaboard and to the continental type in the inland Departments. The number of light rains and showers is generally greater and the number of heavy downpours less than in the Mediterranean coastal area, and as the cloudiness is markedly higher, the climate is on the whole much moister. The principal rainy season comprises the months of April, May, and June, a secondary maximum, only slightly above the normal, occurring in September and November.

The climograph for this region (fig. 2, C) represents the average conditions at Auch, where the majority of the data were collected.

The agricultural characteristics of the Aquitainian zone are rather varied. The plains of the Garonne and the Adour are devoted mainly to cereals, with a mixture of vineyards. The highlands of the Pyrenees furnish pasture for sheep and cattle. A great part of the area near the Atlantic seaboard is occupied by the pine forests of the Landes, bordered on the north by the celebrated vineyards of Bordeaux. This region contains approximately 80 per cent of the total area planted in corn in France, the acreage officially given for this crop in 1922 being about 650,000 acres.

THE RHODANIAN ZONE

The climate of the Rhodanian zone characterizes the region east of the upper Rhone and the valley itself as far south as Privas, Valence, and Digne. A great part of this zone is mountainous. In the low levels the climate is less rigorous than at higher elevations, but it has nevertheless a well-marked continental character, being rather cold in winter and hot in summer.

The mean annual temperature for the districts in which the writers' investigations have been made is about 51° F.; the average

absolute maximum may be as high as 93° and the average absolute minimum a little below 10°.

The cloudiness is somewhat higher than on the coast; fogs are frequent toward the confluence of the Saone and the Rhone. The rainfall is rather high, with a slight maximum in fall and another in summer. North winds dominate; the mistral frequently blows with violence and, alternating with warm south winds from the Mediterranean, determines rapid variations in temperature. The climograph for this zone (fig. 2, D) is constructed with data from the vicinity of Lons-le-Saunier, in the Department of Jura. The annual rainfall in this district averages about 42 inches.

The Jura area, in which the investigations have been carried on, is the second area in France in point of importance for the cultivation of corn, the acreage of this crop in the three Departments of Ain, Jura, and Saone-et-Loire for 1922 having been approximately 65,000 acres. Wheat is grown rather extensively, and in certain districts large and valuable vineyards exist. Hops also are cultivated to some extent in the Cote d'Or Department.

THE VOSGIAN ZONE

The Vosgian zone comprises the northeastern corner of France and takes in Lorraine and part of Champagne and Burgundy. It lies for the most part above the January isotherm of 33° F. and between the July isotherms of 64° and 68°. The topography is diversified, and local differences in climate are therefore considerable. The climate in general is continental, characterized by long, cold winters and hot summers. The mean annual temperature is between 48° and 50°, that of the winter is about 34° and falls even to 32° in the valley of the Moselle, while that of the hottest month is about 66°. The maximum rainfall is in the summer months and is highest in the mountainous districts of the Ardennes. Snow is frequent in winter.

The Rhine Valley, in which the writers' observations on *Pyrausta nubilalis* have been made, has a lower rainfall than the mountainous districts. According to Angot (*1*),[1] the average rainfall for the low-lying regions is about 27 inches, the figure for Mülhausen being a little higher. In the plain there is a dry season comprising the months of November to April, inclusive, with a very marked minimum in February, and a rainy season extending over the six months from May to October, with a maximum in June and July. The average absolute maximum for Strassburg is about 84° and the average absolute minimum about 68°. (Fig. 2, F.)

The relatively warm summer which characterizes the Rhine Valley is responsible for the fact that a considerable quantity of corn is grown, the total area in this crop for the two Departments of Bas-Rhin and Haut-Rhin taken together being about 8,000 acres. The Rhine Valley contains also important and valuable vinelands as well as large areas of tobacco, hops, and cereals.

[1] Italic numbers in parentheses refer to "Literature cited," p. 61.

THE SEQUANIAN ZONE

The Sequanian zone includes the lowlands of north-central France and takes in the region of Flanders and the basin of the Seine, with the exception of its more eastern parts.

The climate (fig. 2, E) is essentially transitional in character. It is mild and moist, but less uniform than the Armorican climate and less extreme than the Vosgian climate. The mean temperature of the year is about 50° F. and that of the winter is 35° to 37°. The average absolute minimum temperature is about 12°, the average absolute maximum about 93°. Frosts occur at intervals from November to May. Grapevines are not infrequently injured by frost during May in the neighborhood of Paris. The maximum rainfall and the minimum summer temperatures occur in the northwestern part of the Seine Valley, where the Sequanian climate merges into the Armorican and assumes maritime characteristics. The minimum summer temperatures occur in Champagne.

According to Angot (*1*), there is a dry season of five consecutive months, December to April, inclusive, with a very marked minimum in February, and a rainy period, including the months from May to October, with two maxima in June and October, the principal one being that in June. In the vicinity of Lille, where extensive collections also have been made, the climate is markedly colder than that of the Parisian area, but the rainfall is heavier, the average for Lille being about 27 inches as against 21 inches for the Parisian district.

The Sequanian zone includes in the east the vinelands of Champagne, but it is for the most part a region of mixed agriculture. The low temperatures during the growing season render it unsuitable for the culture of corn, but in the waste areas along the railway lines which traverse it and around its great cities, especially Paris, *Artemisia vulgaris* L. furnishes an abundant supply of food for the larvae of *Pyrausta nubilalis*.

THE ARMORICAN ZONE

The Armorican zone characterizes the region of Brittany. Of all the climates of France it is the one in which the mean annual fluctuation in temperature is least. The winters are very mild and the summers cool. This uniformity is due chiefly to the prevalence of the west winds, which are very humid, bringing fogs and heavy clouds that diminish the intensity of nocturnal radiation. The mean annual temperature is between 51° and 53° F., that of the winter is above 41°, and that of the hottest month is below 65°, except in the more southerly parts of Brittany.

The rains of this region, though usually fine, are very frequent and of long duration. The total precipitation in the Department of Finistere is about 36 inches. The climograph (fig. 3, B) represents the mean monthly temperature and rainfall at St. Malo.

The soil of this region is rather poor. In the northern part of the peninsula hemp and flax constitute the most important crops, while the so-called landes of central and southern Brittany are chiefly devoted to the raising of sheep, cattle, and pigs. The mild, moist climate permits the development, though not usually the maturation,

of many plants usually considered as southern, such as the pomegranate, aloe, magnolia, and oleander. Fig trees prosper and ripen their fruit in this district. A small quantity of corn is grown for grain in the Department of Morbihan.

SPAIN

THE GALICAN ZONE

The Galician zone includes the northwestern corner of Spain. The climate is of the maritime type, mild and equable, with a very moist atmosphere and heavy rainfall which amounts to over 63 inches in the western part of Galicia, the minimum precipitation being in the months of June, July, and August. The summer is cool and the winter mild. The mean annual temperature at Santiago de Compostela is about 55° F., the yearly range being about 20°. The average absolute maximum is 95°; the average absolute minimum is 28°, but snowfalls and frosts are rare. The average temperature for August, which is the hottest month, is 66°, and the average temperature for January, the coldest month, is 45°. The appended climograph (fig. 3, A) represents conditions at Santiago de Compostela.

The agriculture of this region is in general rather poor, but in spite of the remarkable climatic conditions corn is cultivated extensively.

ITALY

The writers' investigations of *Pyrausta nubilalis*, although they have covered at one time or another practically all parts of the Italian peninsula, have been carried on principally in the region of Naples and in the Po Valley.

THE CAMPANIAN ZONE

The Neapolitan or Campanian zone closely resembles the French Mediterranean zone both in climate (fig. 3, C) and vegetation. However, the Neapolitan district is warmer than the French Riviera, so that such fruit as oranges and lemons can be successfully cultivated. Olives and grapes are extensively grown. Cereals and corn also occupy a very important place in the agriculture of this Province, some 425,000 acres being devoted to the latter crop.

THE PADOVIAN ZONE

The character of the Po Valley is, however, very different. The climate here tends to the continental type, with cold winters and hot summers. The mean annual temperature at Milan is 54.5° F., with a yearly range of about 43°, the average minimum slightly over 32°, and the average maximum about 75°. The average absolute minimum for this region is about 7° and the average absolute maximum is about 101°. The climate on the whole is rather moist, the annual rainfall at Milan averaging about 40 inches, with a maximum in fall and a second maximum in spring, the winter months being drier and the summer months wetter than in the Campanian or Neapolitan zone. The extremes of temperature are greater and the rainfall lower in the districts of the plain than in those lying near the mountains.

In order better to classify their data the writers have therefore divided this area into the north Padovian zone, including the region of Bergamo in Lombardy, and the south Padovian zone, including

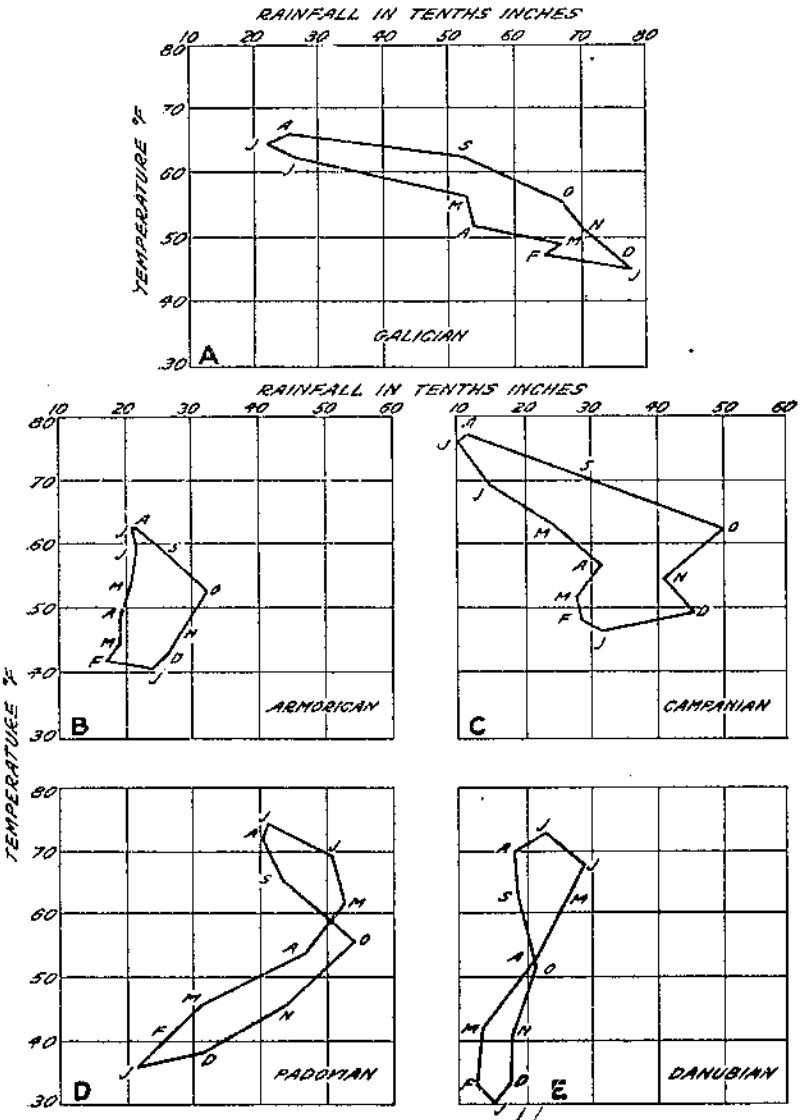

FIG. 3.—Climographs of selected biogeographic zones in Europe. A, Galician; B, Armorican; C, Campanian; D, Padovian; E, Danubian. Letters in the graphs stand for the months of the year

the region of Piacenza in Emilia. The climograph (fig. 3; D) represents conditions at Bergamo.

The culture of the olive is here relatively unimportant, the land being mainly devoted to cereals, including rice, though vineyards also are numerous and extensive. Corn occupies a very important place

in the agriculture of the Po Valley, some 2,300,000 acres being devoted to this crop in the four Provinces of Venice, Piedmont, Lombardy, and Emilia.

CENTRAL EUROPE

THE DANUBIAN ZONE

The Danubian zone, which now includes parts of Hungary, Czechoslovakia, Rumania, Yugoslavia, and Austria, includes the great fertile plain known as the Alfold, bounded on the west by the Italian and Austrian Alps, on the north by the Carpathians, on the east by the Transylvanian and on the south by the Illyrian Alps, and is drained by the Danube River and its tributaries.

The climate is of the continental type, with cold winters and hot summers. The mean annual temperature is about 49° F., with a range of from 42° to 46°. The mean July temperature is about 70°, the mean January temperature from 25° to 28°, the average absolute maximum varies from 91° to 94°, and the average absolute minimum from 10° to 3.74°.

The average annual rainfall is about 29 inches. The maximum precipitation occurs in the months of May, June, and July, with a second maximum in October. The winter is cold and dry, but the snowfall provides a covering sufficient to protect the winter grains. The climograph (fig. 3, E) for this zone represents conditions at Szeged.

The agriculture of the Danubian zone varies considerably in different localities, but in the main it is a grain-growing area, the most important crops being the cereals, though potatoes and sugar beets are also extensively cultivated. In 1926 more than 2,700,000 acres were planted to corn in the Hungarian part of this zone alone.

DISTRIBUTION, HOST PLANTS, AND NUMBER OF GENERATIONS OF PYRAUSTA NUBILALIS IN EUROPE

From the data now available it is evident that the European corn borer is very generally distributed throughout Europe, where its principal host plants are corn, millet, broomcorn, hops, and hemp, and certain wild plants. In the areas of western and central Europe which have been studied up to the present, the favored hosts undoubtedly are corn (*Zea mays*) and mugwort (*Artemisia vulgaris*). In districts in which corn is grown, such as southwestern France, northern Spain, northern Italy, and the Mediterranean littoral in general, the insect has very seldom been found in any other plants, whether cultivated or wild, even when in close proximity to infested fields or intermingled with corn. For example, in districts such as that around Hyeres, on the French Mediterranean coast, the plots of corn are very frequently interspersed with beans, melons, or tomatoes, for which the corn plants furnish shade, but although these plants have been examined frequently, practically no infestation by the corn borer has been discovered, even in fields in which from 50 to 90 per cent of the corn plants were attacked. On one occasion one or two larvae were found in tomatoes and beans planted in a cornfield, and on another a slight infestation was observed in weeds (Polygonum and Amaranthus) growing among the plants, but in

general such infestation is absolutely negligible. In no area studied by the writers has any perceptible attack been noted either on truck crops or flowering plants.

In the Rhone Valley and southwestern France both millet and broomcorn have been examined repeatedly, but no infestation of the slightest importance has ever been found, even in fields adjacent to infested corn plots. Many fields of broomcorn also have been visited in the corn-growing areas of northern and central Italy, but few signs of attack have ever been discovered. Some examinations of hop fields in the corn-growing regions near Dijon, in eastern France, also have been made, but no signs of attack were observed. It seems certain, to judge from the reports of numerous observers, that some of the crops mentioned, such as millet, broomcorn, and hops, have, in certain districts and at certain times, suffered severely from the attack of *Pyrausta nubilalis*. But in the areas studied the writers have not observed in the plants mentioned even slight economic damage. No fields of either broomcorn, millet, or hops have been observed in which the general infestation was as high as 5 per cent.

In the corn-growing area of eastern and southern France, for example, in the environs of Dijon and in the Rhone Valley, the larvae of Pyrausta are found in both corn and Artemisia, but in northern Italy and southern France no infestation of Artemisia has been found, although the borers are common in corn.

