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THE EUROPEAN EARWIG
CRUMB, S.E. FIDE, P.M. BONN, A.E. 1 OF 1

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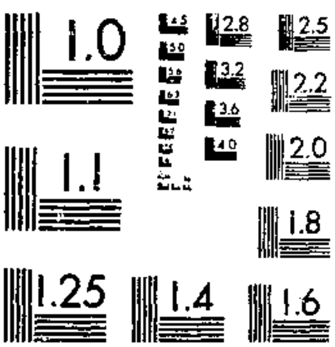

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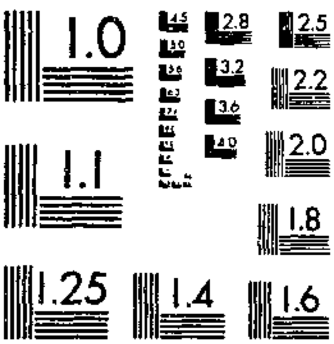

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NATIONAL BUREAU OF STANDARDS-1963-A

Technical Bulletin No. 766 • September 1941

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

The European Earwig [1]

By S. E. Crumb, *entomologist*,[2] and P. M. Eide and A. E. Bonn, *junior entomologists, Division of Truck Crop and Garden Insect Investigations, Bureau of Entomology and Plant Quarantine*

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INTRODUCTION

The European earwig (*Forficula auricularia* L.)[3] has come into prominence largely as a nuisance in and about human habitations rather than as an economic pest. A furtive insect with a foul odor and formidable-appearing forceps, the earwig seems to have a proclivity for creating annoying situations—scuttling out from among the bed linens, lurking among foodstuffs, dropping upon the table from among cut flowers, marring choice ornamental plants, and falling in large numbers when an outer door is opened in the morning. Such occurrences drive the tidy householder to a war of extermination, entered into with a zeal out of all proportion to the actual damage for which the earwig is responsible.

COMMON NAME

There is a popular superstition in Europe to the effect that the earwig enters the ear and from that point bores into the brain, and

[1] Received for publication July 16, 1940.
[2] Retired August 31, 1937.
[3] Order Dermaptera, family Forficulidae.

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so widespread is this belief that in nearly or quite all European languages the common name of the insect bears some reference to the ear, as does also the scientific name. The origin of this superstition is a mystery, as the writers have seen no record of an earwig ever having entered the ear of any creature, although it is quite possible that the insect does so on rare occasions.

DISTRIBUTION

This earwig occurs as a native insect throughout Europe and western Asia and may be a native species in northern Africa. It has been introduced into East Africa, the East Indies, New Zealand, Tasmania, Australia (*30*),[4] and North America. The distribution in North America is given below and shown in figure 1:

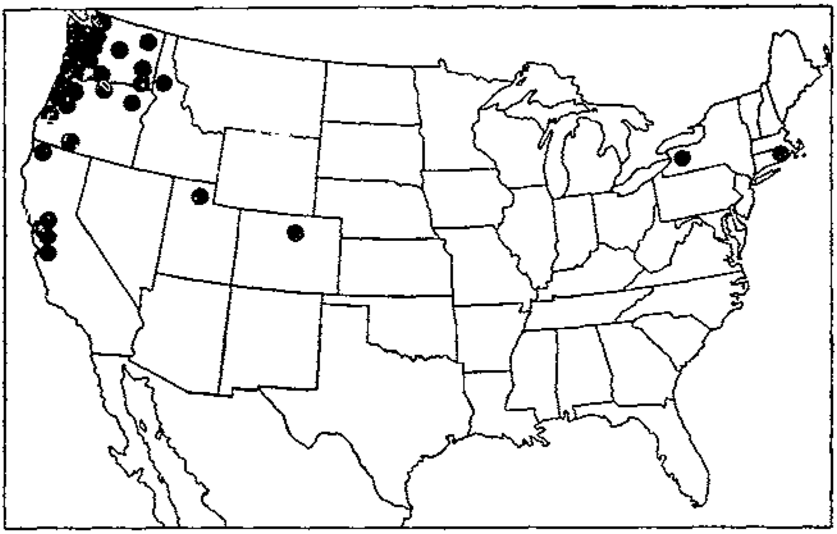

FIGURE 1.—Known distribution of the European earwig in the United States.

MASSACHUSETTS.—Reported from Randolph,[5] Avon,[6] New Bedford (*8*), and Fall River (*55*), all in the eastern part of the State.

RHODE ISLAND.—First reported by Glaser (*28*) and first noted in 1911 according to Jones (*33*). Distribution, according to Stene (*55*) in 1934, limited to the small area bounded by the cities of Newport, Providence, Portsmouth, Tiverton, and Little Compton.

NEW YORK.—First reported by Felt (*20*) at Aurora in 1912. Distribution, according to Crosby,[7] includes Buffalo and Rochester.

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[4] Italic numbers in parentheses refer to Literature Cited, p. 73.

[5] BOURNE, A. I. EUROPEAN EARWIG (FORFICULA AURICULARIA L.) U. S. Dept. Agr. Insect Pest Survey 13: 317. 1933. [Mimeographed.]

[6] PURCHASE, H. C. EUROPEAN EARWIG (FORFICULA AURICULARIA L.). U. S. Dept. Agr. Insect Pest Survey 14: 26–27, 1934. [Mimeographed.]

[7] CROSBY, C. R. EUROPEAN EARWIG (FORFICULA AURICULARIA L.). U. S. Dept. Agr. Insect Pest Survey 13: 259. 1933. [Mimeographed.]

IDAHO.—Abundant in some places in Moscow in 1932, according to Wakeland.[8] Also rather numerous at Coeur d'Alene in 1935, and reported in this year by Wakeland, in a letter, as occurring at Orofino and Lapwai.

COLORADO.—Occurs in large numbers just east of Denver, according to List.[9] This is the only known record for the State.

UTAH.—Abundant in favorable places at Farmington, according to Knowlton.[10]

WASHINGTON.—First noted in the Queen Anne Hill section of Seattle in 1907, according to Coyne (*11*). Reported abundant in Seattle in 1915 by Frank (*24*) and in 1916 by Essig (*17*). Now generally distributed and abundant west of the Cascade Mountains and known to be present in the drier region east of the mountains in Ellensburg, Wenatchee, Tieton, Yakima, Sunnyside, Walla Walla, Dayton, Spokane, Colfax, Pullman, Stevenson, White Salmon, Bingen, and Goldendale. First seen in Pullman in 1928, according to Webster.[11]

OREGON.—Noted at Albany in 1909, according to Fulton (*25*), who also indicates a rather general distribution west of the Cascade Mountains in 1923. Now present throughout the State west of the Cascade Mountains and also occurring at Hood River, The Dalles, Moro, Pendleton, Weston, La Grande, Union, Hermiston, and Klamath Falls in the drier eastern portion of the State.

CALIFORNIA.—First noted in the San Francisco Bay area in 1923, according to Essig (*18*), although said to have been present for at least 4 years previous. Also occurs at Hornbrook, Modesto, and Aptos, according to Mackie (*41*) (*43*), and at Crescent City. Ryan (*51*) reported an infestation in Los Angeles County, but this probably has been eradicated. Rather generally distributed in the San Francisco Bay area but population increasing only slowly.

BRITISH COLUMBIA.—First noted in 1919, according to Gibson and Glendenning (*27*) and Treherne (*61*). Now rather generally distributed in the extreme southwestern part of the Province.

METHODS OF SPREAD

The earwig rarely flies and is not inclined to travel very extensively by crawling, but is admirably adapted for transportation by man. Wandering at night, it crawls into any available hiding place at the approach of day and thus may be carried long distances in bundles of newspapers, the luggage of travelers, cut flowers, packages and crates of merchandise, lumber, and shingles, automobiles, and even rarely in letters. Ships often are infested, and their cargoes are likely to carry earwigs. The female can deposit fertile eggs several months after mating, and the insect is able to survive under a variety of environmental conditions. Hence it seems somewhat strange that the earwig is not more widely established.

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[8] WAKELAND, C. EUROPEAN EARWIG (FORFICULA AURICULARIA L.) U. S. Dept. Agr. Insect Pest Survey 12: 184. 1932. [Mimeographed.]

[9] LIST, G. M. EUROPEAN EARWIG (FORFICULA AURICULARIA L.). U. S. Dept. Agr. Insect Pest Survey 15: 391. 1935. [Mimeographed.]

[10] KNOWLTON, G. F. EUROPEAN EARWIG (FORFICULA AURICULARIA L.). U. S. Dept. Agr. Insect Pest Survey 18: 383. 1938. [Mimeographed.]

[11] WEBSTER, R. L. EUROPEAN EARWIG (FORFICULA AURICULARIA L.) U. S. Dept. Agr. Insect Pest Survey 9: 350. 1929. [Mimeographed.]

CLIMATIC FACTORS IN RELATION TO EARWIG ABUNDANCE AND DISTRIBUTION

The meteorological data used in the discussion which follows are taken from Clayton (*10*), Kincer (*35*, *36*), Ward (*65*), and various publications of the United States Weather Bureau unless otherwise indicated.

CLIMATIC FACTORS IN RELATION TO THE ADULTS

The adult earwig is very resistant to drowning in cold water (p. 37), and the species has become abundant and has spread rapidly in the coastal areas of Washington and Oregon in spite of the excessive precipitation during the hibernation period. Furthermore, the adult hibernating in the soil can withstand low temperatures successfully. Preceding the outbreak in 1920 at Moscow, Union of Soviet Socialist Republics, the mean temperatures for December, January, and February were 16.3, 14.0, and 14.0° F., respectively. Normal precipitation at Moscow in the period October–March is 9.5 inches, and it was 1 inch less than normal preceding the outbreak of 1920, thus giving somewhat less snow protection than usual. It would appear that rather high precipitation and comparatively low temperatures are not important in determining the status of the adult.

On the other hand, the distribution of the earwig and the experimental evidence indicate that the insect is sensitive to low humidity. In the writers' experiments, at an hourly averaged relative humidity of 30 percent, ranging between 25 and 35 percent, earwigs began to die within 3 days and all were dead within 6 days; whereas at an hourly averaged relative humidity of 48 percent, ranging between 43 and 53 percent, the insects began to die within 3 days and all were dead at the end of 12 days. These experiments were carried out in porous paper boxes in a room where mortality in airtight metal boxes was very low. Further evidence of the importance of evaporation in relation to the available moisture was obtained at a series of atmometer stations located in both the humid coastal and the more arid eastern areas of Washington and Oregon (see acknowledgment on back of front cover).

The arrangements at these stations were all exactly alike (fig. 2). Each consisted of a metal barrier enclosing food and 100 earwigs, shaded by a lath screen with the spaces equal to the width of a lath, the laths extending north and south in all cases. A white atmometer sphere equipped with a nonabsorbing valve was placed 3 inches beneath the screen and 1 foot above the surface of the soil, and a similar atmometer sphere attached to a 2- by 4-inch post was placed beside the barrier 5 feet above the surface of the soil. The stations were located where they would have free circulation of air and be without shade other than that provided by the lath screen. Three examinations were made at each station in the course of these experiments, and when no live earwigs were found 100 additional specimens were placed within the barrier. The experiments were continued from about the middle of June to the middle of September, 1930, at most of the stations.