In the areas of western and northern Europe in which corn can not be grown, the larvae of *Pyrausta nubilalis* have been found in a number of species of weeds, but the most important host plant undoubtedly is *Artemisia vulgaris*. This plant, sometimes called common mugwort, widely distributed in Europe, has become naturalized in America, where it exists, according to Gray (*6*), from eastern Quebec to Ontario and Pennsylvania. It grows abundantly in northern France along railway embankments and in waste places where the soil is rich in nitrogen. It has provided practically all the parasite material not collected in corn.[2]

At a very early stage in the investigation of the corn-borer problem it was noted that the differences in seasonal history observed in America existed also in Europe. The variations in life history in the various regions of central Europe have already been studied by K. W. Babcock in connection with the most important meteorological factors. In the warmer parts of its range, comprising the Mediterranean littoral and the valley of the Po, the borer has normally two generations per year. The corn-growing area of southwestern France, lying between the Pyrenees, the central plateau, and the Atlantic, and the Rhone Valley region as far north as Lyons, appear to be transitional areas, in which the number of generations occurring annually varies according to the character of the season. Thus, in 1920, the great majority of first-generation larvae in the region of Auch (Gers), in southwestern France, pupated during July and August, whereas in 1924 and 1925 practically all the caterpillars

[2] The larvae or chrysalids of *Pyrausta nubilalis* have been taken from the following plants in Europe by W. Gamkrelidze: *Achillea millefolium* L., *Artemisia vulgaris* L., a species of Aster, *Cannabis sativa* L., *Cirsium arvense* Scop., *Dipsacus silvestris* L., *Eriqeron canadensis* L., *Humulus lupulus* L., *Inula conyza* D. C., *Lappa officinalis* All., *Polygonum mite* Schr., *Rumex acetosa* L., *R. planstris* Sm., *Senecio jacobaea* L., *S. vulgaris* L., *Sorghum vulgare* Pers., *Urtica dioica* L., and *Zea mays* L.

passed through the summer without pupating, going into hibernation in fall as in true one-generation areas.

In the other regions in which the borer has been studied (northern, western, and eastern France, Belgium, northern Spain, Germany, Austria, Hungary, Czechoslovakia, and Yugoslavia) the corn borer passes through only one generation a year.

The fact that transitional zones exist in which the proportion of individuals of the one and two generation types fluctuates from year to year shows clearly that the variations in life history are more or less directly dependent on meteorological conditions. The writers' observations offer no good grounds for believing in the existence of definite and distinct one and two generation strains, the annual cycle of which is independent of external conditions.

THE CONTROLLING FACTORS OF PYRAUSTA NUBILALIS IN EUROPE

The various factors upon which the control of an insect pest depends may be classified as follows:

A. Natural:
  1. Intrinsic.
  2. Extrinsic—
    a. Organic.
      Parasites.
      Predaters.
      Diseases.
    b. Inorganic.
B. Artificial.

Under the heading of natural controlling factors are included those natural causes of mortality operating in the normal environment, independently of human intervention. This group may be further subdivided into (1) intrinsic factors, and (2) extrinsic factors, among which are such destructive agents as parasitic and predacious organisms and meteorological factors, in so far as their intensity departs from that which is normal for the species considered.

By intrinsic controlling factors the writers mean those characteristics of structure and habits peculiar to the species, by reason of which a high mortality occurs in certain phases of existence, even in the normal environment. It is, of course, true that even in such phases the destruction of any given individual could always be referred to the action of certain external causes, but these causes would be difficult to classify, their destructive action being due chiefly to the extreme delicateness of the organism whereby the limiting effect of many factors is increased and the environment in which existence is possible is narrowly circumscribed.

A careful study of the problem of natural control has convinced the writers that what they have called the intrinsic controlling factors are far more important in connection with the natural equilibrium than is generally realized. They believe that, in the case of many species, more individuals disappear because of their highly restricted adaptive powers than through all the other controlling factors taken together. It is probably true that in many cases the effect of these factors is not sufficient to prevent the increase of a pest unless they are supplemented by other agencies, such as parasites and predators, but that they surpass in importance any other single

group of factors seems certain. It is difficult to make any general statement as to the nature and action of the intrinsic factors of control. In many cases, at least, the mortality from this source appears to occur mainly in the early larval stages. Thus, in several instances with which the writers have been personally concerned, attempts have been made to start artificial colonies of certain insects, either with the object of studying controlling factors or as a method of parasite introduction. In these experiments eggs or young larvae were placed upon the host plant in numbers judged sufficient to produce a heavy infestation, but the results were contrary to expectations. The infestations expected did not develop, and in the case of larval "plantings" the population of the introduced insects actually diminished as time went on until the vast majority had disappeared, though no definite cause of destruction could be observed.

The young larvae of *Pyrausta nubilalis* are extremely delicate. Those which fall to the ground or into a drop of water, or emerge at a point of the plant where food material is not sufficiently tender or is in other ways unsuitable, probably die very rapidly. A slight injury of any kind or a short deprivation of proper food is sufficient to cause a very high mortality among the young larvae. Thus, in the normal course of events, even in the normal environment of the species, intrinsic causes determine indirectly an enormous elimination of individuals.

In order to show the importance of the intrinsic controlling factors it is sufficient to compare the potential population, as shown in the egg masses, with the number of mature larvae on infested plants. Such a comparison will show that only a very small fraction of the population represented by the eggs actually reaches maturity. For example, in examinations of cornstalks containing hibernating larvae which have been made in the region of Auch for a number of years, the average population of the infested stalks has usually been less than two borers. Supposing, as is probable, that at least one egg mass containing at least 19 eggs existed on each infested stalk, this would mean a mortality in the young stages of nearly 90 per cent. As the parasitism is very low and no larvae die from parasitic attack until they have reached the fourth or fifth stage, this mortality, which seems to occur almost everywhere in western Europe, can hardly be attributed to anything but the constitutional weakness of the young caterpillars. Although the elimination which results therefrom doubtless varies under different conditions, it is probably nearly always more important than that resulting from all other controlling factors taken together.

The limitations imposed upon the increase of the insect by the intrinsic factors of control appear also to be of considerable importance in two-generation areas. The number of moths emerging seems generally to be much greater in the summer than in the spring, but the population of the second-generation larvae is rarely larger and often smaller than that of the first-generation larvae. As the mortality in the mature larval and pupal stages is not enormous, a vast number of individuals must be eliminated either in the adult or in the early larval stages. As this elimination is not produced by parasites and is more or less independent of climatic features, it can

only be attributed to the intrinsic factors of control, although, as will be shown later, the environmental conditions at this time are definitely less favorable to the borer than at the beginning of the first generation.

THE PARASITES OF PYRAUSTA NUBILALIS IN EUROPE

The parasites of the European corn borer discovered during the work in Europe are as follows:

Parasites of the egg:
- Chalcididae—
  - *Trichogramma evanescens* Westw.

Parasites of the larva:
- Tachinidae—
  - *Masicera senilis* Meig.
  - *Zenillia roscanae* B. & B.
  - *Nemorilla floralis* Fall.
  - *Nemorilla maculosa* Meig.
  - *Exorista mitis* Meig.
- Ichneumonidae—
  - *Eulimneria crassifemur* Thoms.
  - *Diodes punctoria* Rom.
  - Campoplegine (undetermined).
  - *Exeristes roborator* Fab.
- Braconidae—
  - *Microbracon brevicornis* Wesm.
  - *Microgaster tibialis* Nees.
  - *Apanteles thompsoni* Lyle.
  - *Macrocentrus abdominalis* Fab.
  - Chelonus sp.
- Chalcididae—
  - Eulophid (undetermined).
- Protozoa—
  - *Perezia pyrausta* Pail.
  - *Leptomonas pyraustae* Pail.

Parasites of the pupa:
- Ichneumonidae—
  - *Theronia atalantae* Poda.
  - *Phaeogenes planifrons* Wesm.

THE PARASITES OF THE EGG

TRICHOGRAMMA EVANESCENS WESTW.

The only parasite of the egg observed is the cosmopolitan species known as *Trichogramma evanescens* Westw. This minute chalcid deposits its egg in that of the corn borer, from which it issues in the course of about 18 to 20 days. As the Trichogramma larva approaches maturity the egg containing it turns black, so that in mature masses the parasitized eggs can easily be distinguished.

The fact that the parasite emerges as an adult about the time the eggs of its host hatch, and has to accomplish one or more generations upon other hosts between the periods when corn-borer eggs are available, and the extreme polyphagy which characterizes it, render its action on this host extremely irregular and uncertain.

Under American conditions the percentage of eggs destroyed by it, as noted by the investigators of the Arlington (Mass.) laboratory, may sometimes attain important proportions, especially in the eggs of the second generation. But in Europe its rôle seems to be unim-

portant. It has been found in eggs deposited on corn in southwestern and eastern France and on the Mediterranean littoral, but only in insignificant numbers. Table 2 summarizes the data obtained.

TABLE 2.—*Parasitism of eggs of Pyrausta nubilalis by Trichogramma evanescens*

Zone	Average parasitism	Maximum parasitism	Host plant	Year and generation in which maximum parasitism occurred	
				Year	Generation
	Per cent	*Per cent*			
Rhodanian	2.1	3.2	Corn	1923	First.
Mediterranean (coast)	1.03	4.89	do	1921	Second
Padovian	.01	.01	do	1924	Do.

THE PARASITES OF THE LARVA

The larval parasites of the corn borer fall in two groups. In the first are included the species which attack the younger larvae; in the second, those which attack the mature larvae. All of these parasites, no matter in what stage of the host they begin their parasitic existence, complete their development in caterpillars of the last or penultimate stage, except an occasional Zenillia which issues from the newly formed chrysalid.

PARASITES ATTACKING THE YOUNGER LARVAE

MASICERA SENILIS MEIG.

The dipterous parasite known as *Masicera senilis* Meig. attacks *Pyrausta nubilalis* in corn in all of the principal corn-growing areas of Europe. No reliable data in regard to its distribution or host relations exist in the literature, because, as has been shown in a previous paper (*13*), at least three different tachinids, which are fairly easy to separate in the first larval stage, but practically undistinguishable in the adult condition, are included under the same name by the systematists. Extensive examinations of material from many localities have shown, however, that only one of these species attacks the corn borer in Europe. Furthermore, there exists in America a tachinid (*M. myoidea* Desv.) inseparable from the European form either in the adult or late larval stages. This species, like its European homonym, parasitizes stem-boring larvae, such as *Papaipema nebris* Guen., form *nitela* Guen., but, as has been shown by Vinal and Caffrey (*18*), it seldom attacks the larvae of Pyrausta, even when living in the same individual plants as Papaipema.

Biology

It was originally supposed, from the structure of the female reproductive system and the first-stage larvae (*15*), that *M. senilis* deposited its larvae on the caterpillars of the host. It has since been found, however, that when confined in the laboratory the females of this species deposit their larvae on leaves on which the young caterpillars of the host are feeding and that the parasite maggots, instead of lying

motionless in wait for their hosts, as is the case with certain other tachinids having the habit of "leaf larviposition," start out in search of them, as do the larvae of the dexiine flies. Deposition of larvae seems to be determined chiefly by the odor of the host, as it will occur whether the host is visible or not. Several larvae are often deposited in rapid succession at the same spot.

As has often been noted, the tachinids which have the habit of depositing eggs or larvae upon leaves usually have a very high reproductive capacity, many thousands of eggs being produced by certain species of these groups. In *M. senilis*, however, the reproductive capacity is moderate, and only a few hundred larvae are produced.

As the parasite apparently deposits its larvae whether the host is visible or not, it evidently can not choose for attack the caterpillars of any particular stage. Dissections of caterpillars from the field show, however, that most of the first-stage larvae occur in hosts of the full-grown stages. As the maggots are usually unable to penetrate into the thick-skinned caterpillars, it seems probable that they enter the host when it is in the third stage. The immunity of the younger caterpillars is probably due either to their inaccessible position within the plants or to the fact that in these stages they do not exert a very powerful attraction upon the parasite.

After entering the host, the larva of *Masicera senilis* forces its posterior extremity into one of the main lateral trunks of the host's tracheal system, usually in the tuft of tracheae opposite a spiracle. The irritation caused by the presence of the parasite causes a proliferation of the tracheal epithelium, which forms around the body of the tachinid larva a closely fitting sheath composed of a basal chitinized and pigmented portion, cuplike in form, and a distal unchitinized and colorless portion. While it is within the tracheal sheath the larva apparently feeds only upon the blood of the host, but after it has emerged from the trachea and entered the body cavity it begins to devour indiscriminately all of the internal organs, so that when it issues from the caterpillar it leaves little but the empty skin. The emergence from the tracheal sheath and the change in the feeding habits of the parasite occur after the molt from the second to the third stage at a time when the host has attained its complete larval development.

After it has finished feeding the larva usually emerges from the caterpillar and pupates. On a few occasions, however, its puparia have been found within the skin of the dead host. The larva of *M. senilis* can pupate without difficulty under artificial conditions in almost any receptacle.

Seasonal history.—The seasonal history of *Masicera senilis*, in comparison with a number of the other parasites of Pyrausta, is extremely irregular. This irregularity shows itself particularly in the development of the larvae infesting caterpillars of the one-generation areas or caterpillars of the hibernating brood in the two-generation areas.

The majority of the larvae of *M. senilis* pass the winter in the second stage in the hibernating caterpillars of the host, but a certain number emerge and pupate in the fall, both in the one and two generation areas. Thus, among 460 second-generation caterpillars of Pyrausta collected at Bergamo, Italy, in early October, 1925, 38 were found from which *M. senilis* had emerged and pupated, although a

number of the remaining larvae still contained parasite maggots of this species in the second stage. In regions such as the Mediterranean Riviera (Hyeres, Naples), and even under exceptional circumstances in colder climates, the hibernating larvae of *senilis* emerge from the caterpillars of the host long before the period of pupation. Thus, in material received from southern Italy in 1921, full-fed larvae and puparia of the parasite were found as early as January 25 and more or less continually from that date onward. Similarly in southern France, in the Mediterranean coastal zone, puparia of this species were found in the field in 1925 as early as February 20, while in caterpillars dissected from February 20 to 25, 50 per cent of the *senilis* larvae found were in the third stage, which means that they would have pupated very soon. The development of the specimens which pupate in fall or winter is, of course, delayed to some extent by the prevailing low temperatures, but so far as has been observed none of the fall puparia hibernate, while those formed in the winter and early spring issue long before the time when young larvae of the borer are available.

Nevertheless, even in warm districts, some larvae usually do not complete their development until the season is well advanced, while in colder districts the majority of the larvae do not emerge to pupate until about the time when the host itself is transforming.

The irregularity in the life history of *Masicera senilis* renders it impossible to say exactly how many generations of this parasite occur during the course of the year. It is improbable that the individuals emerging in autumn or winter can successfully attack the thick-skinned adult larvae of the corn borer, though they may, of course, find other hosts. So far as can be gathered from the available data the development of *senilis* as a parasite of the borer follows that of the host; that is to say, it has one generation in the regions where its host has one generation and two generations where its host has two. The larvae of *senilis* issuing from the summer generation pupate, and the adults emerge about the same time as the corn borers themselves, so that the females come to maturity about the time the young larvae of Pyrausta begin to be prevalent in the fields.

Limiting Factors

Under this heading the writers propose to consider in the case of each parasite the factors which limit in a general way or diminish in certain special cases the efficiency of the species as a parasite of the corn borer. The subject is one on which few data are available and concerning which information is extremely difficult to obtain, but it is of the greatest importance.