The results in the coastal area of Oregon are of particular interest. The stations included in this area are indicated below from north to south, together with the approximate July evaporation in cubic centimeters from the shaded atmometer: Portland (550) and Forest Grove (700), Corvallis (1,000), Eugene (975), Roseburg (1,050), Grants Pass (1,200), Talent (1,400). It will be noted that evaporation increases gradually from north to south, except that it is higher at Corvallis

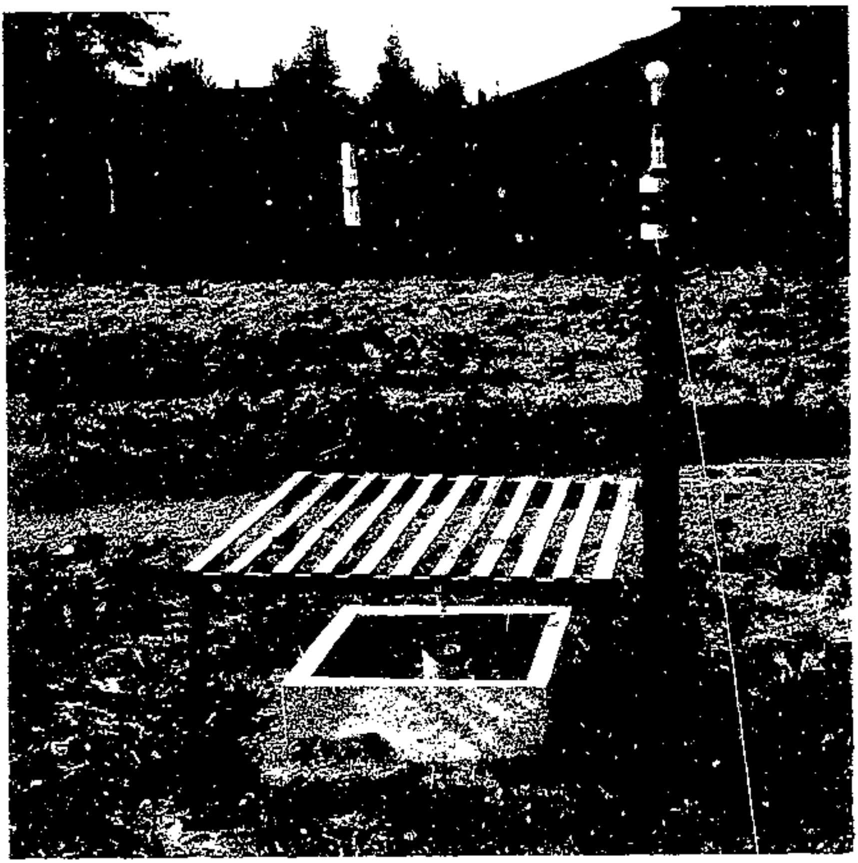

FIGURE 2.—One of the atmometer stations used in the European earwig investigations.

than at Eugene. A reduction in the number of earwigs was found to be distinctly correlated with increase of evaporation, except at Corvallis, which marks the approximate southern limit of the area in which the earwig is abundant. Corvallis is at the southern margin of an incomplete, narrow, transverse bridge of mesophytic coniferous vegetation partially connecting the coniferous areas to the east and west, and there is a break in the mountains to the west which permits the moist ocean breeze to sweep across the valley. A similar relationship between the presence of the ocean breeze and earwig distribution was observed in the arid section along the Columbia River.

Under the conditions of the experiments in the coastal area of Oregon no earwigs survived for as much as a month at stations south of Corvallis, although the insect occurs in nature at Eugene, Roseburg, and Grants Pass mainly, if not entirely, in artificially watered situations.

In the more arid eastern areas of Oregon and Washington earwigs do not occur in nature except in irrigated districts or along streams. Data for comparisons are unsatisfactory in some cases, but the rate of evaporation is high in these eastern areas and, in the experiments, earwigs did not survive except in three irrigated barriers. In at least one of these, at Hermiston, Oreg., the insects overwintered and produced young the following spring.

The earwig is essentially a subterranean insect, the female spending the greater portion of her life in a cell in the soil, and, from the foregoing experiments, it will be seen that the survival and abundance of the insect are particularly dependent on the availability of moisture.

CLIMATIC FACTORS IN RELATION TO THE NYMPHS

The climatic requirements of the nymphs are not known to be essentially different from those of the adults; except that whereas the adults are seldom seriously attacked by disease, and diseased adults have never been observed prior to their having reared at least one lot of young, a heavy mortality occurs among the nymphs in cold, wet weather owing to fungous diseases, particularly that caused by *Entomophthora forficulae* Giard.

THE OPTIMUM CLIMATE FOR THE EARWIG

Of 47 publications in the European literature dealing with the earwig as a pest, 37 have appeared in Germany, the Scandinavian countries, and northwestern Russia. Hence it seems probable that conditions more favorable for the earwig than are found elsewhere in Europe prevail within this region. The mean maximum, average, and minimum temperature and precipitation, based on the records for the following 13 cities in this general region, are given in table 1: Copenhagen, Königsburg, Oslo (Christiania), Leningrad, Moscow, Upsala, Greenwich, Berlin, Breslau, Frankfurt, Gütersloh, Utrecht, and Warsaw. The terms "mean maximum" and "mean minimum" as used in the following tables refer to the extreme means found among the cities under consideration and not to the group of cities as a whole.

TABLE 1.—*Variation in meteorological factors among 13 cities in northwestern Europe where favorable conditions prevail for the development of the European earwig*

[The data cover 20 or more years]

TEMPERATURE

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
Mean maximum	38.8	30.7	41.0	40.0	57.4	63.6	66.0	64.9	59.0	50.6	43.6	40.3
Mean average	28.1	29.4	34.5	43.8	53.5	60.7	63.9	61.9	55.1	45.0	36.5	30.3
Mean minimum	12.6	16.4	24.4	36.4	48.4	57.0	59.8	58.6	49.9	38.8	27.0	17.6

TABLE 1.—*Variation in meteorological factors among 13 cities in northwestern Europe where favorable conditions prevail for the development of the European earwig*—Continued

PRECIPITATION

	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Mean maximum	2.4	2.0	2.1	1.8	2.3	2.8	3.5	3.4	2.4	3.0	2.4	2.8
Mean average	1.6	1.3	1.4	1.5	1.9	2.3	2.0	2.9	2.1	2.0	1.8	1.8
Mean minimum	1.1	1.0	1.0	1.1	1.5	1.9	2.4	2.3	1.7	1.4	1.4	1.3

It will be noted that this is a cool region, the mean never exceeding 66° F., and that the moderate precipitation, averaging 23.5 inches and ranging between 18 and 30 inches, is distributed rather uniformly throughout the year with a slight increase during the warmer months. In more southern Europe, where the earwig has seldom been reported as a pest, but not including Spain, Portugal, extreme southern France, southern Italy, or Greece, the mean temperatures are higher although never rising above 75° F.; and precipitation is higher than in the north except in July and August.

The writers have seen references in the Danish literature to damage by earwigs in 6 years and in 3 of these (1913, 1915, and 1918) the damage was important (*21, 37, 38*). All these reports of injurious prevalence of earwigs fall within a 10-year period 1911–20 and in these 10 years three-fourths of the months were warmer and one-half were drier than normal. It will be noted that most of the infestations in the United States had their origin during this period. In addition there is a report (*34*) of serious damage by earwigs near Moscow, U. S. S. R., in 1920, and Frank (*23*) mentions the occurrence of earwigs in stupendous numbers on the island of Helgoland in 1883. It can be shown that the climatic deviations at Moscow during the outbreak year and the preceding one agree with those to be pointed out in connection with the other outbreaks; but the climate of Moscow is not typical of northwestern Europe as a whole, and the data on this outbreak are excluded from the following discussion.

Climatic factors show the same tendencies in all these years in both Germany and Denmark; and as three of the five references are from Denmark, the climate of Copenhagen is taken as typical. In all the outbreak years at least 4 months of the period March to August, inclusive, were drier and at least 4 months were warmer than normal. Weather records for Copenhagen are available covering 100 years, and the likelihood of the occurrence of this combination of factors in any 1 year is found to be approximately 1 to 4. Hence it would appear that the uniform occurrence of this combination of factors in connection with earwig outbreaks should be considered as having significance. In the years preceding an outbreak at least 4 months of the period March to August, inclusive, were warmer than normal, but only 2 or 3 months were drier than normal. In figure 3, *A*, the average mean temperature and precipitation at Copenhagen for the hibernation period October to December, inclusive, of the years preceding outbreak, and the period January to September, inclusive, of the five outbreak years are compared with the normal. In figure 3, *B*, the same data are indicated for the entire calendar years preceding the outbreaks. Examination of these figures indicates that earwig populations increase during warm seasons, but that it is necessary that such a season be followed by one which is both warmer and distinctly drier than normal if the species is to increase to outbreak numbers.

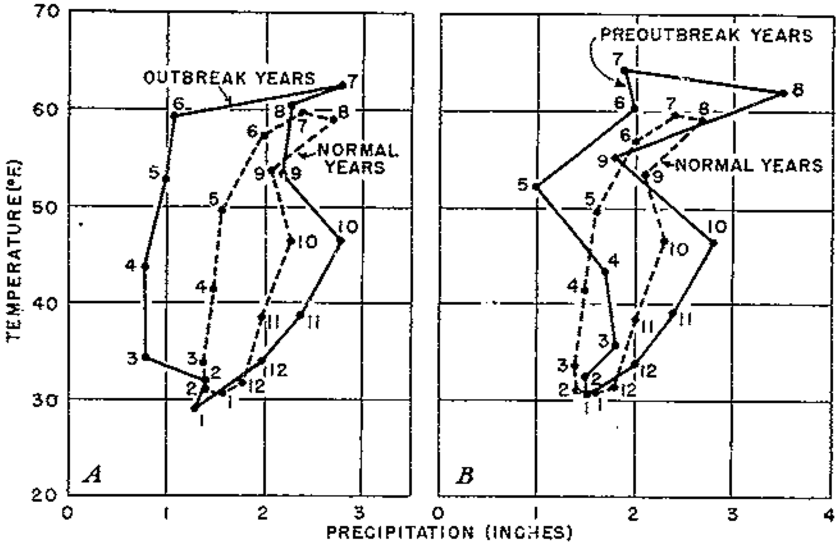

FIGURE 3.—Climographs showing mean temperature and precipitation at Copenhagen, Denmark: *A*, In years in which there were outbreaks of the European earwig, beginning with October of preceding years, compared with the normal. Period, 1911–20; *B*, in entire calendar years preceding outbreaks of the European earwig compared with the normal. Period, 1911–20.

As previously shown, the hibernating adult is able to survive in large numbers under intensities of cold and rates of precipitation far in excess of those found at Copenhagen. Hence it would appear that the occurrence of an outbreak during a warm, dry season is not due to the effect of cold or moisture on the hibernating adult, and an examination of the data shows that deviations from the normal during the period October to February, inclusive, preceding outbreaks are seldom much beyond the normal. For the 5 outbreak years it is found that 11 months were drier than normal during the period October to February, inclusive, whereas the expectation, based on 100 years of observation, would be 13.5 months, while in the period March to August, inclusive, 24 months were drier than normal, with the expectation 15 months. Of the months warmer than normal 14 occurred during the period October to February, inclusive, with the expectation 13.8, whereas in the period March to August, inclusive, the number was 26 with the expectation 15.6 months. The marked climatic deviations occurred in the period March to August, inclusive, in the outbreak years.

Bos (*6, pp. 379–380*) states that eggs are deposited in April, in Germany, and that young appear late in May or early in June; and Vogt (*62*) records that the earwig does not become mature in Germany until in September. Hence the peculiar climate of the outbreak years would affect the eggs and nymphs rather than the adult. As previously stated, a heavy mortality due to a fungus disease occurs among nymphs at Puyallup, Wash., in cold wet weather, and hence in weather drier and warmer than normal this factor would not be present.

REGIONS IN THE UNITED STATES IN RELATION TO THE CLIMATIC REQUIREMENTS OF THE EARWIG

As the survival and abundance of the insect are largely dependent on the degree of dessication to which it is subjected, the earwig finds the best conditions in cool latitudes and apparently does not thrive in areas in which the July mean temperature approaches 75° F., even when a rainfall of 30 inches is well distributed through the year.