It is evident that the habit of Pyrausta of feeding in a more or less protected situation within the flower heads or stems of the corn plant is, in the case of all parasites of Pyrausta with which the writers are acquainted, a very serious limiting factor. It is probable that at any given moment, and indeed in any given generation, only a fraction of the corn-borer population is in such a position on the plant that it can be attacked by the parasites, so that no matter how abundant these become they can hardly reach more than a certain maximum percentage of their hosts. The fact that the parasite

maggots are able to penetrate in search of the caterpillars of the borer to points inaccessible to the adults does not constitute a perfect compensation of this factor. Observations by the writers indicate that the larvae of the parasites are not able to continue their search for the host for more than a short time without becoming too exhausted to bore their way into its body. It does not seem that the reproductive capacity of the parasite is high enough to make up for the loss of progeny which occurs in the search for the host.

On the other hand, though a few pupae, from unknown causes, die without emerging, the elimination due to either hyperparasitism or multiple parasitism is negligible. Few puparia attacked by secondary parasites occur in field collections, and caterpillars of the host infested by *senilis* seldom contain more than one larva of the parasite or larvae of any other species.

Extent of Parasitism

Table 3 summarizes the data collected on the parasitism of the European corn borer by *M. senilis*. The optimum area for this species thus appears to be the warm Mediterranean zone and the hotter parts of the Po Valley, although a high parasitism was observed also in northwestern Spain (Galicia), where the climate is of the maritime type. In the colder parts of Europe this parasite seems in general to be unimportant.

TABLE 3.—*Parasitism of larvae of Pyrausta nubilalis by Masicera senilis*

Zone	Average parasitism	Maximum parasitism	Host plant	Year and generation in which maximum parasitism occurred	
				Year	Generation
	Per cent	*Per cent*			
Campanian	15.90	23.70	Corn	1924	First.
Mediterranean (coast)	12.67	28.60	do	1925	Second.
Galician	12.40	12.40	do	1925	First.
Padovian (south)	7.50	7.50	do	1925	Do.
Mediterranean (Rhone)	3.50	3.50	do	1925	Do.
Padovian (north)	1.65	4.70	do	1924	Second.
Aquitainian	1.56	4.60	do	1924	Do.
Hungarian	.90	1.50	do	1923	First.
Rhodanian	.45	.90	do	1925	Do.
Yugoslavian	.36	.70	do	1925	Do.
Rhodanian	.25	.50	Artemisia	1925	Do.

ZENILLIA ROSEANAE B. AND B.

The tachinid *Zenillia roseanae* is much easier to identify in the adult condition than *Masicera senilis*. The specimens originally described by Brauer and von Bergenstamm (*3*) were reared from the common grape pest *Conchylis roseanae* Hw. Berland and Séguy (*2*) have reared it from *Glyphodes unionalis* Hübn., attacking jasmine on the French Riviera, and P. Chretien has obtained it from larvæ of *Pionea stachydalis* collected at Nay in southwestern France. The latter species, whose larva feeds in August and September on *Stachys sylvatica*, is, like the corn borer, a member of the subfamily Pyraustinae of the family Pyralidae.

The distribution of *Z. roseanae* as a parasite of the corn borer is more restricted than that of *Masicera senilis*. It has been found in material collected in southwestern France, the Rhone Valley, the Mediterranean coastal region, including the French Riviera and the district around Naples in southern Italy, and the valley of the Po. It will be noted that these are all two-generation or transitional zones. In larvae collected in typical one-generation districts, either in corn or Artemisia, *Zenillia roseanae* has never been found, though adults have been collected at Rambouillet (Seine et Oise) in the region of Paris, where Pyrausta is often abundant in Artemisia. It has been fairly abundant in certain seasons both at Hyeres, on the French Riviera, and in southwestern France, but in other regions, including that of Naples, the climate of which is very similar to that of the French Mediterranean zone, it has never been very common during the period covered by these investigations. The species has also been collected in England, where it presumably attacks some other host.

Biology

The females of this species, like those of *Masicera senilis*, deposit their larvae at a distance from the host, whether it is visible or not. As in the preceding species, the odor of the host seems to be the important factor in inducing oviposition, for females will oviposit readily in confinement on fresh leaves of corn or dock which have been moistened with the blood of the corn borer. The habits of the young larva (*14*) are similar to those of *senilis*. It penetrates into the body of the host in the third, fourth, or early fifth stage and enters a lobe of the adipose tissue, in which it remains during the greater part of its existence. The larvae of the fall generation remain in the fat body throughout the winter and during this time have no very evident connection with the tracheal system of the host, although they may have access to air through the tracheoles and fine tracheal branches which supply the adipose tissue. Later on in the second stage the larva applies its posterior extremity to a trachea of the caterpillar and forces an opening through which it secures a more abundant supply of oxygen. After the second molt the parasite larva, like that of the preceding species, abandons the parasitic for the predacious habit and begins to devour indiscriminately all of the internal organs of the caterpillar, and leaves little but the skin. The larvae of *Zenillia roseanae* emerge from the host somewhat later than those of *M. senilis*, not infrequently issuing from the chrysalids, especially in the summer generation. They pupate as a general rule beside the empty skin or pupal case of the corn borer, the fly issuing in about 10 to 14 days, according to the temperature.

Seasonal history.—The seasonal history of *Zenillia roseanae* seems to be more regular and more exactly adapted to that of *Pyrausta nubilalis* than is the case with *Masicera senilis*. The premature emergence of the parasites in fall and winter which frequently occurs in Masicera has never been observed in Zenillia, the larvae of which do not issue from the host until the spring is well advanced, even in districts with warm winters. Thus, in February, 1924, in the same fields where larvae of *M. senilis* were issuing from the caterpillars and pupating, those of Zenillia were still in the hibernating condition, and no pupae were found until the middle of April. In the

southwest of France, where the spring is colder, the emergence of the parasites occurs a little later. In transitional areas, such as the one just mentioned, the larvae of Zenillia do not complete their development during the same year but hibernate within the body of the host when the latter assumes the one-generation habit. In two-generation areas, such as that of Hyeres, the parasites emerge from the caterpillars about the time of pupation, issuing either from the mature larva or from the chrysalid. The adults of this generation emerge during the latter part of July and the early part of August and attack the young caterpillars of the fall generation, in which the Zenillia larvae hibernate in the second stage.

Limiting Factors

The reproductive capacity of *Zenillia roseanae* is relatively limited, like that of *Masicera senilis*, only a few hundred larvae being produced by the female. There can be little doubt that the low reproductive rate, combined with the uncertain method of attack, which consists in the deposition of the larvae at a distance from the host, greatly reduces the efficiency of this species as a parasite of the corn borer. All that has been said in this connection in regard to *M. senilis* applies equally to *Z. roseanae*, which is further handicapped, so far as the corn borer is concerned, by its limited distribution. The absence or relative rarity of *Z. roseanae* in certain regions where the corn borer has two generations, such as northern Italy, seems to indicate that this parasite is very susceptible to variations in meteorological factors, for, like *M. senilis*, it is very seldom attacked by secondary parasites. It is probable that in certain regions it is attracted to other hosts, or that owing to the differential effect of meteorological conditions its life cycle ceases to harmonize with that of *P. nubilalis*, no caterpillars of this host being available in suitable stages at the time the parasite is ready to oviposit.

Extent of Parasitism

The data on the parasitism of *P. nubilalis* by *Zenillia roseanae* are summarized in Table 4. As the collections show, the favored area for this species is the Aquitainian zone, with a mild climate, inducing a seasonal history of the transitional type. In zones in which the summers are markedly hotter or the winters markedly colder than those of the Aquitainian zone this species tends to disappear from the fauna parasitic on the borer.

TABLE 4.—*Parasitism of larvae of Pyrausta nubilalis by Zenillia roseanae*

Zone	Average parasitism	Maximum parasitism	Host plant	Year and generation in which maximum parasitism occurred	
				Year	Generation
	Per cent	*Per cent*			
Mediterranean (Rhone)	5.40	5.40	Corn	1925	First.
Aquitainian	4.14	13.40	do	1924	Second.
Mediterranean (coast)	2.90	6.70	do	1923	First.
Padovian (north)	.06	.17	do	1924	Second.
Campanian	.03	.10	do	1920	Do.

EXORISTA MITIS MEIG.

Three puparia of *Exorista mitis*, recorded previously from *Calymnia trapezina* L., were obtained in April, 1926, from the tunnels of Pyrausta caterpillars in Artemisia in the vicinity of Paris, but it is not yet absolutely certain that they were parasites of the corn borer.

EULIMNERIA CRASSIFEMUR THOMS.

This ichneumonid, originally described by Thomson (*16*) from Sweden, is widely distributed throughout Europe. It has been recorded (*10*) as a parasite of the caterpillars of several Microlepidoptera, such as (*Conchylis*) *Clysia ambiguella* Hübn. and (*Eudemis*) *Polychrosis botrana* Schiff. A parasite said to differ slightly from it, but which closely resembles it in habits and may really be identical with it, has been reared by Paillot (*10*) in the Rhone Valley from larvae of the peach-leaf sawfly (*Lyda*) *Neurotoma nemoralis* L. It is one of the most consistent parasites of the corn borer and has been found attacking it both in corn and weeds in every part of Europe with the exception of the French Mediterranean coast. In this region not a single specimen of the parasite has ever been obtained during the course of many years of exhaustive collecting, though it has been found frequently in the Rhone Valley as far south as Valence and in the vicinity of Naples, where the climatic conditions very closely resemble those of the French littoral.

Biology

The biology of *Eulimneria crassifemur* is similar to that of many other ichneumonids of the Campoplex group, for example, *Limneria valida* Cress., the parasite of *Hyphantria cunea* Drury, studied some years ago by Timberlake (*17*).

The adults of *E. crassifemur* can be induced to copulate in the laboratory only with great difficulty, though they have been observed to do so in the field immediately after liberation. In order to produce mating in captivity it has been found necessary to keep the sexes separate for a considerable period and then to liberate them in a large outdoor insectary. Under these conditions mating occurred, but when the adults were confined together from the moment of emergence in small cages, copulation was never obtained.

The females, whether fertilized or not, oviposit freely in the smaller caterpillars of the corn borer. The egg when first deposited is white in color but darkens rapidly, becoming brown in the course of a few hours. The larva, which is of the typical tailed ichneumoniform type, floats freely in the body cavity of the host. After reaching the last stage it begins to devour the vital organs of the caterpillar and ultimately reduces it to a skin from which the Eulimneria larva emerges to spin its cocoon in the tunnel of the Pyrausta. The empty skin of the host is usually attached to the cocoon of the parasite by a few threads. The larvae of the summer generation rapidly transform, issuing as adults in 10 or 12 days, but those of the fall generation hibernate in the cocoon, transforming the following spring.

Seasonal history.—The seasonal history of *Eulimneria crassifemur* seems to correspond, in both the one and two generation areas, with that of the borer. For example, in the vicinity of Auch in 1920, when there were two generations, the larvae of the first-generation parasites emerged to spin their cocoons in late July and early August, issuing in August as adults to attack the caterpillars of the fall generation. The parasite larvae of the second generation issued in late October and early November and spun their winter cocoons. The life of this species in such districts as the Po Valley and the Neapolitan littoral is of the same type. In the one-generation areas the larvae do not issue from the host until fall and then hibernate in the cocoon exactly as those of the second generation in warmer regions.

When the late winter and early spring are mild the hibernating individuals tend to emerge very early in the year, and even in normal years they issue long before any larvae of the corn borer are available. For example, in Auch in 1921 the great majority of the parasites had emerged by the middle of April, but no host larvae were present in the fields until after the end of June. In 1920 eggs and first-stage larvae were found in the fields toward the end of July.

Laboratory experiments indicate that *E. crassifemur* is capable of living for a long period (70 to 75 days) at moderate temperatures and even longer (100 to 110 days) at low temperatures. A considerable proportion of the early adults can thus survive until young larvae begin to appear in the field. It is possible, however, that these adults attack other lepidopterous larvae which appear earlier than Pyrausta, and even that under some conditions they might complete a generation before attacking the corn borer. But no direct evidence of such an intermediate generation has been found, and it has not been possible to carry out the extensive investigations necessary to determine whether Eulimneria attacks other hosts.

Limiting Factors

The possession of a relatively long ovipositor makes it possible for *E. crassifemur* to reach the larvae of the corn borer even when they are hidden within the plant; it is probable, nevertheless, that some caterpillars are not accessible at the moment of attack, especially in the second generation, when many feed within the ears. A few secondary parasites, such as Dibrachys, Melittobia, and Pezomachus, attack Eulimneria in the cocoon, but the percentage thus destroyed is small. The most important natural cause of destruction in the case of Eulimneria is probably the habit of the females of depositing in the host larva a large number of eggs, of which only one comes to maturity. For example, 167 eggs and young larvae of the species were found in 72 caterpillars of Pyrausta parasitized by Eulimneria. In some cases as many as 10 or 15 eggs are found within a single host. Some of these develop to the point of hatching and are found dead with their heads protruding from the eggshell. Others hatch, but apparently perish immediately afterward. The data indicate that the death of the supernumerary larvae is due in some way to the influence of the first individual that emerges. The only intelligible explanation of the facts seems to be that the Eulimneria larva, shortly after hatching, begins to secrete and pour into the blood of the host a cytolytic enzyme fatal to younger larvae. In any event,

more than 50 per cent of the progeny of Eulimneria may be lost through the habit described, which thus constitutes a very important intrinsic controlling factor. As will be shown in the discussion of the data on parasitism, meteorological factors seem also to be of great importance in limiting the distribution of this species.

Extent of Parasitism

Table 5 summarizes the data on the parasitism of *P. nubilalis* by *Eulimneria crassifemur*.

TABLE 5.—*Parasitism of larvae of Pyrausta nubilalis by Eulimneria crassifemur*

Zone	Average parasitism	Maximum parasitism	Host plant	Year and generation in which maximum parasitism occurred	
				Year	Generation
	Per cent	*Per cent*			
Galician	16.60	16.60	Corn	1925	First.
Aquitainian	9.87	27.90	do	1920	Do.
Yugoslavian	7.20	13.20	do	1926	Do.
Vosgian	6.40	6.40	do	1925	Do.
Mediterranean (Rhone)	6.20	6.20	do	1925	Do.
Rhodanian	5.35	5.70	do	1924	Do.
Do	5.20	9.00	Artemisia	1925	Do.
Vosgian	3.70	3.70	do	1925	Do.
Campanian	2.30	2.60	Corn	1924	Do.
Hungarian	1.58	3.30	do	1926	Do.
Padovian (north)	1.24	3.00	do	1924	Do.
Armorican	1.20	1.20	Artemisia	1926	Do.
Sequanian (all areas)	1.10	3.50	do	1925	Do.
Padovian (south)	.40	.40	Corn	1925	Do.

A comparison of the various climographs indicates that this species can not thrive in districts with hot, dry summers, such as those of the Mediterranean coastal area. *Eulimneria crassifemur* has never been reared from caterpillars collected on the French Riviera. It is true that the species exists in the Campanian zone, but this apparent discrepancy is probably due to differences in the topography of this region.

In the region of Naples the districts with a climate of this type merge, as one proceeds up to the mountain valleys, into others, where the summer months are much wetter and cooler. Thus, even though *E. crassifemur* may be unable to subsist permanently as a corn-borer parasite in the coastal areas, a few individuals can always migrate down into the areas from the upper valleys. On the French Mediterranean littoral such migration from inland regions is not possible. The upper Rhone Valley is cut off from the littoral on the one hand by the chain of the "Massif Central," on the other by the foothills of the Basses-Alpes, and in the Rhone Valley itself by the stony, arid, and wind-swept region called La Crau. According to observations the corn in the lower part of the Rhone Valley is in general remarkably free from infestation, probably owing to the effect of the strong north wind, known as the mistral, which is a characteristic feature of the region. In the lower valleys of the Basses-Alpes very little corn is grown. As the corn-growing areas of the French Mediterranean littoral are thus isolated from those of the northern dis-

tricts, the parasitic fauna of Pyrausta is composed simply of species which are capable of existing permanently under the climatic conditions it presents, and is not likely to be reinforced, except under very unusual circumstances, by species from other zones.

DIOCTES PUNCTORIA ROM.

This ichneumonid, though widely distributed throughout Europe, was unknown to the systematists until discovered during the investigation of the corn-borer parasites in the vicinity of Auch. Nothing is known of its other hosts. It has been found attacking *Pyrausta nubilalis* in corn in southwestern France, the Mediterranean littoral, both at Hyeres and at Naples, the Po Valley in northern Italy, the valley of the Rhone, and very rarely in certain districts of Hungary and Yugoslavia, as well as in larvae attacking Artemisia in the western Sequanian zone. It attains its maximum efficiency in the summer-generation caterpillars of the warmer areas, being often rather abundant both at Hyeres and in the Po Valley.

Biology

The biology of *Dioctes punctoria*, though very similar to that of *Eulimneria crassifemur*, differs from it in a number of important points. The sexes copulate in the laboratory much more readily than do those of Eulimneria. The habit of depositing a large number of eggs in the host does not exist in *D. punctoria*, and the distribution of eggs and larvae occurs approximately according to the law of chance. The egg is colorless when deposited and remains so, being much more difficult to discover in dissected caterpillars than that of the preceding species. The data indicate that the eggs are usually deposited in caterpillars in stages 2 to 4. The larvae are morphologically indistinguishable from those of Eulimneria, though the cocoon as a rule is somewhat flimsier in texture than the winter cocoon of Eulimneria and lacks the white band which often encircles that of the summer cocoon of the other species. The habits of the summer generation are very similar to those of Eulimneria, the larvae emerging from the host caterpillars in stage 5, but the individuals attacking hibernating caterpillars, instead of completing their larval development and emerging to spin their cocoons in the fall, hibernate in the host caterpillars as first-stage larvae, and issue in the spring.

Seasonal history.—Dioctes punctoria, after passing the winter in the hibernating caterpillar of the corn borer, resumes development in the spring about the time the host is preparing to pupate. Adults have been observed in the field about the time the young larvae of the host are abundant in the flowers of the corn. First-stage larvae of the parasite have been found early in July, and cocoons are present from the middle to the end of July or the middle of August, according to local conditions. In the region of Bergamo, in northern Italy, where Dioctes and Eulimneria both attack Pyrausta, the larvae of Dioctes issue from the first-generation host to pupate and emerge as adults some time before those of Eulimneria, whereas in the hibernating generation this order is reversed, the Eulimneria emerging before the Dioctes. The summer-issuing adults oviposit in the

caterpillars of the second generation, in which the parasites hibernate as first-stage larvae. In transitional areas, such as that of southwestern France or the Rhone Valley, where a few caterpillars pupate very late in the season, thus giving rise to a partial second generation, a certain number of Dioctes also come to maturity and emerge, probably attacking the young larvae of the partial second generation or retarded individuals of the first. Cocoons of this species containing adults ready to emerge have been found in the Department of Drome in the Rhone Valley in the early part of September. In typical one-generation areas the larvae apparently never emerge to pupate in the fall, all hibernating in the first stage. It thus seems probable that the condition of the host has a direct influence upon the development of the parasite and that the conditions inhibiting development in the larva of Pyrausta also arrest it in the larva of Dioctes.

Limiting Factors

Little is known as to the factors which limit the increase of *Dioctes punctoria*. It does not have the wasteful habit of ovipositing characteristic of Eulimneria, nor does it suffer to any appreciable extent from the attack of secondaries. Meteorological conditions are undoubtedly of great importance, as high parasitism is observed only in the two-generation districts. The percentage of parasitized larvae diminishes greatly in the second-generation caterpillars, and this may be due to the fact that the parasite attacks other hosts, but it is also quite probable that the falling off is due simply to the fact that in the second generation the young larvae are less accessible to the parasite than in the first generation.

Extent of Parasitism

Table 6 gives a summary of the data relating to parasitism of Pyrausta by Dioctes.

TABLE 6.—*Parasitism of larvae of Pyrausta nubilalis by Dioctes punctoria*

Zone	Average parasitism	Maximum parasitism	Host plant	Year and generation in which maximum parasitism occurred	
				Year	Generation
	Per cent	*Per cent*			
Padovian (north)	6.70	12.00	Corn	1924	First.
Padovian (south)	6.30	6.30	do	1925	Do.
Mediterranean (coast)	4.60	18.60	do	1923	Do.
Mediterranean (Rhone)	2.10	2.10	do	1925	Do.
Aquitainian	.80	1.70	do	1925	Do.
Campanian	.65	1.30	do	1924	Do.
Yugoslavian	(1)	(1)	do	1925	Do.
Armorican	(1)	(1)	Artemisia	1926	Do.

[1] Negligible.

These data indicate that the optimum zones for *Dioctes punctoria* are those characterized by hot summers, such as the Po Valley and the Mediterranean zone. In other districts the species occurs sparingly and never attains any importance as a parasite of the corn borer.

CAMPOPLEGINE

An undetermined ichneumonid of the campoplegine group has been reared on several occasions from cocoons collected during the winter in Artemisia in the vicinity of Lille. The cocoons are difficult to distinguish from those of *Eulimneria crassifemur*, from which they differ only in their smaller size and somewhat thinner texture. As the empty skin of the *Pyrausta nubilalis* larva has been found attached to the cocoon of this species, it is believed to be a parasite of the corn borer, though it appears to attack also certain tenthredinid larvae found in Artemisia. It has not been obtained from any other region.

MICROGASTER TIBIALIS NEES

This braconid species, which is probably identical with the parasite described by Marshall (*9, t. 4*) under the name of *M. globatus* Nees, seems to be very generally distributed throughout Europe. The writers have found it attacking the corn borer in Artemisia in many localities in the northern, northwestern, and northeastern parts of France. It has been found attacking the borer in corn in northern Spain, in southwestern France, in Baden, and in the Italian peninsula, both in the Po Valley and in the region of Naples. However, it is much more common in the Po Valley region than around Naples.

According to Marshall (*9, t. 4*), it is polyphagous and has been reared from a considerable variety of the smaller Lepidoptera, the list given by this author including the following species: *Lithosia lurideola* Zinck., *Spilodes verticalis* L., *Sericoris euphorbiana* Freyer, *Conchylis smeathmaniana* Fab., *Tachyptilia populella* Clerck, *Platyptilia isodactyla* Zell., *Eupithecia linariata* Fab., *E. campanulata* Schaeff., *Tortrix amentana* Ratz., *Phloeodes immundana* Fisch., *Peronea hastiana* L. (for *globatus* Nees); and *Emmelesia decolorata* Hübn., *Peronea shepherdana* Ste., and *Tachyptilia populella* Clerck (for *tibialis* Nees).

Biology

The egg of *Microgaster tibialis* is deposited in such of the young larvae of stages 2 to 4 as are feeding in a fairly exposed position. Usually only one egg is deposited in a larva. During the whole period of embryonic and larval development the parasite floats freely in the body cavity of the host. It completes its development in the fifth-stage caterpillar; from this it emerges to spin up in the burrow of the host beside the empty skin, which is usually found attached to the parasite cocoon. Only a single specimen emerges from a given host.

Seasonal history.—In the north of France *M. tibialis* has but one generation in the corn borer. First-stage larvae of the parasite have been found in the caterpillars of Pyrausta in the early part of August. By the middle of September many individuals have reached the last stage of development, and toward the latter part of the month cocoons begin to appear in the infested plants of Artemisia. *M. tibialis* hibernates as a prepupal larva in its cocoon, from which it emerges as an adult toward the end of April or early in May in northern France. From the time the parasite issues to the period when young larvae of the host are available on the Artemisia plants a considerable period elapses, comprising sometimes over two months.

It is possible that an intermediate generation occurs in some other host, before the attack upon the borer. The writers have found, however, that individuals of this species can be kept alive for almost two months in the laboratory at temperatures considerably higher than those prevailing in the native home of the insect, so that some of the parasites may actually remain in the weed areas without ovipositing until the corn borer larvae appear. In the one-generation areas of northwestern Spain young larvae, probably of this species, were found in caterpillars collected in early September. The seasonal history in this region is probably similar to that of the northern weed areas. In the valley of the Po, in northern Italy, *M. tibialis* has two generations, like its host. In this region first-stage larvae of the parasite are found during the latter half of July. Cocoons appear during late July and early August. Cocoons from which the adults have already issued are found during the last half of August. The larvae of the second generation emerge from the host in late fall and pass the winter as prepupal larvae within the cocoon, just as do the one-generation specimens in the northern areas.

Limiting Factors

Little is known concerning the factors which limit the efficiency of *M. tibialis*. As the parasite has a short ovipositor, many larvae doubtless remain inaccessible to it even under favorable circumstances, especially in corn. The long period which elapses in northern areas, between the issuance of the hibernating adults and the appearance of young corn borers, probably results either in the death of many individuals which have not had an opportunity for reproduction or at least in their dispersion beyond the areas infested by *P. nubilalis*. The extremely polyphagous habits of this braconid may also help to reduce its efficiency as a parasite of the borer; and meteorological conditions seem to have great importance in connection with the attack of Microgaster on Pyrausta in corn, but whether these conditions operate directly or through the medium of other factors is at present unknown. Secondary parasites of several species not infrequently attack the cocoons, especially in Artemisia.

Extent of Parasitism

The variation in the parasitism of *Pyrausta nubilalis* by *Microgaster tibialis* in the various zones investigated is shown in Table 7.

TABLE 7.—*Parasitism of larvae of Pyrausta nubilalis by Microgaster tibialis*

Zone	Average parasitism	Maximum parasitism	Host plant	Year and generation in which maximum parasitism occurred	
				Year	Generation
	Per cent	*Per cent*			
Sequanian (south)	31.40	63.20	Artemisia	1926	First.
Sequanian (north)	15.00	18.70	do	1926	Do.
Vosgian	13.60	13.80	do	1925	Do.
Galician	2.90	2.90	Corn	1925	Do.
Padovian (north)	2.28	3.70	do	1925	Do.
Vosgian	1.40	1.40	do	1925	Do.
Rhodanian	1.35	2.70	Artemisia	1925	Do.
Armorican	.40	.40	do	1925	Do.
Padovian (south)	.20	.20	Corn	1925	Do.
Campanian	(1)	(1)	do		
Aquitainian	(1)	(1)	do		

[1] Negligible.

The favored zone for this species appears to be the one-generation Artemisia area of northern France, characterized by a rather mild climate transitional between the maritime and continental types, though it is also fairly common in the Padovian zone, having in the latter region two generations per annum instead of one.

APANTELES THOMPSONI LYLE

This braconid parasite, hitherto unknown to science, and described in 1927 by G. T. Lyle (*8*), was first found in a larval condition in a caterpillar of *P. nubilalis* collected in Artemisia in the environs of Brussels in 1920. In 1921 a single colony of cocoons, possibly belonging to this species, was found in corn in the Jura area of eastern France.

After a careful comparison of the meteorological features of the areas in which the specimens had been found, it was decided in 1924 to make a special search for it in the region between Lille in northern France and Antwerp in Belgium. This exploration resulted in the discovery of several points where Apanteles was abundant and from which during the following winters it has been found possible to make large shipments of material. Nothing is known about its relations with other hosts.

Biology

Much remains to be discovered as to the life cycle and seasonal history of this interesting species. On July 26 W. Gamkrelidze found a colony of Apanteles cocoons in fresh Artemisia in the Department of Eure-et-Loire in northern France. In the region of Lille, cocoons from which the adults had issued were found about the middle of August, 1925, in the Artemisia of that year's growth. These data seem to indicate that the Apanteles has two generations per year on Pyrausta. In late summer in areas inhabited by this species the Pyrausta larvae contain colonies comprising on an average about 15 individuals in the second stage of development, which pass the winter in this stage, lying free within the body cavity of the host. About the end of April these individuals resume their development and, after devouring the contents of the host, emerge and spin their delicate cocoons in a rather loosely connected mass within the tunnel of the host, upon the empty skin of the latter. Toward the end of May the adults begin to emerge. A most interesting feature of this species, one in which it differs from all other parasites of Pyrausta, is that the colonies so far reared have been composed of females alone. The absence of males indicates that the parasite reproduces parthenogenetically, producing only females, a condition which is rather rare, though it has been observed in several groups of hymenopterous parasites.

Limiting Factors

The writers know too little about the biology of this species to be able to discuss with any certainty the factors upon which its efficiency depends. It is evident from its restricted distribution that its range is very closely limited in Europe by meteorological factors,

but, as has already been stated for other species, almost nothing is known as to the exact way in which these factors operate. Cocoons kept under laboratory conditions showed a rather high mortality, indicating an unusual susceptibility to meteorological variations.

Extent of Parasitism

As the data show, the optimum for this parasite is the colder part of the Sequanian zone, in which the climate is a rather severe variety of the type transitional between the maritime and continental climates.

The parasitism by *Apanteles thompsoni* is negligible in Pyrausta attacking corn in every region studied, and in the Artemisia areas it varies greatly from one area to another and from one year to another, even in the normal habitat. Thus, in a collection of 513 larvae of Pyrausta made in the neighborhood of Lille in 1924, over 40 per cent were found to contain these parasites, while in the following year, of a collection of 1,159 larvae made in exactly the same locality, only about 3 per cent were attacked. In other regions the parasitism was less than 1 per cent. Under favorable conditions this parasite destroys more larvae of *P. nubilalis* than any other which exists in the one-generation weed areas (Table 8), but its distribution seems to be irregular and its action uncertain.

TABLE 8.—*Parasitism of larvae of Pyrausta nubilalis by Apanteles thompsoni*

Zone	Average parasitism	Maximum parasitism	Host plant	Year and generation in which maximum parasitism occurred	
				Year	Generation
	Per cent	*Per cent*			
Sequanian (north)	22.90	42.60	Artemisia	1924	First.
Rhodanian	1.10	1.80	do	1925	Do.
Do	.08	.15	Corn	1925	Do.

MACROCENTRUS ABDOMINALIS FAB.

This braconid parasite, which, according to Marshall (*9, t. 5*), is very generally distributed throughout Europe, is extremely polyphagous. Its host list, as given by this author, comprises the following species: *Vanessa atalanta* L., *Hylophila prasinana* L., *Demas coryli* L., *Hydraecia petasitis* Doubl., *Noctua ditrapezium* Bork., *Calymnia trapezina* L., *Spilodes verticalis* L., *Nephopteryx spissicella* Fab., *Tortrix podana* Scop., *T. corylana* Fab., *T. heparana* Schiff., *T. rosana* L., *T. ribeana* Hübn., *T. viridana* L., *Epichnopteryx radiella* Curt., *Hyponomeuta euonymellus* L., and *Depressaria alstraemeriana* Clerck.

Macrocentrus abdominalis has been found attacking *Pyrausta nubilalis* only in Artemisia, in certain restricted parts of the one-generation area of northern France. It was first discovered in the district around Angers in the Department of Maine-et-Loire, where the average parasitism in both 1924 and 1925 was about 9 per cent. In the vicinity of Lille it has never been found, but a few specimens

were obtained in 1925 from spring collections of *P. nubilalis* made in Artemisia in the environs of Paris.