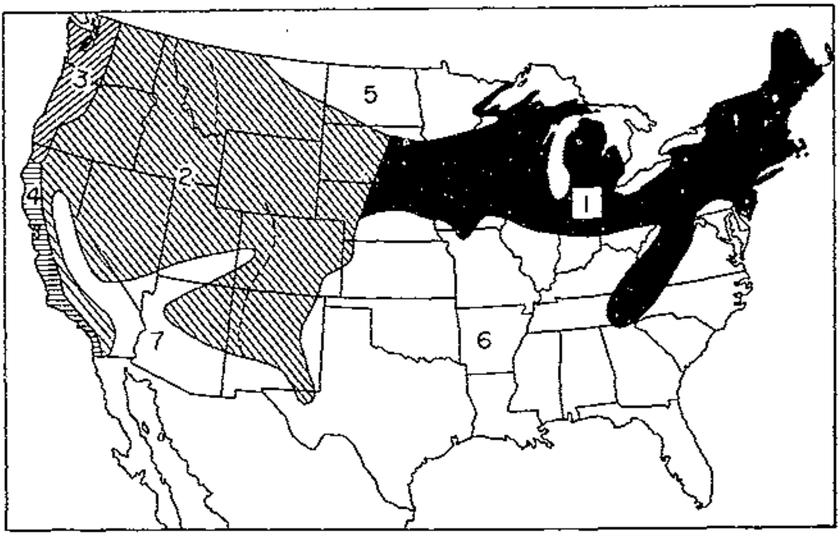

FIGURE 4.—Regions of the United States marked off in relation to the probable survival and abundance of the European earwig.

With these facts in mind, a map has been prepared (fig. 4) in which the United States has been marked off into seven zones, or regions, each having a certain uniformity of climate. It is thought that if the earwig has adapted itself in one part of one of these regions it will be able to extend to any other part if allowance is made for the diversities of climate which will be found in such groupings. Thus, interrelations of climatic factors such as annual snowfall in relation to temperature and of obscure factors such as type of soil may alter the status of the earwig in portions of these regions. Furthermore, the writers lack positive information on which to base the southern limit of some of these regions, but the earwig is not known to occur where the mean temperature for July rises above 75° F., and this isotherm has been used as the southern limit of region 1, as the eastern and southern limits of region 2, and as the eastern limit of region 4. Annual precipitation of 20 inches limits region 1 on the west. The earwig is not known to occur in nonirrigated areas having precipitation less than this, and David Miller, of the Cawthron Institute, Nelson, New Zealand, states in a letter that the insect is not able to establish itself in nonirrigated regions in New Zealand where annual precipitation is less than 20 inches.

REGION 1

Region 1 includes the infested districts in Rhode Island, Massachusetts, and New York. In figure 5, *A* the average mean temperature and precipitation for Block Island, R. I., Providence, R. I., Boston, Mass., and Buffalo, N. Y., are compared with those in northwestern Europe. It will be noted that the mean temperatures are distinctly higher in these cities than in northwestern Europe except in January, February, and March. Oviposition, hatching, and the stages of nymphal development occur two or more months earlier,

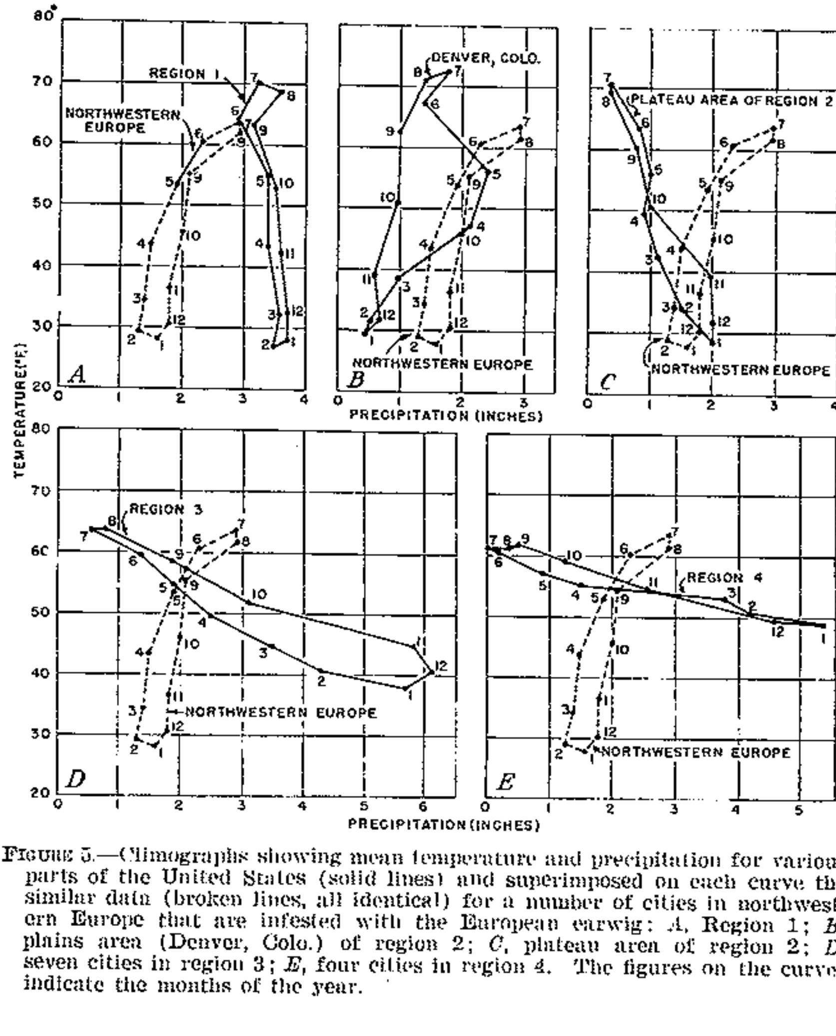

FIGURE 5.—Climographs showing mean temperature and precipitation for various parts of the United States (solid lines) and superimposed on each curve the similar data (broken lines, all identical) for a number of cities in northwestern Europe that are infested with the European earwig: *A*, Region 1; *B*, plains area (Denver, Colo.) of region 2; *C*, plateau area of region 2; *D*, seven cities in region 3; *E*, four cities in region 4. The figures on the curves indicate the months of the year.

however, than in northwestern Europe, and the temperature is distinctly lower in these cities during the time the insects are developing, as given by Jones (*33*), than in northwestern Europe for the corresponding phases of the seasonal history of this insect. Precipitation is much higher throughout the year in these cities than in northwestern Europe.

The earwig has become numerous at Newport, R. I., but in 23 years it has spread over only a small contiguous area, probably not exceeding 25 miles in length. In an equal time the insect occupied the entire coastal regions of Washington and Oregon. Evidently the infestations in region 1 are not developing under highly satisfactory conditions, the main retarding factor probably being the wet, cold weather in the spring.

The averaged mean maximum, mean average, and mean minimum temperatures and precipitation, based on records for 15 cities well distributed over the region, are given in table 2.[12]

TABLE 2.—*Averaged records from 15 cities in region 1 showing the variation in meteorological factors which may affect the survival and abundance of the European earwig*

[The data cover 20 or more years]

TEMPERATURE

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	° F.	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F*
Mean maximum	31.2	32.3	39.6	51.2	62.4	70.7	74.6	72.9	66.4	56.0	45.9	30.5
Mean average	23.0	24.0	33.1	45.7	57.0	66.4	71.4	70.3	63.1	52.1	38.9	28.1
Mean minimum	12.6	15.8	24.8	37.8	49.0	58.9	64.0	63.8	57.5	46.7	32.5	19.0

PRECIPITATION

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
Mean maximum	3.77	3.88	3.99	3.63	4.22	4.31	4.08	4.29	4.01	3.65	3.06	3.90
Mean average	2.3	2.3	2.6	2.8	3.4	3.5	3.5	3.2	3.2	2.8	2.0	2.4
Mean minimum	.92	.92	1.43	2.15	2.85	2.64	2.92	2.61	2.58	2.20	1.30	1.06

The weather conditions throughout region 1 as a whole are similar to those in the small infested area. There are, however, considerable climatic variations in the region from east to west. Winter is warmer and summer cooler near the Atlantic than at the same latitudes to the west; annual rainfall and snowfall gradually decrease toward the west, and the period of maximum rainfall comes in August on the Atlantic coast, in July in the median area, and in June in the western part, but the total March-June rainfall at the western border of region 1 is no greater than at Providence, R. I. On the whole, nothing in the spring and summer conditions indicates that the earwig could not survive in many localities throughout this region.

Turning to winter conditions, snowfall increases from south to north throughout this region and the winters are distinctly colder in the west than at the same latitudes near the Atlantic Ocean. In this connection it should be emphasized that the protection afforded by a covering of snow often aids in the survival of over-

[12] The cities are Burlington, Vt.; Boston, Mass.; Block Island, R. I.; New York and Buffalo, N. Y.; Pittsburgh, Pa.; Cleveland, Ohio; Marquette and Grand Rapids, Mich.; Fort Wayne, Ind.; Green Bay and Madison, Wis.; Chicago, Ill.; Saint Paul, Minn.; and Dubuque, Iowa.

wintering forms of insects. Saint Paul is the coldest city among the 15 considered, having winter temperatures and snowfall similar to those found at Moscow, U. S. S. R., and the earwig not only survives at Moscow but also sometimes appears in outbreak numbers. Hence it would appear that the earwig should be able to survive winter conditions in the northern portions of region 1. Along the southwestern margin of this region the annual snowfall averages only about 27 inches, which is less than half that found at places of comparable temperatures in the East. If the earwig should be unable to survive in the southwestern portion of region 1, this probably will be due to the lack of permanence in the snow cover in conjunction with a rather high summer temperature.

REGION 2

Owing to the range in latitude and the great variation in topography, conditions in region 2 are very diverse and discontinuous. The region as a whole may be divided into an eastern plains area and a western plateau area, as indicated by the broken line in figure 4. The average temperature is lower in the plains area, but the most striking difference is in the yearly distribution of precipitation. The average precipitation is highest during the period November to May, inclusive, in the plateau area and lowest during November to April in the plains area. The average mean temperature and precipitation of certain typical localities of the two areas are given in table 3.

TABLE 3.—*Variations in meteorological factors that may affect the survival and abundance of the European earwig in region 2*

[Data cover 20 or more years]

TEMPERATURE

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
In the plains area:	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*
Mean maximum	29.0	32.9	41.6	50.1	59.2	69.0	74.2	72.7	64.6	52.0	39.4	31.6
Mean average	24.0	26.4	34.9	45.3	54.6	64.2	70.0	68.0	59.7	47.5	35.4	27.2
Mean minimum	14.5	16.8	28.6	40.9	50.3	60.0	66.7	65.6	55.7	44.2	30.0	21.3
In the plateau area:												
Mean maximum	33.8	38.7	46.0	53.8	61.6	68.5	76.6	75.3	64.9	54.2	43.2	306.
Mean average	28.3	32.7	40.9	46.8	55.8	63.5	70.1	69.7	60.1	49.6	38.8	30.6
Mean minimum	20.4	23.3	32.9	43.6	51.1	57.6	64.1	62.8	53.5	43.5	32.4	24.9

PRECIPITATION

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
In the plains area:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
Mean maximum	0.90	0.86	1.16	2.13	2.05	2.06	2.65	2.40	1.53	1.11	0.75	0.78
Mean average	.61	.62	.88	1.50	2.08	1.70	1.77	1.41	1.15	.94	.59	.65
Mean minimum	.31	.49	.59	1.09	1.07	1.18	1.14	.70	.75	.66	.36	.50
In the plateau area:												
Mean maximum	2.09	1.46	2.05	2.08	2.00	2.06	1.49	1.47	1.24	1.53	2.08	2.12
Mean average	1.61	1.27	1.15	1.00	1.10	.92	.52	.52	.78	.98	1.33	1.40
Mean minimum	.96	.68	.29	.36	.52	.29	.10	.13	.41	.48	.08	.65

The Plains Area

The only known infestation in the plains area is that in Denver, Colo. In figure 5, *B*, the average mean temperature and precipitation at Denver are compared with those of northwestern Europe. The mean temperature at Denver is distinctly higher throughout the year than in northwestern Europe, although the July mean is but 72.2. The mean annual precipitation is 14.28 inches as compared with an average mean for northwestern Europe of 23.5 inches, which is more uniformly distributed through the year than at Denver, where the period November to February, inclusive, is dry.

In the seven cities,[13] as a whole the average mean temperature is lower than in northwestern Europe during the period November to February, inclusive, although never falling below temperatures at which the earwig is known to survive, and is higher throughout the remainder of the year, with an average mean for July of 70° F. Annual precipitation averages 13.99 inches for these cities, with a maximum of 15.06 and a minimum of 11.67 inches as compared with an average of 23.5 inches for northwestern Europe. Precipitation throughout the plains area is similar in seasonal distribution to that of Denver and is near the average throughout the year, the greatest deviation being an excess of 0.63 inch at Denver in April.

The indications are that the earwig should be able to survive and slowly become locally numerous along streams and in artificially watered situations throughout the plains area excepting that it may be limited toward the south by the high daytime temperature.

The Plateau Area

Infestations in the plateau area of region 2 include those in Moscow and Coeur d'Alene, Idaho; Farmington, Utah; Sacramento, Calif.; and in a number of cities in eastern Washington and Oregon. In figure 5, *C*, the average mean temperature and precipitation for 11 infested cities[14] in the plateau area are compared with corresponding data for northwestern Europe. Temperatures here are much higher, and, in general, precipitation is much less than in northwestern Europe.

The earwig has been able to maintain itself for about 10 years at least, at some places in this area where it has become moderately abundant, although progress has been slow both in development of numbers and in spread.

The warm, dry spring and early part of summer probably are favorable for the eggs and nymphs, but low humidity and high temperatures in July and August confine the species to situations along streams or where there is irrigation. The area in central Otago, New Zealand, in which the earwig has become a pest receives only about 15 inches of rainfall annually; but summer temperatures are much lower than in region 2, and the rainfall is rather uniformly distributed through the year.

The mean maximum, mean average, and mean minimum temperatures and precipitation based on records for 12 cities are indicated in table 3. Among the cities selected,[15] annual precipitation ranges

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[13] The mean maximum, mean average, and mean minimum temperatures and precipitation for the plain area are based on records for the following seven cities: Miles City and Helena, Mont.; Sheridan and Cheyenne, Wyo.; Denver and Pueblo, Colo.; and Santa Fe, N. Mex.

[14] Data are included for Spokane, Pullman, Walla Walla, Wenatchee, Yakima, and Goldendale in Washington, and The Dalles, Moro, Hermiston, La Grande, and Klamath Falls in Oregon.

[15] The table includes data for Kalispell, Mont.; Boise, Idaho; Spokane, Yakima, and Walla Walla, Wash.; Arlington, Pendleton, Baker, and Burns, Oreg.; Modena and Salt Lake City, Utah; and Winnemucca, Nev.

between 6.7 and 16.6 inches, averaging 12.57 inches, and earwigs survive, in irrigated areas, at both extremes.

As in the plains area, the earwig should be able to survive locally and slowly increase in numbers along streams and in artificially watered districts throughout the plateau area, except that spread may be halted toward the south by the high daytime temperature.

REGION 3

The entire region marked as No. 3 in figure 4 is infested with earwigs, but conditions become less favorable in southern Oregon. In table 4 the temperatures and precipitation for seven cities[16] in this region (excluding southern Oregon) are given, and in figure 5, *D*, the averages for what are at present the most favorable conditions known in the United States are compared with those of northwestern Europe, where the insect is apparently in its optimum habitat.

TABLE 4.—*Variation in meteorological factors which affect the survival and abundance of the European earwig in seven cities in region 3*

[Data cover 20 or more years]

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
TEMPERATURE												
	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
Mean maximum	39.5	42.0	47.0	51.6	57.2	62.2	67.0	66.6	61.5	54.3	46.4	41.7
Mean average	38.0	40.9	44.7	49.5	54.8	59.6	63.8	63.6	58.5	51.7	44.9	40.2
Mean minimum	34.2	39.4	42.5	47.6	52.7	57.0	60.2	59.8	56.0	49.6	43.2	37.8
PRECIPITATION												
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
Mean maximum	7.10	5.66	4.82	3.00	2.30	1.67	0.83	1.51	2.10	3.91	7.10	6.90
Mean average	5.70	4.30	3.50	2.50	1.90	1.40	.60	.80	1.90	3.10	5.80	6.10
Mean minimum	4.50	2.81	2.51	1.60	1.20	.90	.32	.15	1.70	2.54	4.40	5.30

It will be noted that the two climates are very different, but when viewed in relation to the adaptations of the earwig the differences are not so great as they at first appear. The fertilized female earwig remains in the soil, in region 3, from October to April, and the insect is not readily drowned in cold water. Occasionally females tending eggs are drowned in their cells and a considerable number are forced to abandon their eggs and come to the surface during periods of excessive rain, but on the whole the heavy precipitation during the period October to April, inclusive, ordinarily is not very harmful to the species. When the young appear in April, conditions become increasingly favorable; the low precipitation during the warmer months is offset by a moist ocean breeze, and the temperatures after the adults appear are moderate. Earwigs survive under natural conditions throughout this region except in southern Oregon.

REGION 4

Region 4 includes most of the coastal area in California which is reached and distinctly affected by the moist "on-shore" breeze from

[16] The data are for Victoria, British Columbia; Bellingham, Seattle, Tacoma, and Vancouver, Wash.; and Portland and Corvallis, Oreg.

the ocean and which has a mean temperature for July below 75° F. Infestations are found about San Francisco Bay and at Aptos and Modesto. The writers lack climatological data for Modesto, which is near the borderline and may belong in region 2.

In figure 5, *E*, the mean temperature and precipitation for four cities in or near infestations are compared with corresponding data for northwestern Europe. It will be noted that the temperature is rather uniform and much above that of northwestern Europe, except from June to August, inclusive, and that rainfall is very low from June to September, inclusive.

The earwig has become only moderately abundant in this area, and its spread has been slow. One of the retarding factors apparently is not operative in any other infested region in the United States. S. E. Flanders, of the California Agricultural Experiment Station, in a letter states:

> In making collections of the European earwig in the San Francisco Bay region, we have found that the earwig undergoes a period of aestivation of about four months. Earwigs that develop from eggs deposited during the winter and early spring begin to aestivate about July. During the aestivation period they practically disappear from areas where in the late spring they have been abundant enough to cause considerable injury to garden crops and annoyance to householders.

The earwig is a single-brooded species, and an increase in temperature brings a quick response, as is necessary in cooler latitudes, but in the warm climate of the San Francisco Bay districts the cycle of development must be made to occupy a full year in spite of the tendency toward acceleration, and this is accomplished through the interpolation of a period of retarded development as pointed out by Dr. Flanders. It has been indicated (*12 p. 5*) that this necessity for a slowing down of development may become an inhibiting factor at a certain point in the southern advance of some species of Noctuidae, and this probably is also true of the earwig.

The mean maximum, mean average, and mean minimum temperatures and precipitation, based on records for nine cities[17] in this region, are indicated in table 5. The average annual precipitation is 18.86 inches, ranging among these cities between 10.30 and 27.68 inches.

TABLE 5.—*Variation in meteorological factors which may affect the survival and abundance of the European earwig in nine cities in region 4*

Temperature

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	°F.	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*
Mean maximum	54.6	55.5	57.5	59.4	62.2	66.4	70.2	71.1	69.0	65.3	60.9	56.6
Mean average	50.9	52.7	54.4	56.7	58.8	62.2	64.3	64.8	64.3	61.3	56.6	52.2
Mean minimum	47.8	50.3	52.3	55.0	56.5	58.5	58.5	59.0	61.2	58.5	53.0	47.9

Precipitation

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
Mean maximum	5.82	4.72	4.25	1.74	1.05	0.20	0.03	0.05	0.65	1.45	2.65	5.15
Mean average	4.02	3.38	3.07	1.21	.62	.12	.01	.03	.35	.88	1.72	3.45
Mean minimum	2.06	2.03	1.72	.77	.35	.05	(1)	.01	.05	.54	.76	1.87

1 Trace.

[17] The cities represented in these data are Berkeley, San Francisco, San Jose, Santa Cruz, Salinas, San Luis Obispo, Santa Barbara, Los Angeles, and San Diego, all in California.

The mean temperature of region 4 is much above that of northwestern Europe, except during June and July, while the mean annual precipitation averages distinctly lower than that of northwestern Europe and is distributed quite differently through the year, the period from June to September, inclusive, being very dry in region 4, whereas this is the wettest part of the year in northwestern Europe.

The earwig infestations in this area occur in cities having annual precipitation near the maximum for the region. Owing to the very low rainfall during the period June to September, inclusive, conditions, from the standpoint of earwig survival and abundance, are more like those of region 2 than of region 3. Furthermore, the earwig is handicapped in much of this area by being forced to aestivate. Owing to these considerations it seems probable that the earwig will be less abundant in most of this area than it has been in eastern Washington and Oregon.

REGION 5

No infestation is known in region 5, which is characterized by a January mean temperature below 10° F. and an annual snowfall of less than 40 inches except in the extreme eastern part. Earwigs are known to survive in localities having a January mean of 12.6° and may be able to survive in this region.

REGION 6

No earwig infestation has been recorded from region 6, a recent (1938) report of the occurrence of this insect in Alabama apparently being based on a misdetermination. This region is characterized by a July mean temperature above 75° F. and rather high precipitation throughout the year. The annual precipitation, however, does not exceed that occurring in the infested area in region 1, except in parts of the southern half. In Europe the earwig seems to be less abundant as the July mean temperature approaches 75° F., and it seems probable that the insect will have difficulty in becoming established in region 6 except in areas adjacent to the more favorable regions to the north and west.

REGION 7

Figure 4 gives the general location of region 7, which is very irregular in outline. The region is characterized by July mean temperatures above 75° F. and very low humidity and precipitation. No earwig infestation is known here, and the insect probably will not be able to survive in most of this region.

FOOD HABITS AND ECONOMIC IMPORTANCE

The European earwig is omnivorous and is as much at home in a garbage dump feeding on dead fish and greasy paper as it would be in the heart of a rose or about foodstuffs in the pantry. A decidedly greater portion of the food is derived from plant than from animal sources, but animal food is taken regularly, even in the presence of favored plant materials, and seems to be required. The animal food includes insects, spiders, mites, and Protozoa; and much of this probably is dead when eaten, although the earwig feeds on living aphids and other small insects and, while ordinarily timid, sometimes will boldly attack insects larger than itself. The earwig is inclined to accept any reasonably satisfactory food which may be readily available, and for this reason the stomach contents of specimens collected within a few feet of one another often show striking differences. It is somewhat difficult to determine which are the preferred foods of the insect, as it will accept readily whatever is at hand, but mosses (*Ceratodon purpureus* (L.) Brid.[15] and probably other species), lichens, the green alga (*Pleurococcus*[15]) which grows on trunks of trees, and spores of fungi seem to be preferred to higher plants, with the exception of grasses; and aphids ordinarily make up the bulk of the animal food. Living plants are preferred to dead plants, although the earwig can survive on the latter; and the vegetable food seldom is derived entirely from a single plant species.

The economic status of the earwig is something of an enigma, since it is capable of causing serious damage to a wide variety of cultivated plants but seldom does so. In North America the insect has attained prominence as a serious nuisance in residential districts rather than as an enemy of plants, and there are those who look upon the earwig as beneficial because of its predaceous habits. The writers trapped and removed more than 40,000 earwigs from a large city lot, and the insects seemed to be as numerous at the end of the experiment as in the beginning, yet no serious damage to vegetation was observed. Opinion as to the economic status of the earwig in Europe is very diverse, but those who have given most attention to the insect seem, in general, to believe that the importance of the earwig, both as a pest and as a benefactor, has been exaggerated, although agreeing that it occasionally does serious damage to a wide variety of cultivated plants and likewise is sometimes beneficial.

This potentiality for harmfulness coupled with the fact that the earwig has become a major pest in New Zealand renders somewhat hazardous any prediction as to the final status of the earwig in the United States. Certainly the occurrence of the insect in a new environment should not be taken too lightly.