Biology

The early phases of the biology of this species are as yet little known. It passes the winter as an undeveloped egg in the adipose tissue of the overwintering caterpillars, a fact which makes it extremely difficult to estimate the percentage of hosts attacked at this time, the parasite eggs being minute and extremely hard to find. From full-grown caterpillars collected in the region of Angers in 1926, larvae of the parasite emerged during the period from April 21 to May 14, while empty cocoons were found in the field in early July. The adults issued at Hyeres from Angers material from May 31 to June 3. The species is gregarious, 100 or more larvae being found in one individual of the host, where they float freely in the body cavity like those of Apanteles. Although both females and males are produced, the specimens which emerge from a given mass of cocoons, so far as observed, are all of the same sex. This fact suggests the possibility of polyembryonic development, but no proof of this has yet been found. An interesting feature of the life of this parasite is that the third-stage larvae, after emerging from the caterpillar, continue to feed for a time externally, so that they are first endophagous and then ectophagous, a character which the writers have not hitherto observed in any parasite studied. The larvae of *Macrocentrus abdominalis* spin long brown cocoons in a loose elongate mass covered with a gauzelike sheet of silk, through which the outlines of the separate cocoons can be clearly seen.

CHELONUS SP.

This braconid species, which seems to approach *C. carbonator* Marshall, has been reared from the Padovian zone, both north and south.

In 1925 three specimens were reared from thin, whitish, papery cocoons taken in corn at Piacenza on July 29; one was collected at Bergamo on August 5. Eleven more specimens were reared in the summer of 1926 from cocoons taken around Bergamo.

It is probable that the eggs are laid in some early stage of *P. nubilalis*,[3] for the cocoon usually bears the head capsule of the fourth or fifth stage larva. The percentage of parasitism is very low, as in 1926 only 11 specimens were obtained from approximately 200,000 *P. nubilalis* collected.

PARASITES ATTACKING THE MATURE LARVAE

Five parasites, two dipterous and three hymenopterous, attack the mature larva of the corn borer. Of the Hymenoptera, one (*Exeristes roborator* Fab.) belongs to the family Ichneumonidae, one (*Microbracon brevicornis* Wesm.) belongs to the family Braconidae, and the third (Eulophus sp.) to the family Chalcididae. The first two

[3] So far as is known all species of the group to which Chelonus belongs oviposit in the egg of the host.

are very easy to rear in quantity in the laboratory, though they seem to be extremely polyphagous and are usually not of any importance as enemies of *Pyrausta nubilalis* in Europe. Efforts to rear Eulophus, however, have been unsuccessful.

Only a few specimens of the dipterous parasites (*Nemorilla floralis* Fall. and *N. maculosa* Meig.) have been found.

EXERISTES ROBORATOR FAB.

The large and handsome ichneumonid *Exeristes roborator* Fab. appears to be fairly generally distributed throughout Europe, but is most frequently found in the southern part of the Continent. It is apparently very polyphagous, attacking the larvae of both Lepidoptera and Coleoptera. The species on which it preys seem, however, all to be like Pyrausta, insects such as the clearwing moths (Sesia spp.), and the weevil *Cryptorrhynchus lapathi* L., which in the larval stage are borers living in tunnels in various plants.

Exeristes roborator has occasionally been found attacking the corn borer in Artemisia in the vicinity of Paris, but only in extremely small numbers. It has been reared from Pyrausta larvae in corn in southwestern France, the Rhone Valley, the French Mediterranean coastal zone, and the Po Valley in northern Italy, but has not been found in the corn areas of the one-generation type.

Biology

The adult female of *E. roborator* deposits her eggs on the outside of the body of the full-grown caterpillars of *P. nubilalis* which have been reduced to an inert condition by the injection of some poisonous fluid. The egg, which is a white fusiform object large enough to be easily visible to the naked eye, is not attached to the body of the host. In captivity a considerable number of eggs may be deposited on the same individual caterpillar, but this is uncommon in nature, where larvae of the parasite are almost invariably solitary. The egg hatches in the laboratory in about 42 hours. The larva grows rapidly, completing its development in about 6½ days, after which it spins a rather irregular semitransparent cocoon in the tunnel of the host. The adult emerges under ordinary summer conditions in about 9 days, though its development takes, of course, much longer in the colder seasons of the year. The adults developing from pupae which have been exposed to high temperatures are mostly red, especially on the abdomen, while those from pupae which have been exposed to low temperatures are mainly black.

Although the larva of *E. roborator* is normally a primary parasite on the caterpillar of *P. nubilalis*, its habits are somewhat flexible, and it has been obtained on several occasions from the cocoons of Eulimneria or Dioctes in which it has developed as a hyperparasite on the larvae of these species. The writers have often reared it in the laboratory on the larvae of certain large ants, such as Camponotus.

Seasonal history.—It is probable that in nature *E. roborator* passes through several generations a year on various hosts. It appears as a parasite of Pyrausta when the summer-generation caterpillars are in the fifth stage, and the adults emerge about the same time as those of the host. On the Mediterranean littoral the writers have occa-

sionally found its cocoons containing developing pupae in the winter months in old cornstalks containing hibernating host larvae, but it has never been found attacking the hibernating larvae in other regions, and little is known as to its complete seasonal history in any zone.

Limiting Factors

So far as the writers have observed, *Exeristes roborator* is not attacked by secondary parasites. Furthermore, the possession of a long and very efficient ovipositor makes it possible for the female to reach the larvae of the corn borer even when they are concealed within their tunnels in the stalks. The unimportance of the species as a parasite of *Pyrausta nubilalis* is thus due neither to its natural enemies nor to its inability to attack this particular host, but depends probably partly on the meteorological conditions, which perhaps restrict the range of the parasite or induce a seasonal history which does not harmonize with that of the corn borer, and partly on the polyphagous habits of the species, to which Pyrausta may be, under natural conditions, one of the less attractive hosts.

Extent of Parasitism

The data on the parasitism of *Pyrausta nubilalis* by this species are summarized in Table 9.

TABLE 9.—*Parasitism of larvae of Pyrausta nubilalis by Exeristes roborator*

Zone	Average parasitism	Maximum parasitism	Host plant	Year and generation in which maximum parasitism occurred	
				Year	Generation
	Per cent	*Per cent*			
Mediterranean (coast)	0.23	1.70	Corn	1922	First.
Mediterranean (Rhone)	.10	.10	do	1925	Do.
Aquitainian	(1)	(1)	do	1920	Do.
Padovian	(1)	(1)	do	1924	Do.
Sequanian	(1)	(1)	Artemisia		

[1] Negligible.

The data indicate that the favored zone for this species is the Mediterranean area; this agrees with the fact recorded by collectors that *Exeristes roborator*, though widely distributed, is more frequently found in the southern parts of Europe.

MICROBRACON BREVICORNIS WESM.

The data which exist in the literature concerning the distribution and host relations of *Microbracon brevicornis* are unreliable. As has been shown by Cushman (*4*), two species have been commonly confused under the name *brevicornis* Wesm. One of these, which is really *M. hebetor* Say, is a common parasite of the Mediterranean flour moth (*Ephestia kuehniella* Zell.). Its biology and economic importance have recently been studied with great care by Hase (*7*). The other, which is the true *brevicornis* Wesm., is probably the po-

lyphagous form attacking the majority of the other hosts usually attributed to this species. The writers have never found *M. brevicornis* Wesm. attacking hosts other than the corn borer in nature, but it has been reared in the laboratory on a considerable number of other Lepidoptera. It has been obtained from *Pyrausta nubilalis* in southwestern France, the French Mediterranean littoral, the Rhone Valley, the region of the Jura, and the Po Valley, and from various points in central Europe. On one occasion it was also found attacking the borer in Artemisia near Paris.

Biology

The biology of *Microbracon brevicornis* has been described in some detail in a recent paper by Genieys (*5*). The female, which produces male offspring when unfertilized and a mixture of males and females when fertilized, deposits 10 to 20 eggs on the exterior of the host after first paralyzing it by the injection of a poisonous fluid. It may continue to oviposit during several weeks, destroying a considerable number of caterpillars, at least under laboratory conditions. The eggs are not attached to the body, but as the host has been paralyzed within its burrow this habit is not prejudicial to the welfare of the species. The young larvae, which hatch in about 35 hours, remain on the exterior of the host, feeding apparently by suction through small openings they make in the skin. They complete their larval development in about 72 to 96 hours, and spin their whitish, thin-walled but tough cocoons in a mass beside the remains of the host caterpillars, the adults issuing in 10 to 15 days, according to the prevailing temperature. An interesting feature of the behavior of this parasite is that the female feeds principally upon the blood of the host sucked through openings in the skin which it makes with its ovipositor. As females sometimes feed in the laboratory on specimens upon which they do not oviposit, it may be that in the field they have a certain value not only as parasites but as predators.

Seasonal history.—From what is known of this parasite it is certain that normally it has several generations a year, but in most districts only one or at most two of these are passed on the corn borer. In certain districts of Hungary this species has been found by K. W. Babcock attacking the hibernating larvae of Pyrausta in piles of old cornstalks during May, June, and July, and it occurs also in growing corn during August, September, and October. It probably completes two full generations on the overwintering caterpillars in the spring. In other areas it has been obtained only during the summer months, appearing in the field when the host is in the last larval stage, and after completing a generation is not seen again until the following year, though the cocoons found in Artemisia were collected in October. The species does not seem to have any definite resting period. Hibernation is thus entirely dependent on low temperature.

Limiting Factors

This species, like *Exeristes roborator*, is undoubtedly very polyphagous and is thus not an obligatory but merely an accidental parasite of *Pyrausta nubilalis*, which it attacks from time to time

under particular conditions which can not be defined. Its efficiency is still further reduced by its gregarious habits, since a few caterpillars of the borer suffice to support the entire progeny of a female. The parasite usually does not oviposit until it comes into immediate contact with the host and thus can attack only the caterpillars into whose tunnels it is able to penetrate. Therefore, although it apparently has no parasitic enemies, it is of little importance except under the conditions prevailing in certain areas of central Europe, and as these conditions are inconsistent with good entomological practice they are unlikely to occur in America.

Extent of Parasitism

Table 10 summarizes the data on parasitism of *P. nubilalis* by this species.

TABLE 10.—*Parasitism of larvae of Pyrausta nubilalis by Microbracon brevicornis*

Zone	Average parasitism	Maximum parasitism	Host plant	Year and generation in which maximum parasitism occurred	
				Year	Generation
	Per cent	*Per cent*			
Hungarian	7.12	19.50	Corn	1923	First.
Yugoslavian	3.05	3.20	do	1925	Do.
Mediterranean (Rhone)	.6	.6	do	1925	Do.
Padovian	.20	.20	do	1925	Do.
Mediterranean (coast)	.03	.23	do	1921	Do.
Aquitainian	(1)	(1)	do		
Sequanian	(1)	(1)	Artemisia		

[1] Negligible.

As Table 10 shows, Microbracon has never been of any importance as a parasite of *Pyrausta nubilalis* in western and southern Europe, where the maximum percentage of parasitism has never attained even 1 per cent. The optimum area for the species appears to be central Europe, where a maximum parasitism of 19.5 per cent has been observed by Babcock in certain districts. It must, however, be noted that, although climatic factors are perhaps responsible in part for the abundance of the parasite in these localities, the areas in which Microbracon attains its maximum efficiency are those in which old cornstalks containing hibernating larvae are kept in piles for fuel until after the moths have emerged in the spring. The observations indicate that these piles of stalks afford an excellent refuge for the parasite almost up to the time when fifth-stage larvae of the next generation appear in the field, so that at the beginning of every season large parasite populations are available as soon as the host reaches a stage suitable for attack.

EULOPHUS SP.

Distribution and Host Relations

This chalcid parasite, whose specific identity has not yet been determined, has been found attacking the mature larvae of Pyrausta in

corn in the Campanian and Mediterranean coastal zones and in Artemisia in the Parisian area. Nothing is known in regard to other hosts of the species.

Biology

The adult chalcid deposits her eggs on the outside of the *P. nubilalis* larva in numbers of from 5 to 15, the average being about 10. The resulting larvae feed together externally on the Pyrausta caterpillar, consuming it almost entirely. When they are full grown—that is, in 8 to 15 days—they pupate on the spot, giving rise to the adults of the next generation in about 15 days, depending on the temperature.

The egg taken from the unpaired oviduct, or vagina, is oblong oval in form, slightly larger at one end than at the other, of a whitish color, and without spines or tubercles. The larva is a typical chalcidiform larva with head and 13 body segments. It is whitish, possesses a functional respiratory system with nine pairs of open spiracles, and has no conspicuous setae or other external sensory organs.

The pupa is a typical flattish eulophid pupa inclosed in a rather thick chitinous skin. The skin of the winter pupa is thick and black, while that of the summer pupa is thinner and of a dark-brown color.

Seasonal history.—The winter is passed in the pupal stage in the Pyrausta tunnels. In the spring the adults emerge and either attack some other host or wait around until there are larvae of Pyrausta. The writers have found the young larvae of *P. nubilalis* in early August in the Paris district bearing full-grown Eulophus larvae. These larvae pupated immediately and transformed into adults shortly thereafter, emerging without doubt to deposit their eggs for the overwintering generation. It is thus likely that there are at least two generations per year on *P. nubilalis*.

Extent of Parasitism

Parasitism by this species is negligible, it having been found only about a dozen times during the course of the work.

PEREZIA PYRAUSTA PAIL.

In 1925, during the course of the studies on hibernating caterpillars, a number of individuals were discovered with diseased malpighian tubes. A histological study of these specimens showed that they were infected by a protozoan subsequently determined by G. F. White as a neosporidian belonging probably to the Nosema group, which contains a number of species pathogenic for insects. The organisms, whose existence was recorded by the writers in a paper (*12*) on hibernation in Pyrausta, published in March, 1927, were found to be present not only in the cells of the malpighian tubes, but also in the epithelium of the midintestine. The writers have no evidence that the health of the caterpillars is seriously affected by the presence of this protozoan, although the problem deserves further study. This parasite was rediscovered by A. Paillot in 1927 and described by him under the name of *Perezia pyrausta* n. sp. (*11*).

A summary of the observations on parasitism of larvae of *Pyrausta nubilalis* by *Perezia pyrausta*, made in the winter of 1924–25, is as follows:

Zone:	Parasitism
Padovian (north)	per cent 53.5
Mediterranean (coast)	do 9.6
Hungarian	do 6.6

There is thus no obvious correlation between the abundance of this organism and conditions in the zone inhabited by the host insect.

LEPTOMONAS PYRAUSTAE PAIL.

This protozoan, discovered and described as new by A. Paillot (*11*) in 1927, appears to be very uncommon. It occurs in the malpighian tubes and in the intestine, but does not seem to be of any great importance.

THE PARASITES OF THE PUPA

THERONIA ATALANTAE PODA

The ichneumonid *Theronia atalantae* is a common parasite in the chrysalid of many Lepidoptera. It has been reared from pupae of *Pyrausta nubilalis* at Hyeres, on the Mediterranean littoral, and at Bergamo, in northern Italy, but only on one or two occasions during the course of several years' observations.

PHAEOGENES PLANIFRONS WESM.

The ichneumonid *Phaeogenes planifrons*, which is generally distributed throughout Europe, is the only parasite of any importance which has been obtained from the chrysalids of *Pyrausta nubilalis*. Its range appears to be restricted to the warmer parts of the European corn belt. It occurs abundantly as a parasite of the borer in northern Italy and the Mediterranean littoral, though specimens have occasionally been obtained from the Rhodanian zone (Cote d'Or), where the species has been reared from chrysalids collected both in Artemisia and in corn, and from southwestern France.

Biology

Though it has been found possible to obtain mating in the laboratory and to keep females alive in captivity for many months, attempts to induce them to oviposit have given disappointing results. A few eggs have been deposited in fresh chrysalids on one or two occasions, but efforts to breed the species in confinement on a large scale have been unsuccessful. In nature the female of Phaeogenes apparently enters the tunnel, depositing her eggs directly in the chrysalid of its host. The young larva which hatches from the egg floats freely in the coelomic cavity, and after completing its development transforms within the empty pupal shell, emerging about the same time as the adults of the host. These adults possibly oviposit in chrysalids of some other species, or perhaps they wait until the corn borers of the following generation pupate in the spring, hibernating as adults. At all events, adults ready to oviposit are present in the fields in the spring, for they have been reared occasionally from the pupae of the hibernating generation.