Atwell (*1, p. 87*) states that the "* * * *density of earwig infestation* in any area is *directly in proportion to the frequency of human visitations to that area*." In general, this is true at present, but it is also true that when once introduced and established the earwig is capable of building up a large population covering a wide area in the open country not visited by people in large numbers and far from human habitations, as has occurred on the gravelly prairies in a locality adjacent to Parkland, Wash. In western Washington the earwig has become established in wild land in innumerable places through visits of sportsmen and picnickers and through the dumping of refuse. With the gradual development and spread of these infestations, it seems probable that all suitable uncultivated areas in this region eventually will be infested. Then, if conditions become unfavorable in the uncultivated places, serious general damage to

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[15] Determined by Geo. N. Jones of the University of Washington.

crops may occur. Apparently the earwig did not become a major pest in New Zealand until about 25 years after its introduction.

Although observations on the food habits of the earwig have been appearing in the literature for more than 150 years, the only thorough work dealing with the food of the insect in nature is that done by Lüstner (*40*), who examined the contents of the digestive tract of 162 field-collected earwigs. His summary is translated as follows:

On the basis of the results of our crop investigations, we are of the opinion that the food of the earwig varies according to its abode. In general, it is to be considered an omnivorous insect in the widest sense of the word, whose food under normal conditions consists predominantly of dead plant parts, sooty fungus, and the alga *Cystococcus humicola* which is everywhere common on tree trunks. This accounts for the frequent occurrence of fungus and fungus spores in its crop and stomach. Under favorable conditions, however, the insect attacks living plant parts—leaves and especially blossoms—and thus becomes a pest. Its special preference for the anthers of the stamens is a striking example of this.

It appears that animal matter is eaten largely in a dead condition. In consequence the earwig cannot be looked upon as a beneficial insect.

The intake of vegetable matter is very much greater than that of animal matter. The latter presumably is devoured only occasionally, accidentally, or in the absence of other food.

Taken all in all, the earwig is a harmless creature which is to be combatted only in those cases in which it happens to become a pest.

However, the behavior of the insect toward ripe fruit as well as the role it plays in the vineyard and in the field remain to be elucidated.

It is rather unfortunate that most of Lüstner's specimens were taken from apple, pear, and peach trees, and from a vine (*Ampelopsis* sp.) trellised to the side of a house, since, as we have learned, earwigs in such situations are more or less independent of the ground. In the remaining cases specimens were taken from a blossoming dahlia, and here also the preponderant liking of the earwig for this plant would preclude their wandering far afield in search of anything else. Hence his conclusions, while based on the food of the earwig in nature, are drawn from rather special cases.

In spite of these limitations his conclusions, in the main, agree closely with those of the writers.

Lüstner gave dead plant material an important place in the diet of the earwig, a material the writers have never identified in the stomach contents. Furthermore, he did not identify any grass at all and found moss in only a very few specimens, although these have been very important components of the food in the earwigs examined in this investigation. Lüstner's failure to find them probably was due to the special conditions under which his specimens lived. Finally, the writers are inclined to give the earwig somewhat more credit for the destruction of living injurious insects than is accorded it by Lüstner.

Brindley (*7*) reviews much of the literature and concludes that the universally bad reputation borne by the earwig among gardeners is founded on tradition and lack of judgment in the face of increasing evidence that the insect sometimes is beneficial. Reh (*50, p. 146*) lists the injuries done by the earwig as (1) to flowers, (2) to grasses and grains, (3) to young fruit, (4) to vegetables, (5) to ripe fruit, (6) to vegetables through presence of excrement, and (7) to honeybees. He also mentions larvae and aphids as being fed upon.

Schwartz (*53*) conducted extensive feeding experiments on earwigs in captivity. He concluded that vegetable food is decidedly preferred to animal food, but that when simultaneously offered both were eaten, except that the mature pupae of such Lepidoptera as the cabbage butterfly (*Pieris brassicae* L.) and *Hemerophila pariana* (Clerck) were always unharmed, apparently owing to inability of the earwig to penetrate the pupal shell.

Fulton (*25*) found that the earwig is omnivorous, the normal diet consisting principally of green vegetation, although sugar, starch, vegetable oils, and fat or lean meat are taken readily. Among plants noted as being seriously damaged are bean, potato, beet, cabbage, cauliflower, pea, dahlia, zinnia, sweet-william, and fig. It also was observed that holes were eaten in leaves of orchard trees and berry bushes and that strawberry fruits were attacked.

Gibson and Glendenning (*27*) state that the earwig is omnivorous, the diet including both animal and vegetable materials. Garden plants, both vegetables and ornamentals, were attacked freely, and beans, potatoes, peas, dahlias, roses, carnations, and asters were noticeably injured. One report was received of injury to apples on the trees.

Tillyard (*60*) states that the insect is said to be very destructive to vegetables and flowers and, in some places, swarms into houses, where it feeds on flour, starches, and sugar.

Stene (*55*), reporting on the economic status of the earwig in Rhode Island, concludes that it is the general feeling in the heavily infested area that the earwig is a serious nuisance in residential districts and more or less of a pest of flowers and vegetables.

Dimick and Mote (*14*) concluded that the earwig, after it had been established in Oregon for 25 years, was important as an obnoxious pest in and about human habitations rather than as an enemy of plants, although often reported as damaging flowers, vegetables, various fruits, ornamental shrubs and trees, and infrequently as feeding on honey in hives of bees. The damage to higher plants observed by these writers was small compared with the hordes of earwigs present, apparently indicating food resources other than cultivated plants, and results of their examinations of a few digestive tracts in each of several years indicate that the diet consisted largely of lichens and pollen.

In the present studies of the food habits of the European earwig 347 specimens have been dissected. These were collected in several years, at various places in Washington and Oregon, and during the entire active season for the earwig, and only a few were dissected at any one time. Of the mature earwigs 119 had fed principally on vegetable matter and 36 had included a preponderance of animal matter in their diet, and of the immature earwigs 180 had fed mostly on vegetation and 12 mostly on animal matter. It is evident that the main food is usually of vegetable origin and there seems to be a greater tendency among the adults to feed upon animal matter than is the case with immature earwigs. In a great majority of cases, however, both vegetable and animal food had been taken, and the former seldom was derived entirely from a single species of plant.

In many cases the nature of either the plant or animal food could not be determined definitely, but the definite records of food components that were obtained show that 205 earwigs fed on lower plants as against 139 on higher plants. The lower plant materials eaten and the number of stomachs in which each was found were as follows: Moss (112); lichens (50); spores of fungi, mosses, and probably ferns (32); and algae (11). The records for higher plants are as follows: Grass (57), miscellaneous (44), pollen (22), dandelion (16), Douglas-fir (4), and *Draba* seed (12). The determinable animal food included aphids (50), earwigs (25), various larvae (22), moth scales (17), flies (9), mites (7), springtails (4), spiders (2), thrips (2), Protozoa (2), and a minute beetle (1). The moth scales rarely occurred in large numbers, which seems to indicate that the earwigs picked up the individual scales.

Nine experiments were conducted in which earwigs, both mature and immature, were confined by a metal barrier about 3 feet square containing a section of tree trunk bearing lichens, a box of earth in which moss was growing, and dandelion plants infested with aphids which were renewed from time to time. Grass, also, was growing in some of these enclosures. From 25 to 40 earwigs were put in each of these enclosures, and after from 2 to 10 days had elapsed 6 earwigs were removed from each and dissected.

Fifty of the dissected earwigs contained food of mixed vegetable and animal origin. Of the other 4, 3 contained vegetable matter only, whereas in the remaining specimen the stomach was nearly empty, containing but a trace of aphids. In only 4 of the 53 specimens containing vegetable food was this derived from a single species of plant. Aphids were the main food in the case of only one earwig that had fed upon vegetation.

In two experiments, in which immature earwigs were used and the metal barrier was placed about the base of an apple tree well infested with aphids and other insects and which also was covered with lichens, the main food was lichens, although all the earwigs had fed to some extent on insects.

Injury to Hops

Theobald (*56, p. 61*) gives an account of serious damage to hops involving the whole of a 5-acre field. He says:

> At night one could watch these insects by the aid of a lantern devouring the foliage with great rapidity, especially the young tender leaves. As these pests grew the damage naturally increased, and much harm was done to the young plants.

Injury to Cereals

Injury to barley, rye, and wheat has been mentioned in the literature, but the most conspicuous damage to cereals has been that done to corn. Eckstein (*16*) records a general infestation in the main corn-growing area of Baden, Germany, in which an average of three to five earwigs per ear were found in August and September and 18 to 47 percent of the ears were damaged. In many cases part or all of the silks had been eaten away, and the kernels at the tip of the ear were either eaten away or abortive. A noteworthy parallel between the occurrence of earwigs in individual fields and the abundance of corn smut (*Ustilago zeae* (Beckm.) Ung.) was evident, suggesting at least the probability that infection had been brought about through inoculation by earwigs. Hearle (*32*) reports that earwigs caused serious damage to corn in one section of British Columbia by feeding on the silks, while Coyne (*11*) records earwig damage to 5 acres of corn in which practically all the ears were injured.

Earwigs frequently are found beneath the husks of corn in western Washington and often are distributed through fields several acres in extent. The silks are eaten and where this occurs before pollination has taken place a varying degree of failure of the kernels results (fig. 6).

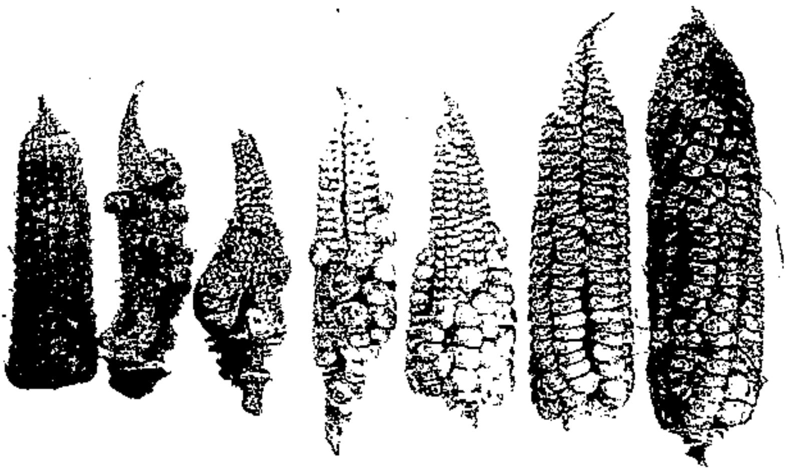

FIGURE 6.—Ears of corn with grains undeveloped because of the feeding of the European earwig on the silks.

INJURY TO FLOWERS

In articles dealing with the food of the earwig, damage to flowers is the form of injury most frequently mentioned. A great variety of flowering plants are attacked, but dahlias, pinks, carnations, and zinnias (fig. 7) are among those most severely injured.

Earwig damage is a source of serious loss to commercial growers of dahlias in the infested areas. All parts of the plants are attacked. Seedlings are devoured completely, and the larger plants are subjected to varying degrees of defoliation (fig. 8). The terminal buds of dahlia are eaten, causing the plants to become misshapen, the flower buds are injured, producing deformed blossoms (fig. 9), and the petals of the blossoms are disfigured.

The earwig is particularly fond of pollen, and its feeding on stamens in some cases interferes seriously with pollination of various plants.

FIGURE 7. Zinnia plants damaged by the European earwig.

FIGURE 8. Dahlia plant damaged by the European earwig.

FIGURE 9.—Dahlia blossom damaged by feeding of the European earwig on the developing bud.

Injury to Fruit

There are numerous references in the European literature to earwig damage to sweet fruits such as apricots, peaches, plums, pears, and apples; but these accounts, of which that of Frank (*23*) may be taken as an example, do not give any details as to the extent of the damage. Some of these writers state that earwigs do not climb trees to attack fruit, which is contrary to observations on this point in Washington: and others associate rot infection with earwig damage.

Theobald (*57*) gives an account of damage to plum blossoms, definitely shown to be caused by earwigs, in which a maximum of 90 percent of the blossoms were eaten. This damage occurred in a young plum orchard where clean culture prevailed and in which the earwigs found a satisfactory hiding place in bands of burlap about the stakes and trees.

Tillyard (*60*) states that the earwig has become a major pest of fruit in central Otago, New Zealand, eating into peaches, nectarines, and apricots and rendering them useless for sale. Dr. David Miller, of the Cawthron Institute, Nelson, New Zealand, in conversation with the senior writer stated that earwigs bored into immature peaches, and remained alive in the seed cavity until the fruit ripened, the entrance growing shut in the meantime so that live earwigs were found in apparently sound peaches. This seems contrary to the general habit of the earwig, which tends to avoid green fruits and hard tissues, but the senior writer found an earwig in the seed cavity of what appeared to be an entirely sound peach, and Wm. W. Baker of the Puyallup, Wash., laboratory found one in the core of an apple.

Newcomer [19] reports considerable damage to apricots and peaches on back-yard trees at Yakima, Wash.

In the present experiment with metal barriers, blackberry, raspberry, loganberry, youngberry, and gooseberry plants, and two varieties of strawberries were grown in each of the enclosed cultivated plots, and apple, prune, cherry, peach, and plum trees were planted in the strip of turf. The everbearing strawberry formed fruit throughout the season, but very little damage to the fruit was observed, and this damage may have been caused by slugs. Earwigs, however, have been found feeding on the flower parts of strawberry. A small degree of feeding was noted on raspberry fruit, but none on any of the other berries. With the exception of the apple trees, all the trees were in their first season and bore no fruit, although they all bloomed to some extent, and no damage to blossoms was observed. There were two moderately large apple trees in the infested plot. On one of these trees two limbs were so situated that earwigs could not drop upon them from higher up in the tree. These two limbs were banded with a sticky material before the blossoms opened to determine whether the exclusion of earwigs would have any effect on the crop of fruit. The fruit set no better and no more fruit was borne on these limbs than on the others, and there was no evidence that the earwigs damaged the unprotected apples. These apples, of the King variety, were firm and not very sweet when ripe. It had been noted

[19] Newcomer, E. J. European earwig (Forficula auricularia L.) U. S. Dept. Agr. Insect Pest Survey 15: 339. 1935. [Mimeographed.]

with sweet apples that earwigs climbed the tree and began to feed on the fruit as soon as it approached ripeness and sometimes bored in to the core and lurked in the seed cavity. Prunes are attacked (fig. 10) both on the tree and on the ground.

Injury to Vegetables

Articles published on the food habits of the earwig mention damage to a great variety of garden vegetables, but specific accounts of injury are not numerous.

Lind and others (*37*, *38*) report that earwigs fed on roots and leaves of sugar beets and mangels in fields, and these writers also

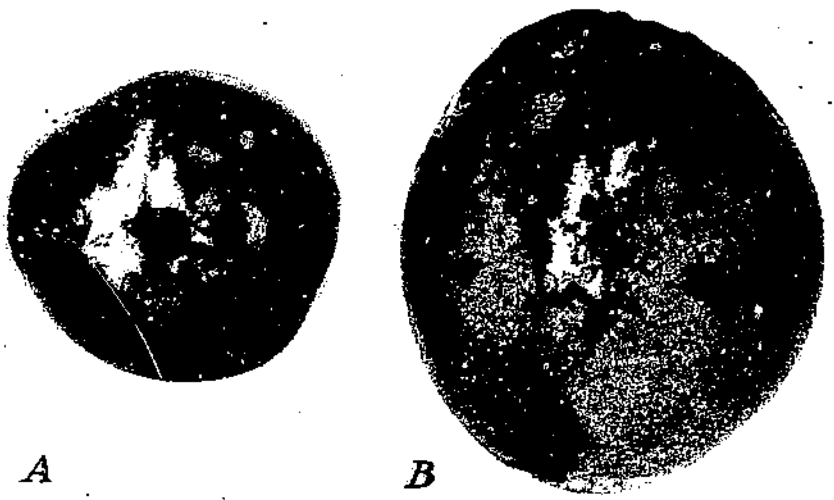

Figure 10.—Prunes damaged by the European earwig: *A*, A fruit with a hole made at the stem end; *B*, an earwig entering a prune.

state that cauliflower heads in several places were attacked to such an extent that they were rendered worthless. Frank (*23*) reports an outbreak of earwigs in which potato stalks were eaten bare of foliage in many instances.

A number of reports have been received of serious damage to seedling plants, including cabbage, carrot, and cucumber.

In the present experiments to determine the status of the earwig as a vegetable pest, an area 70 by 90 feet was surrounded by a metal barrier coated with a sticky material. Next to the barrier a strip of turf about 6 feet wide was left all the way around, and the central portion was cultivated and planted to bean, beet, cabbage, celery, corn, cucumber, lettuce, onion, pea, potato, radish, rhubarb, Swiss chard, strawberry, and tomato. A transverse metal barrier was then constructed at the middle, cutting across the various plantings and dividing the area into two plots 45 by 70 feet. One plot was almost free of earwigs, but in the other, 20,000 earwigs were liberated. All the plants were fed on to some extent, and the rows of potato, cabbage, bean, beet, and rhubarb (fig. 11) were severely attacked for a short distance at the ends next to the turf, but as the season advanced the plants outgrew most of this injury until finally there was very little difference between the vegetables in the infested and uninfested plots. It was noted that celery, Swiss chard, heads of cabbage and lettuce, and ears of corn provided lurking places for earwigs, and the presence of their foul-smelling excreta rendered these vegetables repugnant.

FIGURE 11.—Rhubarb leaf injured by the European earwig.

INJURY TO SEEDS

The literature indicates a distinct liking on the part of the earwig for developing seeds, including those of carrots, pinks, dahlias, and various cereals, and it has been noted in divided dandelion heads that the earwigs had neatly cut out the developing seeds before attacking the remainder of the blossoms, except possibly the stamens; and earwigs are fond of the seeds of a species of *Draba*.

POSSIBLE INJURY TO CLOTH

Pieces of both cotton and woolen cloth, plain and treated with fish oil, were placed with numbers of earwigs in containers provided with very little other possible food, and the supply of earwigs was renewed from time to time; but there was no sign of feeding on these cloths even after an exposure of several weeks. It seems probable, however, that earwigs are capable of cutting cloth, since out of several hundred closely woven, strong cotton bags in which earwigs were sent from Europe two or three contained small holes through which the earwigs had escaped, and these holes were surrounded by a narrow stained area such as might have been produced by the salivary secretion of the earwig. Also, several unsubstantiated reports have been received of damage to silk garments hung on a clothesline, the cuts occurring at the line and earwigs being found at these points.

Occurrence in Beehives

There are not many references in the European literature to the occurrence of earwigs in beehives, and Du Buysson (*15*), in reporting such an occurrence in a hive occupied by a run-down colony of bees, states that the presence of earwigs in beehives never had been reported in any work on apiculture. This would seem to indicate that earwigs are of very little importance to beekeepers.

The writers have received a few reports of earwigs in beehives, and one of these was investigated. Earwigs taken from this weak colony of bees were found to contain beeswax, and presumably honey, in most cases; but, in addition, every specimen had fed on plant material also, indicating that the earwigs found it necessary to leave the hive for a portion of their food. Acting on this indication, poisoned bait was scattered on the ground around the hive, and the earwigs soon disappeared from the hive.

Occurrence in Shipments of Ornamental Plants

Most of the earwigs intercepted in shipments from Europe have been found about nursery stock or ornamental plants or bulbs; and in the United States interstate shipment of balled shrubs and trees, in particular, has resulted in heavy loss in a number of instances owing to the presence of earwigs.

Earwigs as Carriers of Diseases

The earwig lurks in all kinds of unsanitary situations and there can be no doubt that it sometimes carries organisms dangerous to health; and since it often is found about foodstuffs in homes, this insect may be of some importance in the transmission of disease. However, no specific cases of disease transmission to a person can be attributed to this insect. In previous paragraphs reference has been made to the possibility that the earwig might be a carrier of spores of corn smut and of rot in fruit.

Predatory Habits

Views as to the predatory habit of the earwig and its value are "as varied as the observers."

Von Schilling (*52*) says (in translation):

> The earwig, because of its mode of life, is extraordinarily misunderstood and is often portrayed in a false and contradictory light even in good books on natural history. It is a very voracious insect and lives by no means exclusively on plant material but also on animals. On apple trees it is decidedly beneficial and this far outweighs any slight damage the insect may do.

Thiele (*58*) questions Von Schilling's findings, stating that he cannot speak for the usefulness of the insect.

Goe (*29*) thought that the earwig was strictly carnivorous, whereas Fulton (*26*) writes in reply that a little observation with a flashlight will prove this to be erroneous.

Littler (*39*) reports that he has seen every larva of the codling moth (*Carpocapsa pomonella* (L.)) that had gone into the pupal stage in a badly infested orchard eaten out by earwigs, but Muggeridge (*48*) states that where earwig infestation was heaviest the codling moth was more prevalent than for some years.

Maclagan (*44*) records that earwigs were the most voracious of the predators of *Sminthurus*. Two female earwigs ate 958 of these insects in 79 days, capturing them alive.

Lüstner (*40*), who carried out an extensive investigation of the food of the earwig, concludes that the earwig cannot be looked upon as a beneficial insect. Brindley (*7*) is inclined to disagree with Lüstner and cites numerous records of a predacious habit from the literature. Schwartz (*53*) considers that earwigs eat only weak-textured insects of slight activity which they accidentally encounter in their search for vegetable food.

In the present investigation several instances of a predaceous habit were observed in the course of the barrier experiments previously described (p. 25). A clump of Michaelmas daisy (*Aster* sp.) was grown in each of the plots, and each clump became heavily infested with a species of aphid. The aphids disappeared from the plants in the earwig-infested plot while remaining still abundant in the area from which earwigs were excluded, and the clump where there were earwigs did not develop any further infestation although aphids from the uninfested plot were transferred repeatedy to the clean plants. On the other hand, dandelion in the earwig-infested plot was heavily infested with aphids, and earwigs collected within 10 feet of an aphid infestation did not have any aphids in their stomachs. The apple trees were heavily infested with the European red mite (*Paratetranychus pilosus* (C. and F.)) when the experiment began, and these mites became very scarce in July although still abundant in a tree outside the barrier. The trees were infested also with the San Jose scale (*Aspidiotus perniciosus* Comst.), and young scales were numerous beneath flakes of bark, but when these flakes were removed the earwigs ate the young scales.

Codling moth larvae frequently spun their cocoons in the grooved boards used in determining the earwig population in baiting experiments, and earwigs almost invariably perforated these cocoons and ate the occupants, probably in either the prepupal or early pupal stage.

Aphids are the animal food most often eaten by earwigs, and there is evidence that they are capable of destroying large numbers of these insects. One male earwig ate 53 living aphids and 13 aphid exuviae in 45 minutes, and a female earwig ate 36 living aphids and 7 exuviae in an equal time. In spite of this beneficial tendency, roses have been found heavily infested with aphids in gardens where earwigs were numerous.

During an outbreak of tent caterpillars (*Malacosoma disstria* Hbn. and *M. pluvialis* (Dyar)) earwigs were reported frequently from the webs of these caterpillars, and they also were found in webs of *Hyphantria textor* Harris and *Halisidota argentata* Pack. The idea gained currency that the earwig was rendering valuable service in the control of these pests: and dissection of earwigs from the webs tended to support this view, since remains of caterpillars were found in their digestive tracts. To determine the role of the earwig in such situations several experiments were conducted in which about 10 larvae of *Hyphantria textor*, 10 mm. long, were confined with about 25 mature earwigs in a pint-size paper box which also contained apple and dandelion leaves. When any of these larvae died they were devoured, but not a single live caterpillar was attacked although the caterpillars used were immature and each experiment was continued for 7 days. It appears very probable that earwigs found in the webs of caterpillars merely act as scavengers.