Limiting Factors

It is evident from the distribution of this species that it can attack the borer under a variety of conditions. On the other hand, since it develops only in the chysalid of the host, emerging therefrom at the same time as the adults of the latter, it is obliged to seek out intermediate hosts or to subsist as an adult during the long intervals between the pupal periods of the corn borer. As the female has a very short ovipositor, she can attack only individuals into whose tunnels she is able to penetrate, which further restricts the efficiency of the species as a parasite of this host.

Extent of Parasitism

The data on the parasitism of *Pyrausta nubilalis* by *Phaeogenes planifrons* are summarized in Table 11.

TABLE 11.—*Parasitism of pupae of Pyrausta nubilalis by Phaeogenes planifrons*

Zone	Average parasitism	Maximum parasitism	Host plant	Year and generation in which maximum parasitism occurred	
				Year	Generation
	Per cent	*Per cent*			
Padovian (north)	7.60	14.00	Corn	1925	First.
Padovian (south)	2.7	2.7	do	1925	Do.
Rhodanian	.35	.70	Artemisia	1925	Do.
Mediterranean (coast)	.15	.40	Corn	1922	Do.
Rhodanian	.12	.25	do	1925	Do.
Aquitainian	.01	.01	do	1925	Do.

The collections indicate that the optimum region for this species is the north Padovian zone, where Phaeogenes is at times of considerable importance. The maximum percentage of parasitism given in Table 11 was not a mere local phenomenon, but was calculated from a lot of 46,000 chrysalids of the summer generation collected at various points around Bergamo in 1925.

THE INORGANIC FACTORS OF NATURAL CONTROL

The inorganic factors of natural control constitute the group generally known as meteorological factors, in so far as they tend to deviate from the optimum intensity for the species considered. Thus, excessive heat or cold, extreme drought, drenching rains, or violent winds, if they occur at certain critical periods during the life history, such as the moment when young larvae are emerging from the eggs, or the adults from the chrysalids, or during the period of oviposition, may and undoubtedly do cause a more or less heavy mortality of Pyrausta. Unfortunately, for the importance of these factors is probably considerable, little is known as to the part they play in the control of the borer in the various parts of Europe. It has been noted, however, that in the lower part of the Rhone Valley, where the cornfields are constantly swept by the strong northerly wind known as the mistral, only very slight infestations have been noted, and it is thought that this is due to the destruction of the adults or young larvae by this agency.

Some observations made by K. W. Babcock in central Europe indicate that the physiological condition of the corn plant as determined by the character of the soil has perhaps some influence in respect to infestation, but this point also requires more extensive investigation.

ARTIFICIAL CONTROL

The artificial control of the corn borer in those regions of Europe which the writers have studied, though it is indeed due to human intervention and a result of certain agricultural practices, is simply an accidental effect of measures whose object has nothing to do with *Pyrausta nubilalis*. It may be said in a general way that in the corn areas cultivation is generally cleaner than is the case in the United States, and waste areas overgrown with weeds are much less common because of the density of population.

In some districts, such as that of the French Mediterranean littoral, where corn is grown only in small plots to provide grain for poultry, the corn plants are often pulled up by the roots and burned with such thoroughness that on some occasions it has been found impossible to discover any stalks in the region during the late winter and early spring months. The practice of pulling and burning the stalks is followed to some extent even in districts, such as southwestern France, where corn is grown on a large scale. In other cases the stalks are cut 2 or 3 inches above the ground and the stubble is plowed under; farmers have even been observed in the act of plowing the stalks under without troubling to cut them. But as a general rule they are either burned or used to supply litter for the cattle during the winter. In the Po Valley, after the ears have been collected, the stalks may be used when dry for litter or they may be cut while still fairly fresh and green and either cut up by hand into small pieces or passed through a shredding machine, after which they are used as fodder. Live larvae have been found in this material even after it has passed through the machine, but probably few survive after it has been given to the cattle. The practice of using the stalks for litter is also followed to some extent in the Jura region in eastern France.

Another measure which has been very generally adopted in many parts of Europe and which results in the destruction of numerous larvae, is that of topping and stripping the stalks after fertilization has occurred and the silks have dried. The upper part of the plant down to the tip of the highest ear is then removed, together with all the leaves, and given to sheep or cattle as fodder. This practice, which usually occurs about the time of pupation, not only results in the destruction of large numbers of borers, but also changes completely the ecological characteristics of the cornfield. The plants are now completely exposed to wind, sun, and rain, and tend to dry up to a very marked extent, especially in warm districts such as the Mediterranean littoral. It is, however, difficult to decide exactly what effect stripping and topping produce on the increase of the borer, because by hastening desiccation it perhaps tends to drive the caterpillars more deeply into the plant, where they are less accessible to parasitic attack than otherwise would be the case.

The various measures described no doubt contribute to a large extent to the control of *Pyrausta nubilalis* in Europe. It is true that they are not universally practiced. Many farmers leave the old

stalks standing in the field until spring, and occasionally, after they are cut, they are not burned but are left on the ground for a year or more or are employed to make temporary windbreaks, shelters, or roofs, or to protect the trunks of fruit trees. Nevertheless, in most districts the great majority of stalks have disappeared in one way or another by spring. In certain districts in Hungary, where the cornstalks are left in piles until after the emergence of the adult moths in spring, infestations much heavier than those observed in western Europe recur at frequent intervals, according to observations made by K. W. Babcock.

INTERRELATIONS AND EFFECTS OF THE CONTROLLING FACTORS IN VARIOUS PARTS OF EUROPE

In the preceding pages the individual factors which affect the increase and abundance of the corn borer have been briefly considered. But all of these factors do not operate everywhere with equal intensity, nor do they all exist in every area inhabited by *Pyrausta nubilalis*. For this reason, in order to get a correct idea of the status of this species in the various parts of its natural home, the various environments in which it is found must be considered separately.

In order clearly to understand the situation of the insect in a given area a knowledge is required (1) of its numerical status, (2) of its potential rate of reproduction, (3) of its actual rate of reproduction, (4) of the factors which limit its increase, and (5) of the part played by each one of these factors in reducing the potential rate of increase to the rate which actually occurs.

Unfortunately, however, the problem is much easier to formulate than it is to solve, and in spite of numerous attempts it has not been found possible, in the time available for this aspect of the work, to accumulate, even for a single locality, data sufficiently accurate and extensive to permit a complete solution of the problem. The writers have some idea of the variations in the population from year to year in a number of regions, but of the factors involved in bringing about the condition observed they know very little. There can be no doubt, for example, that the action of meteorological factors at certain periods of the insect's life may cause heavy mortality, but of the variation in the effect produced by these factors from year to year little is really known. The same is true in regard to the effects of such agricultural practices as topping. It is evident that the proportion of the population destroyed by these measures depends on the proportion of the corn-borer population which has transformed and emerged, but no definite information on the point is available. The only factors to the intensity of which the writers are able to assign numerical values are the parasitic factors, and even there the figures are of very uncertain significance because they indicate, not the percentage of the total population destroyed in a given generation, but merely the percentage of the population present at the time of the collection.

For these and other reasons on which it is unnecessary to dwell at length, it has been impossible to extract, from the data on the various areas investigated, any detailed and definite explanation of the actual status of the corn borer in any given season. The writers are unable to assign to each of the several factors involved its quantitative

value in the environmental system which produces control in any given area, but they have at all events a fairly accurate idea of the composition of the complex of controlling factors in each of the main areas studied and have thus identified the principal forces responsible for the natural equilibrium of the insect in Europe, although the exact manner in which these forces operate is still obscure.

FRANCE

MEDITERRANEAN ZONE (COAST)

Status of Infestation

Only very slight infestation of either weeds or cultivated plants other than corn has been observed in this area. Provencal cane (*Arundo donax*), which is cited by some authors as a host of *P. nubilalis*, has frequently been examined but always with negative results.

A general examination in the first generation of 1921 showed that about 60 per cent of the corn plants were infested. In the second generation of 1923 the examination of 688 stalks in four fields showed an infestation of only 21.5 per cent, the larval population being about 1.4 larvae per infested stalk. The maximum population per infested stalk in this season was five.

In 1924 the larval population of the summer generation in four fields averaged only 19 larvae per hundred stalks examined. In the winter generation the study of some 2,700 stalks showed a larval population of 36 larvae per hundred stalks taken at random.

In 1926 a careful study of 19 fields in the vicinity of Hyeres was made. During the course of this work some 10,600 plants were examined; 23 per cent of the plants were infested, the larval population averaging about two borers per infested plant.

The infestation in this region, though sometimes high, is thus in general slight, the average being probably less than 40 per cent.

Parasitism

The fauna parasitic on *Pyrausta nubilalis* in the Mediterranean zone comprises ten species, of which five occur only at rare intervals. Table 12 summarizes the data on parasitism obtained for Hyeres and adjacent districts during the period from 1921 to 1925, inclusive.

Table 12.—*Parasitism of Pyrausta nubilalis in the Mediterranean zone (coast)*

Species	Average parasitism	Maximum parasitism	Remarks
	Per cent	*Per cent*	
Trichogramma evanescens	1.03	4.80	
Masicera senilis	12.67	28.60	Maximum in 1925, second generation.
Zenillia roseanae	2.90	6.70	
Nemorilla maculosa	(1)	(1)	
Dioctes punctoria	4.60	18.80	Maximum in 1923, first generation.
Exeristes roborator	.28	1.70	
Microbracon brevicornis	.03	.23	
Eulophus sp	(1)	(1)	
Phaeogenes planifrons	.15	.40	
Theronia atalantae	(1)	(1)	
All species	21.66		

[1] Negligible.

The maximum total parasitism for this region was 45.35 per cent; it occurred in the summer-generation larvae in 1922.

The most important parasites in this region are *Masicera senilis* and *Dioctes punctoria*. *Zenillia roseanae* is always present, sometimes in appreciable numbers, but the other species are of little or no practical importance. *Eulimneria crassifemur*, which attacks the borer in practically all other regions, has never been found in the coastal area of the Mediterranean zone.

Meteorological Factors

Conditions are such as to produce in practically all seasons a complete or nearly complete two-generation cycle. The climatic conditions are, on the whole, favorable to the borer, as drenching rains occur at intervals during the period preceding the pupation of the hibernating larvae, while the period during which the moths of both generations are flying is usually dry and warm.

Agricultural Factors

On the Mediterranean coast corn is a crop of minor importance which is grown only for grain and can be cultivated successfully only on irrigated land. It is seldom planted two years in succession on the same soil. Beans, melons, tomatoes, or violets are sometimes grown between the rows.

The land in this district is valuable and is cultivated intensively during practically the whole year. The practice of removing both the leaves and the part of the plant above the ear is almost universal in this region. The material thus removed, which usually contains a considerable number of larvae or pupae of the borer, is given to sheep or cattle as fodder. This practice thus results in the elimination of a fair proportion of the individuals of the species. Furthermore, after the removal of the leaves, the corn plants, exposed to wind and sun, dry up rapidly, so that little suitable food is available for the young larvae of the second generation. As soon as the ears have been collected the stalks are pulled up by hand and destroyed by burning in such a thorough manner that well before the time when the hibernating larvae are ready to pupate it is practically impossible to find any borers in the field.

MEDITERRANEAN ZONE (RHONE)

Status of Infestation

In the winter of 1924–25 a number of small fields of corn as well as several large fields of broomcorn were examined in the Department of Vaucluse, and a count of 400 plants was made, but no corn borers were discovered. In the early summer of 1925 another examination was made of four large fields in the Department of Vaucluse and two in the Department of Bouches-du-Rhone. The proportion of plants attacked in Vaucluse was then only 1.25 per cent, and in Bouches-du-Rhone, 2.5 per cent. Numerous other fields were examined in passing, but in none were any signs of infestation noted.

Higher up in the valley of the Rhone, in the Department of Drome, infestation seems to be heavier. An examination of some 3,000 plants in 1925 showed a 24 per cent infestation, with an average of about 1.6 larvae per infested stalk. In 1926 about 4,500 plants were studied, and a 23 per cent infestation was found, the larval population being about the same as in the preceding year.

Parasitism

The only reliable data concerning this area were obtained from a collection of first-generation larvae made in 1925. In this material six species of parasites were present, including *Eulimneria crassifemur*. The most important parasites were Eulimneria and Zenillia, but Dioctes and Masicera were also present in fair numbers. The results of the examination of 770 larvae of *P. nubilalis* from the northern part of the Mediterranean zone, tabulated below, show that the parasitic fauna of the district was in that instance transitional between that of the southwestern and the Mediterranean coastal areas.

Species:	Parasitism
Masicera sentilis	per cent 3.5
Zenillia roseanae	do 5.4
Eulimneria crassifemur	do 6.2
Dioctes punctoria	do 2.1
Exeristes roborator	do .1
Microbracon brevicornis	do .6
Total	do 17.9

Meteorological Factors

The meteorological characters of the Rhone Valley are to some extent intermediate between those of the Aquitainian zone and those of the Mediterranean littoral. The summers are somewhat colder than on the coast and the winter temperatures fall below those of the Aquitainian zone. The early months of the year (January to April) are drier than on the coast, the spring maximum of precipitation occurring in May instead of March, while the summer months are damper than on the littoral. The climate thus tends to the continental type and seems unfavorable to the rapid development of the borer. Observations indicate that in fact the Rhone Valley is a transitional zone in which a certain proportion of larvae transform during the summer months, while the remainder goes into hibernation. A factor which seems to be distinctly unfavorable to the borer in the Rhone Valley is the mistral. This wind blows with special violence in the lower part of the valley. Its influence on the vegetation is marked and makes the use of windbreaks a general necessity. The examinations in this district have shown an almost complete absence of the borer, while higher up in the region of Valence, where the violence of the wind is less marked, the infestation is definitely higher.

Agricultural Factors

The agriculture of the Rhone Valley is much less intensive, and the destruction of the cornstalks after the collection of the ears is less thorough than in the Mediterranean coastal area. Nevertheless, when

the period of spring pupation arrives few stalks remain, the vast majority having been utilized as litter for cattle during the winter months.

AQUITAINIAN ZONE

Pyrausta nubilalis has been found in practically every district of this zone in which an examination of corn has been made, but it has not been found in any other cultivated plant excepting broomcorn, in which a few specimens have occasionally been collected; nor has it been obtained from weeds, which, however, are rather scarce in this region, where the land is practically all under cultivation, and large cities, with their outlying waste ground, are very few in number.

STATUS OF INFESTATION

Although a few records of economic damage to the corn crop by *Pyrausta nubilalis* in southwestern France exist in entomological literature, and complaints of injury have occasionally been received at the agricultural offices of several Departments (Gers, Gironde, Hautes-Pyrenees) since the inception of the work, it can not be said that the corn borer normally constitutes a serious problem in this area. Few agricultural officials are acquainted with the insect, and the damage attributed to it is sometimes due, at least in part, to the noctuid *Sesamia nonagrioides* Lef.

The data on infestation in the southwest of France are derived mainly from the dissection of stalks from which the ears had been collected and the upper portion of the stalk removed for fodder shortly after fertilization.

In the winter of 1921–22 no definite information was obtained from Gers as to the percentage of stalks infested. The larval population in plants showing signs of attack varied from 0.08 to 0.86 per stalk, the average for the region being about 0.3.

During the winter of 1922–23 about 115,000 stalks from Gers were dissected. Of these about 86 per cent were injured, the damage being partly due to *Sesamia nonagrioides*. The larval population per damaged stalk averaged about 0.48 for Pyrausta and 0.23 for Sesamia.