Earwigs in confinement ordinarily have seemed to be timid, hesitating to attack any insect of considerable size, such as a large fly, as long as it showed any signs of life. They sometimes are quite bold, however, for when a predatory beetle, *Pterostichus algidus* Lec., was confined with several earwigs, they attacked the beetle at once and managed to pull off one leg at the thorax. The exuding blood of the beetle seemed to excite them, and the earwigs pursued the beetle and fed at the wound. The next day the beetle was dead. Large spiders often have been killed and eaten when confined with earwigs.

From the foregoing it will be seen that the earwig is as unpredictable in the exercise of its predaceous habit as it is in its attack on plants. On the whole it seems probable that this insect is more beneficial than otherwise in orchards in which no sweet fruits are grown, but that in other situations the annoyance and damage caused by the earwig outweigh the good it does.

DESCRIPTION OF THE STAGES

The Egg

The egg (fig. 12, *A*) is shining, pearly white tinged with yellowish, most often elliptical but sometimes distinctly oval, 1.13 mm. in average length and 0.85 mm. in average width when first deposited. Near the end of the incubation period the egg swells and gradually attains a volume nearly twice that when first deposited.

The average number of eggs in 67 egg masses deposited in the field was 30.3 and the maximum number found was 58. The eggs are deposited in cells in the soil, and, at least in the latter part of the incubation period, they usually occupy a special cell near the surface while the female has another cell deeper in the soil to which she retires when not attending the eggs. The eggs usually are found within 2 inches of the surface but may be found occasionally at a depth of as much as 6 inches.

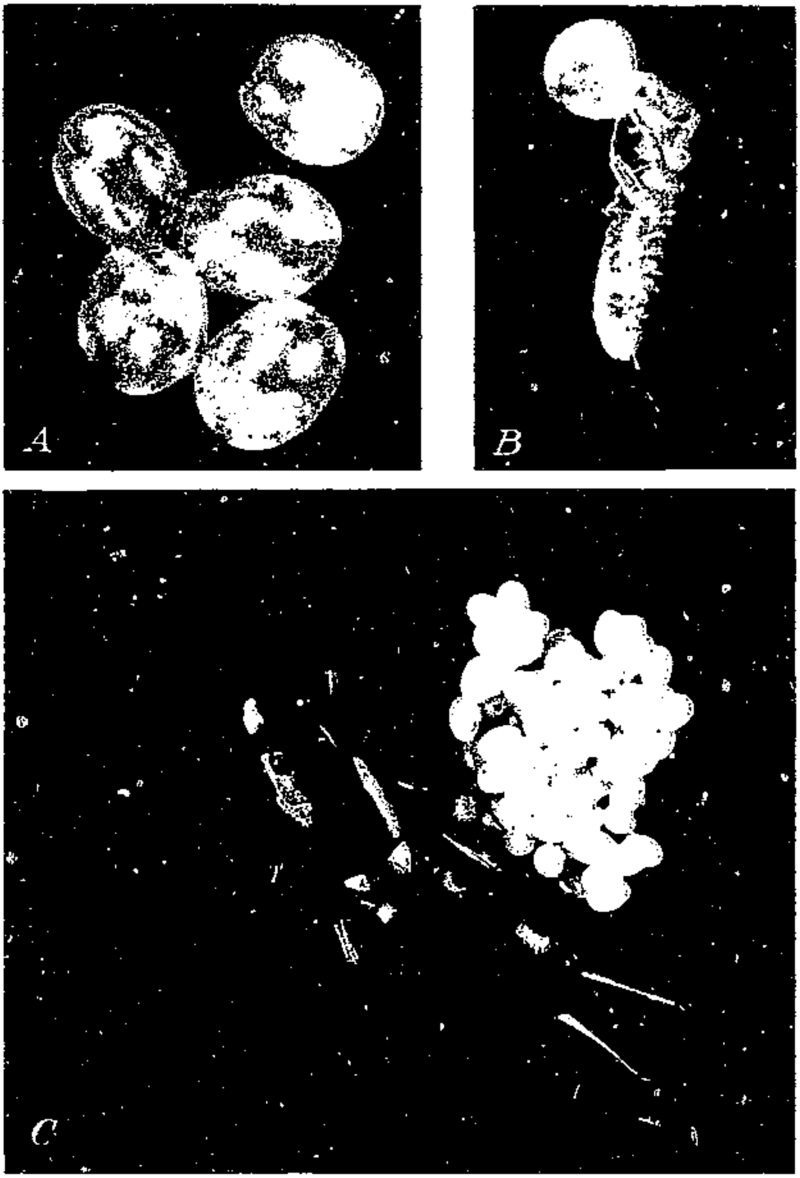

FIGURE 12.—The European earwig: *A*, Eggs, × 20. (The light spots are reflections from the lights used in taking the photograph.) *B*, Earwig freeing itself from the egg pellicle. *C*, Female earwig attending her eggs.

The Nymph

FIRST NYMPHAL INSTAR

Head 0.91 mm. broad. Body about 4.2 mm. long exclusive of the forceps. Antennae with 8 segments. General color a dark sordid gray, the head tinged with brown. Legs and thorax ventrally pale, translucent. Forceps slightly curved, tapering very slightly apically, set with short hairs. (The nymphs described were 10 days old.)

SECOND NYMPHAL INSTAR

Head 1.14 mm. broad. Body about 6 mm. long exclusive of the forceps. Antennae with 10 segments. General color a dark, faintly brownish gray, the head tinged distinctly with brown. Legs and venter of thorax pale. Forceps slightly curved, terete, tapering somewhat toward the tips, set with short hairs. (The specimens had been 8 days in the instar when described.)

THIRD NYMPHAL INSTAR

(fig. 13, *A*)

Head 1.5 mm. broad. Body about 9 mm. long, exclusive of the forceps. Antennae with 11 segments. Head and abdomen dorsally infuscate, thorax pale. Venter pale-brown. Legs tinged distinctly with brown. Forceps distinctly curved toward apices and somewhat flattened basally, set with short hairs. Wing pads not evident, metathorax dorsally broadly emarginate posteriorly. (The nymphs had been 11 days in this instar when described.)

FOURTH NYMPHAL INSTAR

(fig. 13, *B*)

Head 1.9 mm. broad. Body about 9 to 11 mm. long exclusive of the forceps. Antennae with 12 segments. Dorsally infuscate (blackish), the thorax and wing pads with a pale lateral margin. Venter of thorax pale, the abdomen infuscate, becoming darker posteriorly. Legs pale tinged with brown. Wing pads distinct, the lobes meeting posteriorly in an acute angle. Forceps chitinized, somewhat curved toward apices, somewhat flattened basally, terete at tips, set with short hairs.

The Adult

Head 2.2 mm. broad. Body about 13 to 14 mm. long, exclusive of the forceps. Antennae with 14 segments. General color brown, somewhat paler ventrally, the first three and last dorsal abdominal segments partially infuscate. Prothorax dark medially, with broad, pale margins laterally and posteriorly. Wing covers pale brown, the pale folded wings somewhat visible beneath them. Tips of wings extending posteriorly to wing covers dark medially with a broad lateral margin pale. Legs brown. Head a strong translucent brown, usually infuscate anteriorly, the eyes black. On the dorsum of both the second and third abdominal segments a pair of pores set on the posterior face of a callus from which the insect is able to eject a repugnatorial liquid to a distance of 3 or 4 inches. (This secretion causes a browning of the skin similar to that produced by the secretion of bombardier beetles (*Brachinus* spp.)). Forceps of female but slightly curved (fig. 13, C), minutely roughened on the opposing margins. Forceps of male strongly curved (fig. 13, D).

The earwig is able to develop to maturity under very adverse conditions, and adults may be found of but little more than half the normal length. The insect also shrinks in dry situations or in the absence of sufficient food, and females vary in length according to whether they are bearing eggs.

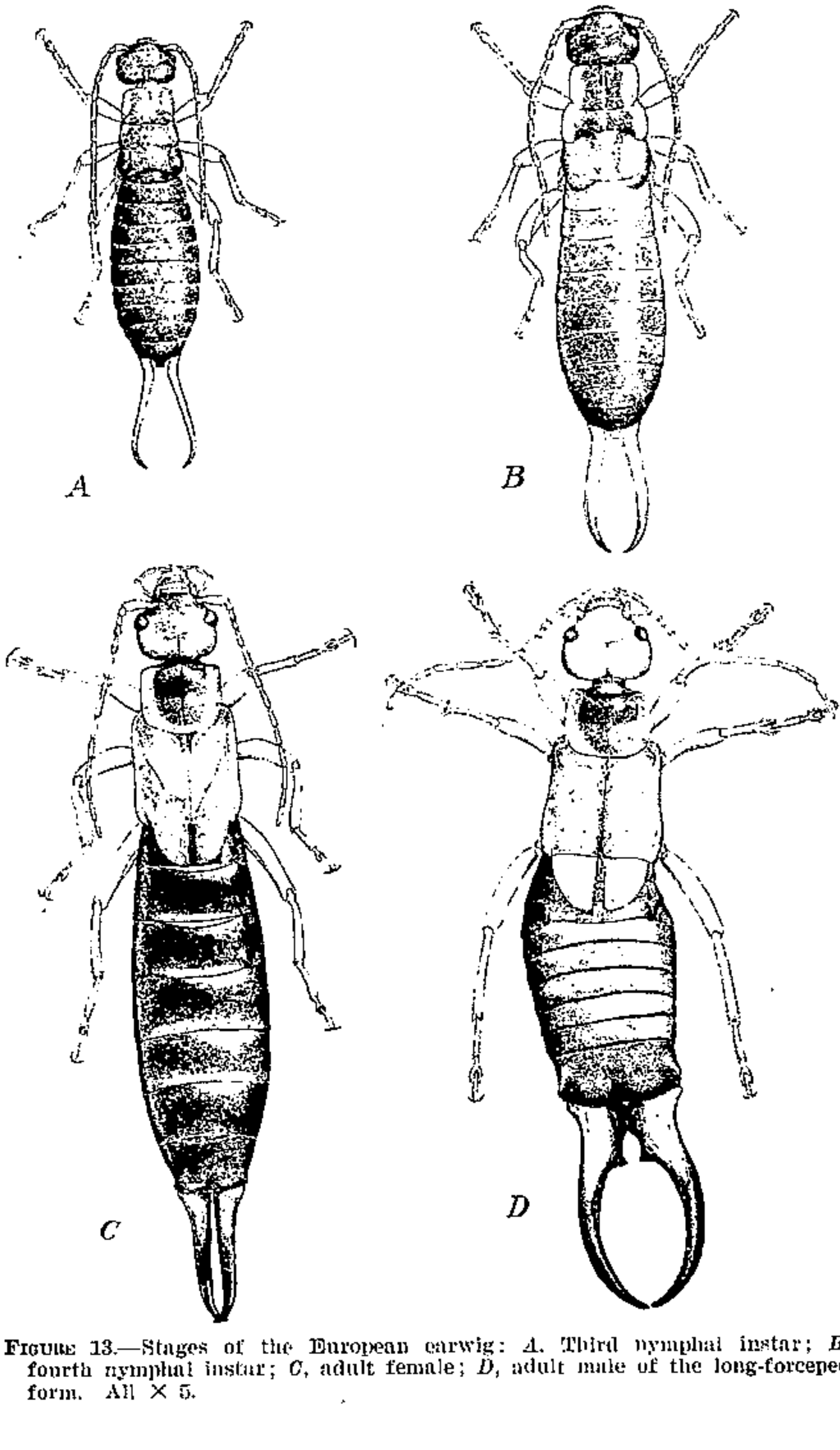

FIGURE 13.—Stages of the European earwig: *A*, Third nymphal instar; *B*, fourth nymphal instar; *C*, adult female; *D*, adult male of the long-forceped form. All × 5.

The systematic relation of the European earwig to other species is indicated in publications by Blatchley (*5*), Buckell (*9*), Essig (*19*), Morse (*45*), and Walden (*63*).