The winter examinations of 1924–25 comprised about 150,000 stalks. No figures as to the percentage of infestation were supplied by the collectors. The larval population, taking injured and uninjured stalks together, averaged in this season about 0.34 caterpillar per plant, which was somewhat lower than the figure for the preceding year.

During the winter collections of 1925–26, made at seven different points in the Department of Gers, an examination of 1,000 stalks was made from each locality. The average larval population per stalk, infested and uninfested plants being taken together, was 0.32, the minimum, in the vicinity of Levignac, being about 0.04, and the maximum, in the vicinity of Condom, about 0.94. In certain fields around Condom 100 per cent infestation was observed, with a larval population averaging two borers per stalk.

In 1925 a survey to determine infestation was made in the principal corn-growing Departments of the Aquitainian zone; detailed

examinations of 10,750 plants in 24 fields, scattered throughout the zone, showed an average infestation of 5.2 per cent of the plants, the maximum, in the Department of Gers, being 8.7 per cent, and the minimum, in the Department of Landes, 0.87 per cent. A large number of other fields were examined in passing through the country, but in no districts were any signs of heavy attack observed.

In 1926 an extensive study of infestation was made in the Department of Basses-Pyrenees. A total of 65 fields were studied and 15,000 plants were examined, the average infestation being only 5 per cent.

Parasitism

The fauna parasitic on *Pyrausta nubilalis* in the region of southwestern France comprises eight species, one of which has not yet been certainly identified, though it probably is identical with *Microgaster tibialis* Nees, the species found abundantly in the northern weed areas. Table 13, summarizing the data collected in this region during the last six years, will give an idea of the status of the parasites. The percentage of hosts destroyed and the relative importance of the various species vary considerably from one year to another and even from one generation to another. It is sufficient for the purposes of this bulletin, however, to give for each of the regions considered the average and maximum parasitism noted.

Table 13.—*Parasitism of Pyrausta nubilalis in the Aquitainian zone*

Species	Average parasitism	Maximum parasitism	Remarks
	Per cent	*Per cent*	
Trichogramma evanescens	0	0	
Masicera senilis	1.56	4.6	
Zenillia roseanae	4.14	13.4	
Eulimneria crassifemur	9.87	27.0	1920, first generation.
Dioctes punctoria	.80	1.7	
Exeristes roborator	(1)	(1)	A few specimens found in 1920, first generation.
Microbracon brevicornis	(1)	(1)	1920.
Microgaster tibialis	(1)	(1)	1926, first generation.
Phaeogenes planifrons	(1)	(1)	1925.
All species	16.37		

[1] Negligible.

The maximum total parasitism, 22.7 per cent, was observed in the hibernating larvae in 1924–25.

The most important parasites in this region are *Eulimneria crassifemur* and *Zenillia roseanae; Masicera senilis* and *Dioctes punctoria* are much less important, and the other species exist here only in negligible numbers.

Meteorological Factors

Little that is definite can be said on this point, except that in normal years the climate of this region is such as to favor the one-generation type of seasonal history, although i. '920 the great majority of the borers had two generations.

Agricultural Factors

In this region the practice of topping and stripping the corn about the time the silk begins to dry is very extensively followed. When this operation is performed many larvae of the borer are still in the upper part of the plant, and as the leaves and stalks are used as fodder, a considerable elimination occurs in this way. The effect of the removal of the leaves and tops in two-generation years, at about the time the borers are pupating, has also a considerable effect upon the general ecological characteristics of both the individual corn plant and the field as a whole. The softer parts of the plant are removed and the bare stalks exposed to wind and sun. These conditions, though their effect has not been the subject of any experimental investigations, would seem to be in general adverse to the borer.

The disposal of the stalks after the ears are collected varies somewhat, but in the majority of cases they are left standing in the fields throughout the greater part of the winter, during the course of which they are usually cut by hand, made up into sheaves, and burned. In rare instances they may be left lying in a heap for a year or more in a corner of the field. In certain seasons when straw is high priced the stalks are used to some extent as litter. In small plots near the towns, where the land is used for market gardening, the stalks are sometimes pulled by hand. On the other hand, in small fields in the country districts they are sometimes plowed under as they stand. Although the method of dealing with the old stalks thus varies considerably in individual cases, the great majority of the stalks have usually disappeared before the overwintering corn borers have begun to pupate in the spring. No infestation of weeds has been observed in this region, so the continued existence of *P. nubilalis* presumably depends largely upon the larvae which are present in the stubble or have migrated from the cornstalks before the beginning of the winter.

RHODANIAN ZONE

Status of Infestation

Examinations of corn in the Rhodanian zone have not been made on as large a scale as in some other districts because the relative rarity of parasites rendered the region unsuitable for practical operations. Inquiries made at the agricultural offices of the principal corn-growing Departments of the region showed that the borer was not familiar to the officials, nor were any agriculturists found who considered it a pest. A preliminary study in 1921 revealed only a relatively slight infestation over most of the area. In 1924 and 1925 some investigations were made on both corn and Artemisia in the Departments of Jura and Cote-d'Or, with results as follows:

Host plant	Number of plants examined	Per cent infested	Average number of P. nubilalis per infested plant
Corn	2,700	48.9	1.3
Artemisia	600	45.0	2.6

Parasitism

The data concerning parasitism in this area are derived from collections made from corn in the Department of Jura and from Artemisia in the adjoining Department of Cote-d'Or, in the environs of Dijon.

In the corn areas five species of parasites were found, the parasitism for two years of collection being shown in Table 14.

Table 14.—*Parasitism of Pyrausta nubilalis in the Rhodanian zone*

Species	In corn		In Artemisia	
	Average parasitism	Maximum parasitism	Average parasitism	Maximum parasitism
	Per cent	*Per cent*	*Per cent*	*Per cent*
Trichogramma evanescens	2.10	3.20		
Masicera senilis	.45	.90	0.25	0.5
Eulimneria crassifemur	5.35	5.70	5.20	9.0
Apanteles thompsoni	.08	.15	1.10	1.8
Phaeogenes planifrons	.12	.25	.35	.7
Microgaster tibialis			1.35	2.7
All species	8.10		8.25	

The maximum observed parasitism, not including egg parasites, was about 6.3 per cent and occurred in 1925.

In the Artemisia areas five species of parasites were found, the results of the collections being summarized in Table 14.

The maximum parasitism observed was 14.7 per cent and occurred in 1925.

The main points of interest are the absence of *Dioctes punctoria* and *Zenillia roseanae*, the occurrence of *Masicera senilis* and *Phaeogenes planifrons* in Artemisia collections, and the occurrence of Apanteles in borers attacking corn, which indicates perhaps a tendency to a mixture of the corn and Artemisia faunas in regions where infested specimens of these two host plants are grown side by side.

Meteorological Factors

The climate in the low-lying districts where corn is cultivated, being of the continental type, with long, cold winters and short, hot, dry summers, produces a seasonal history of the one-generation type. The rainfall in the months of January to April is rather low, which, as Babcock has shown, tends to delay the transformation of the hibernating larvae. The rainfall reaches its first maximum about the time the adults are ovipositing, the average rainfall for June and July for the Departments of Ain, Doubs, Jura, and Haute-Saone being 8.6 inches, as against 5.15 inches for these months in the Departments of Gers, Lot, Lot-et-Garonne, and Tarn-et-Garonne. To this is perhaps due the relative rarity of the borer in the districts nearest the Rhone Valley, where the characteristics described are most marked.

Agricultural Factors

The practice of stripping and topping is stated by the agricultural officials of the region to be rather uncommon in the Rhodanian region,

but the stalks are frequently cut for litter or fodder almost as soon as the ears have been gathered. In some cases, however, they are left standing in the fields during the winter.

VOSGIAN ZONE

STATUS OF INFESTATION

Knowledge as to the status of the corn borer in the Vosgian region is based on examinations made in the Rhine Valley in 1925. The results of a study of Artemisia areas was as follows:

Department	Number of plants examined	Per cent infested
Bas-Rhin	800	3.57
Haut-Rhin	1,200	11.90
Total or average	2,000	8.56

A point of interest is that in Haut-Rhin an infestation of forage corn was found, though this has elsewhere been practically free from attack. In field corn a slight infestation was noticed and a collection of about 500 larvae was made for parasite study.

PARASITISM

The data on parasites in this region were obtained from the collections made in the Departments of Haut-Rhin and Bas-Rhin in 1925. In this material, comprising 140 larvae from corn and 500 larvae from Artemisia, only Eulimneria and Microgaster were found, the data on parasitism being shown in Table 15.

TABLE 15.—*Parasitism of Pyrausta nubilalis in the Vosgian zone*

Species	Average parasitism in Artemisia	Average parasitism in corn
	Per cent	*Per cent*
Eulimneria crassiformur	3.70	6.40
Microgaster tibialis	13.80	1.40
Both species	17.50	7.80

The parasitism by Eulimneria in caterpillars from Artemisia was approximately the same in the two departments, but that of Microgaster was much higher in Haut-Rhin (23.90 per cent) than in Bas-Rhin (5.50 per cent). This may be due, however, to purely local variations in the districts concerned.

No definite information is available concerning the other controlling factors operating in this zone.

SEQUANIAN ZONE

STATUS OF INFESTATION

In the Sequanian or Parisian zone very little corn is grown, and in plots planted for experimental purposes in the vicinity of Fontaine-

bleau no infestation was observed. The principal host is *Artemisia vulgaris*, though other weeds are sometimes attacked.

The occurrence of *P. nubilalis* in the weed areas is very irregular. Certain "pockets" are found, varying in extent from two or three plants to areas 8 to 10 yards in diameter, where every plant is infested, while in other areas practically no larvae are to be found. As many as 10 to 15 larvae are often found in the larger plants.

Some test examinations in 1925–26 show infestation as follows:

Department	Number of plants examined	Per cent infested	Average number of P. nubilalis per infested plant
Loire-Inferieure	540	0	0
Seine	2,143	24.6	2.1

An examination of 1,430 plants at various points around Lille in the north Sequanian zone in the winter of 1925–26 showed that 19 per cent of the plants were infested and that there was an average of two and one-half *P. nubilalis* per infested plant.

In the winter of 1924–25 examinations of 1,600 plants made in the region of Paris gave an infestation of 20 per cent and an average of two *P. nubilalis* per infested plant.

In the region of Lille in 1924–25 very similar conditions were found. An examination of 1,600 plants showed an infestation of 20 per cent, with an average of 1.39 *P. nubilalis* per infested plant.

In Belgium results obtained the same season were as follows:

Locality	Number of plants examined	Per cent infested	Average number of P. nubilalis per infested plant
Antwerp	400	62.0	2.0
Brussels	800	62.0	2.0
Bruges	400	.5	1.0
Total or average	1,600	46.6	1.9

PARASITISM

SOUTHERN AREA

In the region of Paris six parasites have been found. The results obtained for the years 1922–1925, inclusive, are shown in Table 16.

The maximum total parasitism occurred in 1925 and was 66.70 per cent. It must be noted, however, that these figures were obtained from collections made in places where cocoons were most abundant and are thus in all probability considerably too high.

NORTHERN AREA

The data from this region are derived from collections made in Artemisia in the environs of Lille during the winters 1924–25 and 1925–26. The parasitism is shown in Table 16.

TABLE 16.—*Parasitism of Pyrausta nubilalis in the Sequanian zone*

Species	Southern area		Northern area	
	Average parasitism	Maximum parasitism	Average parasitism	Maximum parasitism
	Per cent	*Per cent*	*Per cent*	*Per cent*
Eulimneria crassifemur	1.15	3.50	0.95	1.90
Exeristes roborator	(1)	(1)		
Microbracon brevicornis	(1)	(1)		
Microgaster tibialis	31.40	63.20	15.00	18.70
Macrocentrus abdominalis	(1)	(1)		
Eulophid	(1)	(1)		
Apanteles thompsoni			22.00	42.50
All species	32.55		38.85	

[1] Negligible.

The maximum total parasitism was 58.90 per cent and occurred in certain fields examined in 1924.

The most important difference between this region and that around Paris is the presence of the Apanteles. Microgaster seems to be a little less abundant in the north than in the south, but it is not certain that the difference is constant.

ARMORICAN ZONE

STATUS OF INFESTATION

In 1925 some fields near Cherbourg (Department of Manche) containing a considerable number of plants of Artemisia were carefully examined, but no trace of *Pyrausta nubilalis* was found. Later in the season an examination was made in the inland Departments of Sarthe and Maine-et-Loire, which lie about on the border between the Armorican, Sequanian, and Aquitainian zones. Results were as follows:

Department	Number of plants examined	Per cent infested	Average number of P. nubilalis per infested plant
Maine-et-Loire	500	13.00	2.00
Sarthe	200	6.50	1.00
Total or average	700	14.71	1.71

An examination of the Department of Morbihan, in which the climate is of the true maritime type, revealed no infestation; this result concurred with the results obtained in Manche.

PARASITISM

The results of winter collections in 1924–25 in the Armorican zone are given below:

Species:		Parasitism
Eulimneria crassifemur	per cent	1.2
Dioctes punctoria	do	(1)
Microgaster tibialis	do	.4
Macrocentrus abdominalis	do	8.9
Total	do	10.5

[1] Negligible.

It is probable that the percentage of larvae attacked by Macrocentrus over the whole region is less than the figures given, which are based upon the study of only 1,000 larvae. The fact remains that, in the district studied, on the eastern border of the Armorican zone, the character of the parasitic fauna of the Artemisia caterpillars differs remarkably from that of both the north and south Sequanian areas. Apanteles seems to be absent and Microgaster is scarce, while Macrocentrus, of which a few individuals only were obtained in other areas, appears in considerable abundance. Collections of three years have shown that the presence of this parasite is a fairly characteristic feature of the area in question.

Meteorological Factors

The examinations made in regions with a well-marked maritime climate, such as Brittany and northwestern Spain, have shown that in such regions *Pyrausta nubilalis* is very uncommon; a fact which agrees with the records from England, where the insect is regarded as very rare. This condition is not due to the absence of proper host plants, as both Artemisia and corn flourish in certain maritime climates, but is probably due to the excessively moist and mild winters, though exactly in what way these are prejudicial to the corn borer is at present uncertain.

SPAIN

GALICIAN ZONE

Status of Infestation

Knowledge as to the status of the corn borer in Spain is based entirely upon an investigation made in the fall of 1925 in the districts of Santiago di Compostela, Padron, Arcade, and Redondela, in which vast areas are planted in corn. During this trip many fields were examined, but few signs of infestation were seen. The detailed study of 4,000 plants in 40 fields showed an average infestation of about 1.7 per cent, which is one of the lowest observed in any of the corn-growing regions. At the experiment station of Santiago di Compostela, in charge of Mr. Gallastegui, a large plot was examined in which the stalks of the previous year were still standing with the growing plants, representing some 60 varieties, but practically no infestation was noted.

Parasitism

On account of the great rarity of *Pyrausta nubilalis* in the corn-growing areas of northwestern Spain in 1925, only a very small number of larvae could be collected for the study of parasitism in the Galician zone. The results obtained from these collections, made at Santiago di Compostela, Padron, and Arcade, are as follows:

Species:	Parasitism
Masicera sentilis	per cent 12.4
Eulimneria crassifemur	do 16.6
Microgaster tibialis	do 2.9
Total	do 31.9

The interesting feature of this collection is the precence of Microgaster and the relatively high percentage of attack by Eulimneria and Masicera.

Meteorological and Agricultural Factors

No definite information in regard to agricultural practices is available. The meteorological characteristics, however, are well known. The region has a distinctly maritime climate with abundant rainfall, which in Santiago averages 5.1 inches or higher in every month except June, July, and August. The annual rainfall in this locality is more than 65 inches. A climate of this type, even though it permits cultivation of corn, is probably unfavorable to the borer. As the departure of the conditions during the summer months from what is observed in the other areas is not very marked, it is probable that the reason for the rarity of the borer is to be sought in the effect of the exceptionally mild and damp winters, as has already been suggested for the Armorican zone.

ITALY

PADOVIAN ZONE

Status of Infestation

The first examinations of corn in this region were conducted in late June, 1924. Many fields were examined in the Provinces of Lombardy, Venice, and Piedmont, with the following results:

Region	Number of plants examined	Per cent infested
Southern Lombardy	450	21.6
Northern Lombardy	800	46.5
Venice	700	1.0
Piedmont	450	41.0
Total or average	2,400	27.0

On returning later to the region of Bergamo in northern Lombardy at a period when the entire infestation was apparent, the writers found that in the most heavily infested fields about 70 to 80 per cent of the plants were attacked. Only the earliest-planted fields, however, were heavily infested, the fields just beginning to flower or not yet in flower being very slightly attacked or altogether free from injury.

In the winter of 1924–25 a lot of 2,400 stalks from this region was examined and gave 3,390 larvae, the population thus averaging over 1.4 larvae per random stalk. The percentage of stalks attacked is not known.

In 1925 the infestation in northern Lombardy was lower than in the preceding season. Near Bergamo the infestation was determined by the study of 2,600 plants, of which 14.5 were attacked, with 4 larvae per infested plant. On the high plateau of Clusone (altitude 2,100 feet) the infestation was only 4 per cent with 1.1 larvae per

infested plant, while at Ombrego di Onore, situated at an altitude of 2,600 feet, no evidence of the presence of Pyrausta could be found.

In 1926 the infestation was also low, many fields showing no sign of attack. The highest infestation was between 40 and 50 per cent, while the average was not more than 10 to 15 per cent.

Parasitism

The fauna parasitic on *Pyrausta nubilalis* in the districts of the Po Valley, where studies have been made, is composed of the same species which are met with in the region of Auch (Aquitainian), though a few specimens of the cryptogastrine braconid Chelonus, never obtained from any other area, also have been reared. The relative importance of the various species of parasites is very different, however, from that observed in the southwest of France. Table 17 gives the results of collections from the district around Bergamo from 1924 to 1926, inclusive.

The maximum parasitism observed in this district was 30.55 per cent and occurred in the summer generation of 1925.

The most interesting features of the Po Valley fauna are the importance of *Dioctes punctoria* and *Phaeogenes planifrons*, the appearance of *Microgaster tibialis* as a two-generation parasite in corn, and the low parasitism by *Masicera senilis*, *Zenillia roseanae*, and *Eulimneria crassifemur*.

In the southern part of the Po Valley only one examination has been made, and that on the summer generation of 1925 in the vicinity of Piacenza. The results obtained are shown in Table 17.

Table 17.—*Parasitism of Pyrausta nubilalis in the Padovian zone*

Species	Northern area		Southern area, average parasitism
	Average parasitism	Maximum parasitism	
	Per cent	*Per cent*	*Per cent*
Trichogramma evanescens	(1)	(1)	
Masicera senilis	1.65	4.70	7.50
Zenillia roseanae	.06	.17	
Nemorilla floralis	(1)	(1)	
Eulimneria crassifemur	1.24	3.60	.40
Dioctes punctoria	6.70	12.00	6.30
Exeristes roborator	(1)	(1)	
Microbracon brevicornis	(1)	(1)	.20
Microgaster tibialis	2.28	3.70	.20
Chelonus sp	(1)	(1)	.01
Phaeogenes planifrons	7.60	14.00	2.70
All species	19.53		17.31

[1] Negligible.

The general character of the fauna from this examination appears to be much the same as that of the northern foothills.

Meteorological Factors

The climate of the Po Valley appears on the whole to be favorable to the borer. The maximum spring rainfall occurs in May, following a cold and dry winter; these conditions are favorable for the

development of the hibernating larvae. The summer months are fairly moist and warm, producing normally a two-generation cycle, though in certain years with a late cool spring a considerable number of individuals pass through the summer without pupating.

Agricultural Factors

The effect of the agricultural factors is difficult to estimate, as agricultural methods vary considerably. It may be said, however, that the vast majority of the winter stalks are disposed of before the adults emerge in the spring. Topping and stripping are very prevalent in most districts, though the agricultural offices discourage these practices. After the ears have been removed the stalks are usually collected, put under shelter, and given to the cattle during the course of the winter as food or litter. Sometimes, especially in the fall while they are still green, they are passed through a shredding machine or cut up by hand. In some cases stalks are used for the construction of small shelters, temporary walls, and fences, or for the protection of the trunks of fruit trees, but only a small proportion of the stalks is utilized in this way. Thus, though no definite methods of attack against the borer have been developed, the normal practices result in the destruction of a large number of individuals.

CAMPANIAN ZONE

Status of Infestation

Information on the status of the borer in the region of Naples is in general rather meager. In 1924 some 8,750 stalks were examined in this region, and from them 1,332 larvae were obtained, but the percentage of infested stalks is not known.

In 1925, 6,380 plants were examined during the first generation, and 190 larvae were obtained therefrom. In the winter generation of this year about 12,000 stalks were examined and 1,400 larvae were collected. The data thus indicate a low general infestation in this region, but, as they were furnished by comparatively untrained local collectors, their value is somewhat uncertain.

Parasitism

The data on parasites from the Neapolitan region are derived from the study of second-generation larvae in 1920 and 1924 and from first-generation larvae in 1925. The results obtained are summarized in Table 18.

Table 18.—*Parasitism of Pyrausta nubilalis in the Campanian zone*

Species	Average parasitism	Maximum parasitism
	Per cent	*Per cent*
Masicera senilis	15.90	23.7
Zenillia roscatae	(1)	(1)
Eulimneria crassifemur	2.30	2.6
Dioctes punctoria	.65	1.3
Microgaster tibialis	(1)	(1)
Eulophid (undetermined)	(1)	(1)
All species	18.85	

[1] Negligible

The maximum parasitism observed occurred in the first-generation larvae of 1925 and was 27.6 per cent.

It is probable that some of the other parasites found on the Mediterranean Riviera, such as *Exeristes roborator* and *Phaeogenes planifrons*, exist also in the Neapolitan zone, but the writers have no proof of this. The fauna resembles that of the Po Valley in its general character, though *Masicera senilis* is much more abundant, occupying about the same position as in the French Mediterranean zone.

Meteorological Factors

The climate in the coastal areas of the Campanian zone resembles that of the French Mediterranean zone, the summer months being somewhat hotter and perhaps less favorable to the borer than in the French littoral.

Agricultural Factors

The writers know very little concerning the agricultural practices in the region of Naples. Destruction of stalks seems to be very thorough, as very few can be found in the spring months.

CENTRAL EUROPE

DANUBIAN (HUNGARIAN) ZONE

Status of Infestation

It has long been known that the European corn borer frequently causes considerable damage in certain parts of the Hungarian corn-growing areas. In 1924 a preliminary investigation was made in this and adjacent countries by K. W. Babcock. The most severe injury was found in the Banat and Bâcs-Bodrog. The average infestation was about 27.35 per cent. The attack in many districts was comparatively slight, but in some districts, such as that of Mesohegyes and Novisad, from 80 to 95 per cent of the stalks were infested. The average loss due to the insect was estimated as about 5 per cent of the crop, but in the zone of heavy infestation a loss of over 90 per cent was reported.

In 1925 a very thorough and detailed study of infestation was made by Mr. Babcock and his assistants. The heaviest damage was observed in central Hungary, where about 70 per cent of the plants were attacked. In the northern and southern sections from 40 to 50 per cent of the plants were damaged. In many areas about 25 per cent of the ears were injured, while an average of about 40 per cent of the stalks were broken over as a result of the larval attack.

The data gathered thus indicate that infestation and damage in the Hungarian corn belt, though varying considerably in different localities, and from one year to another, attain a degree of severity rarely observed in other European areas.

A slight infestation has been observed in Hungary, not only in millet, broomcorn, and hemp, but also in wild plants (Amaranthus and Solanum).

Parasitism

The fauna parasitic on Pyrausta in the Hungarian zone apparently comprises only three species, *Eulimneria crassifemur*, *Masicera senilis*, and *Microbracon brevicornis*, all known from western Europe as well. The relative importance and abundance of these species apparently vary somewhat in different parts of Hungary. In the region of Mesohegyes, where the cornstalks are kept in large piles for long periods, collections from this material in 1925 revealed very slight parasitism by two species and heavy parasitism by the third species, while in other districts where this practice is not followed the parasitism is more evenly distributed among the three species. (Table 19.)

Table 19.—*Relative abundance of parasites of Pyrausta nubilalis under different agricultural practices in Hungary*

Species	Parasitism in regions where cornstalks are kept in large piles for long periods	Parasitism in regions where corn stalks are not kept in piles
	Per cent	*Per cent*
Masicera senilis	0.30	3.1
Eulimneria crassifemur	.17	3.0
Microbracon brevicornis	17.20	6.7
Total	17.67	12.8

Observations made by Babcock indicate that the high parasitism by *M. brevicornis* in the Mesohegyes region is due in large measure to the habit of leaving the stalks until after the period of emergence of the adults. Once the parasites have entered the pile, they pass readily from stalk to stalk and thus ultimately destroy a considerable number of larvae. The high parasitism by *M. brevicornis*, however, is not a constant feature, even under these conditions, for in the spring of 1926 only 0.7 per cent of the hibernating larvae were destroyed by this species.

The data collected up to the present in this region are summarized in Table 20.

Table 20.—*Parasitism of Pyrausta nubilalis in the Danubian (Hungarian) zone*

Species	Average parasitism	Maximum parasitism
	Per cent	*Per cent*
Masicera senilis	0.90	1.5
Eulimneria crassifemur	1.58	3.3
Microbracon brevicornis	7.12	19.5
All species	9.60	

The highest parasitism observed in any season occurred in the hibernating larvae of 1923 and was 23.3 per cent; Microbracon was responsible for 19.5 per cent.

Agricultural Factors

The investigations seem to indicate that the districts in which the stalks are destroyed before the emergence of the borer are those which show the lowest infestation, while the regions of severe attack are those, like Mesohegyes, in which the stalks are kept in piles for long periods.

DANUBIAN (YUGOSLAVIAN) ZONE

Status of Infestation

An extensive investigation in Yugoslavia was made by K. W. Babcock and assistants in 1925 and 1926.

The average infestation was 69.6 per cent in the dent corn of northern Yugoslavia and 74 per cent in the flint corn. An average of 20.6 per cent of the ears were infested and 19 per cent of the stalks were broken over as the result of injuries in dent varieties, while in flint about 39 per cent of the ears were attacked and 21 per cent of the stalks broken. In certain districts the attack was thus very severe. Weed areas (Xanthium) adjacent to heavily attacked fields of corn have also shown severe infestation.

Parasitism

The data collected up to the present on parasitism in Yugoslavia are summarized in Table 21.

Table 21.—*Parasitism of Pyrausta nubilalis in the Danubian (Yugoslavian) zone*

Species	Average parasitism	Maximum parasitism
	Per cent	*Per cent*
Masicera senilis	0.36	0.7
Eulimneria crassifemur	7.20	13.2
Microbracon brevicornis	3.05	3.2
All species	10.61	

From the collections the composition of the parasitic fauna appears to be similar to that of the Hungarian area. In 1926 a few specimens of *Dioctes punctoria* were reared from this section. The maximum total parasitism observed was 16.13 per cent and occurred in 1926, 13.2 per cent of the host mortality being due in this case to *Microbracon brevicornis*.

CONCLUSIONS AND RECOMMENDATIONS

The European corn borer is very generally distributed throughout Europe and practically always present in corn-growing areas, but it is rarely of any real economic importance except in certain areas in central Europe. During six years of study of the insect in the corn belts of France, Italy, and Spain, the writers have never seen a single corn plant broken over or a single ear seriously injured through the attacks of this insect. Thus, although sporadic out-

breaks occur from time to time in corn, hops, hemp, and other crops, it remains true that the corn borer is normally controlled by environmental factors over the greater part of its range on the European Continent.

The control of *Pyrausta nubilalis* in Europe is not due to any simple cause, but is produced by a complex group of agricultural, meteorological, and parasitic factors. The composition of this group of factors is not constant over the whole range of the corn borer, but varies both quantitatively and qualitatively in the different zones inhabited by the insect, and also, though to a lesser degree, in different years and generations in the same zone.

The variation in the composition of the fauna parasitic upon *Pyrausta nubilalis* in different zones is often considerable. Each zone has its characteristic group of parasites, differing both quantitatively and qualitatively from those of other zones. The existence of a species in a given zone depends on the variations in its limiting factors. It must be noted, however, that species which are sometimes parasitic on the corn borer may sometimes exist outside the range of the host, or, conversely, may exist in the same zone as the borer without necessarily attacking it, being at this point parasites on some other insect.

No definite correlation has been observed between the quantitative or the qualitative composition of the fauna parasitic on the borer and the degree of infestation or extent of damage observed in the various zones. Areas in which parasitic species are numerous or parasitism is high are not necessarily those in which *Pyrausta nubilalis* is least injurious; also, a parasitic fauna poor in species or causing a low parasitism is not always or even generally accompanied by high infestation and severe damage. It has been suggested that in order that an insect pest be kept in control it must be attacked in its successive stages by a series or sequence of parasites capable of acting independently without mutual interference. The results of these investigations lend no support to this hypothesis. Natural control exists in many regions in which no such sequence exists or in which the destruction actually produced by the members of the sequence attacking certain stages, such as the egg, full-grown larva, or chrysalid, is absolutely negligible. As a matter of fact the percentage of parasitism observed is not necessarily correlated with the presence or absence of a sequence, nor does it bear any particular relation to the number of species present in the parasitic fauna. Thus an average parasitism of over 36 per cent has been observed in the northern Sequanian zone, where only four parasites are present, while in the Aquitainian zone, where the parasitic fauna comprises nine species, the average parasitism is less than 15 per cent.

The absence of any definite correlations between the qualitative or quantitative importance of the parasitic fauna of the corn borer and the degree of economic damage produced by the insect must not be taken as an indication that the work of the parasites is of no importance. The consideration of an area in which the borer population remains constant and in which the average parasitism is 20 per cent would show that the disappearance of the parasites from this area, other things being equal, would result in a rate of increase of the host of one and one-fourth fold per generation. At such a rate of increase the infestation in a field having originally 50 per

cent of the plants infested with one caterpillar per stalk would rise in 15 generations to a 100 per cent infestation with 14 borers per stalk, and thus eventually cause enormous damage. The average destruction by the parasites varies, as we have seen, from one region to another, and is sometimes rather small. Nevertheless, since control in any given region results from the action of all of the factors working together, it seems reasonable to assume that the absence of any constant cause of mortality will ordinarily disturb the natural equilibrium, and permit an inevitable though perhaps gradual increase in numbers from generation to generation until great economic injury results.

Therefore, since the destructive increase of the European corn borer in America may be due to a considerable extent to the absence of the parasitic enemies which attack it in its native home, it is desirable that as many as possible of these parasites be acclimatized in the infested areas.

As the parasites discovered do not all exist together in any one zone yet studied in Europe, and as the composition of the parasitic fauna differs in every region, it is not probable that all the species introduced into America will become acclimatized in any particular zone inhabited by the borer. The recoveries made in the area in which parasites have been liberated up to the present indicate that the acclimatized parasitic fauna (Eulimneria, Dioctes, Microgaster, Exeristes, and Phaeogenes) is similar in composition to that of the Po Valley zone in Europe. In order to obtain the best results from the parasite introductions, the species not yet acclimatized should be reintroduced as the borer reaches areas differing climatically from those now infested. Such a method is more likely to result in a general reestablishment of the natural equilibrium than a few colonizations in the same area.

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