LONG-FORCEPED AND SHORT-FORCEPED MALES

There are two forms of forceps in the male earwigs which tend to be nonintegrating. In the short-forceped form the forceps enclose an apical space which is subcircular (fig. 14), whereas in the long-forceped form this space is more elongate (fig. 13, *D*). Ordinarily the short-forceped form is much the more common of the two. There

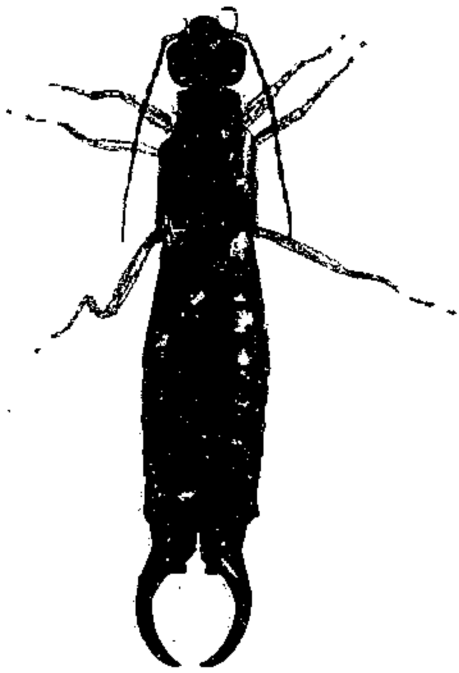

FIGURE 14.—European earwig: Adult male of the short-forceped form, × 5.

is considerable evidence that this characteristic is inherited. All the males in 94,200 earwigs received from Bergamo, Italy, in connection with work on earwig parasites were long-forceped; and there are certain localities in western Washington in which a great preponderance of the males are long-forceped. Earwigs from 7 egg masses were reared to maturity, and long-forceped males appeared in only one lot, which included 5 long-forceped and 7 short-forceped males. Both sexes of adults from this long-forceped ancestry were mated with earwigs of both long-forceped and short-forceped ancestry. The experimental conditions were unsatisfactory and did not preclude the possibility of contamination. No progeny were obtained from the mating of long-forceped ancestry, but in the other rearings, in the second generation, both long-forceped and short-forceped males appeared in every case, although there was a preponderance of the long-forceped males through the long-forceped female ancestry only.

The majority of the specimens in which one side of the forceps appears to be female and the other male are functional males; but rarely a specimen is found which is a true gynandromorph, possessing in more or less complete development both male and female parts (fig. 15).

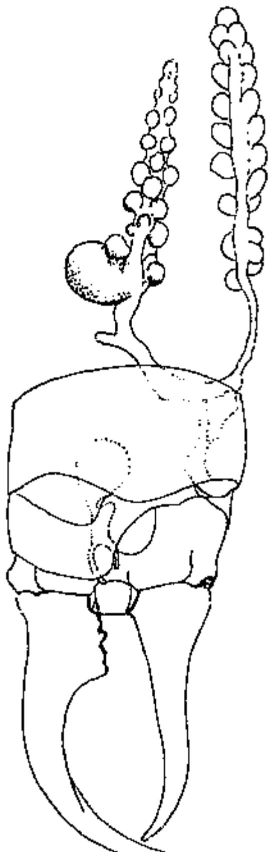

FIGURE 15.—Diagrammatic drawing of the forceps and sexual organs of a gynandromorph earwig, showing male and female parts.

SEASONAL HISTORY

There is a delicate relationship between the rate of development in the earwig and the temperature; and as temperature varies not only from year to year but also according to the location and, in the case of eggs, according to the depth in the soil, hatching of the eggs or the occurrence of any stage of development may occur earlier in one year or in one situation than in another. In 1934 hatching was 3 or 4 weeks earlier than usual, with a corresponding advancement in subsequent stages of development.

In this bulletin the seasonal history is given as found by the writers under the climatic conditions at Puyallup, Wash., during the years 1929 to 1935, inclusive.

When earwigs enter the soil in the fall they form cells which usually are occupied by a pair. An occasional male dies during the winter, but nearly all that enter hibernation survive, at least until they leave the cells. In January all the males leave the cells, and most of them come to the surface. The males then occur in numbers until the last of April or early in May, when they disappear rapidly, some of them entering the soil with females for the second time.

There is some indication that the males leave the cells under compulsion from the females, since, under laboratory conditions which preclude their escape, males sometimes are found mangled when in the company of females tending eggs.

The females begin to leave the soil late in April, and most of them have appeared on the surface by the middle of May; but most of them have disappeared again by the latter part of May or early in June, a portion of them entering the soil to deposit a second lot of eggs. Mating has been observed in February, May, September, and December.

As just stated, some of the females deposit two lots of eggs. The seasonal history of the more numerous females that oviposit only once will be considered first.

Jones (*33*) records the occurrence of eggs in the fall, but examinations at Puyallup have never disclosed any eggs in November or December although they have been found as early as January 5. Oviposition here begins in January, and most of the eggs have been deposited by the middle of February. Hatching begins about April 8, and most of the eggs have hatched by the latter part of April. Young begin to appear above the ground the last week in April or the first week in May. Most of these are still in the first nymphal instar up to about the middle of May, in the second up to about the last week in May, in the third up to about the middle of June, and in the fourth nymphal instar up to near the end of June. New adults begin to appear late in June or early in July, and a majority of the earwigs are mature by the latter part of July.

About a month after the first lot of eggs has hatched, many of the overwintered females enter the soil again, and rather meager evidence indicates that about 15 percent of these deposit a second lot of eggs, the egg masses usually including distinctly fewer eggs than in the first oviposition. This second oviposition begins early in May and continues until early in June. Hatching begins early in June and continues through the third week in June. Young appear above ground late in June or early in July and a majority are in the fourth nymphal stage late in July or early in August. Mature earwigs are in the majority by the middle of September.

Adults begin entering the soil for hibernation the latter part of September, and entrance is completed by the last of October, the period of maximum entrance apparently depending on the advent of cool weather. Numerous males, an occasional female, and rarely a nymph remain above the surface throughout the winter. Nearly all the hibernation cells are within 2 inches of the surface, there being more cells within 1 inch than at any other depth, but cells have been found 6 inches deep in the soil. The females spend about 7 months in the soil without food.

Overwinter Survival

Experiments, conducted through three winters at Puyallup, Wash., by putting known numbers of earwigs in small plots enclosed with metal barriers (fig. 16) in the fall and determining the survival by

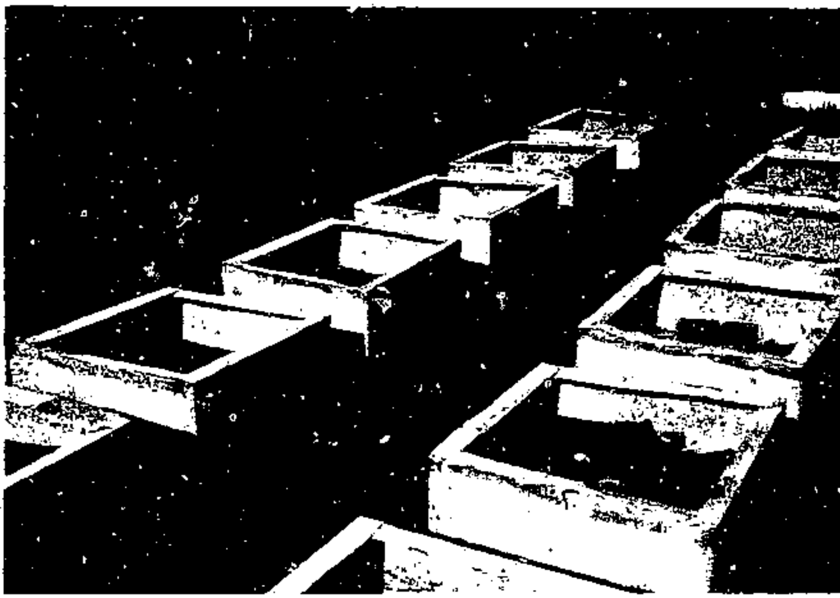

Figure 16.—Metal barriers used in experiments with European earwigs.

digging them up in the spring, have shown that the earwig overwinters most successfully in a sandy loam or black loam. Survival of female earwigs in sandy loam ranged from 5 to 37 percent in different years with an average of 18.6 percent. In other experiments it was found that a preponderance of sand reduced survival and that there was no survival in pure, coarse sand. In black loam survival of females ranged from 15 to 29 percent with an average of 22.5 percent, but experiments with this type of soil were not conducted during one year in which survival was low. In shot clay, a soil containing many small, hard pellets, the survival of females ranged from 0 to 7 percent, with an average of 3.1 percent.

In these barrier experiments it was noted that survival was lower when the soil in the barrier was lower than that outside, thus affording poor drainage. Even in well-drained barriers a considerable percentage of the eggs were found to be addled after excessive rains, and occasionally under such conditions the females were found dead or moribund in their cells. It also has been observed in nature that an abnormally large percentage of females are on the surface after times of excessive rain during the hibernation period.

About 175 experiments were conducted to determine the time required to obtain complete mortality in groups of earwigs completely submerged in water at various temperatures. Ten earwigs were placed in each of a series of 2-ounce bottles which were filled with water at the test temperature. The bottles were fitted with cork stoppers and placed in a water bath, the temperature of which was thermostatically controlled. The cork stoppers were replaced by coarse-meshed cloth in some cases but no difference in results was observed when the two methods were compared. Mature hibernating earwigs were used in these experiments. The results are given in the following tabulation:

Temperature (°F.):	*Time required for complete mortality (minutes)*	Temperature (°F.):	*Time required for complete mortality (hours)*
110	5	80	5
105	20	75	11
100	40	70	18
95	75	60	31
90	120	50	52
85	195		

It will be noted that earwigs are killed very quickly in water at a temperature of 110° F. but that 52 hours complete submergence is required at a temperature of 50°, this ability to withstand submergence in cold water being important for an insect that spends much of its mature life in a cell in the soil. Female earwigs were no more resistant to these treatments than were the males, and in some additional experiments it was indicated that immature earwigs are less resistant than the adults.

A pair normally occupies each hibernation cell until the time for oviposition approaches; but the presence of the male in the cell apparently is not essential for the fertilization of the eggs, since in some cases lone females not only deposit fertile eggs late in the winter but also deposit a second lot of fertile eggs in the spring.

Females were confined within hibernation barriers without males during each of 3 winters, with rather peculiar results. In each of 2 winters 200 females were isolated in a well-drained barrier containing sandy loam; but not a single female survived, although survivals of females confined with males within two adjacent sandy-loam barriers were 12 and 27 percent, respectively. In the third winter 100 females were used, 6 of which survived, while survival of females in an adjacent enclosure containing males was 33 percent. In digging up the first lots it had been observed that in some cases the females were dead in narrow tunnels, and this led to the conclusion that the female was not able to form a satisfactory hibernation cell; but the survival of 6 in the last experiment indicates that this is not true, and it also has been found that the female will form a cell in which to gather her eggs when they are scattered on the soil. The relation of the male to survival of the hibernating female remains to be elucidated.

LIFE HISTORY AND HABITS

The Egg Stage

The average incubation period for winter egg masses in the soil outdoors, based on 16 records, was found to be 72.8 days. The period ranged from 56 to 85 days, varying with the warmth of the location and the depth of the eggs in the soil. For the second, or spring, egg laying the period is about 20 days. In the laboratory the winter eggs hatched in about 15 days and the spring eggs in about 12 days. It will be noted that the time spent in the egg stage was greatly shortened under higher temperatures.

Immediately after they have hatched the young are nearly helpless, being as likely to lie on their backs with their legs waving in the air as otherwise, and the abdomen is long and disproportionately heavy. They sometimes have difficulty in freeing themselves from the egg pellicle (fig. 12, *B*); but the mother earwig, while guarding them solicitously, has never been observed to aid her young in disentangling themselves, although she gathers them unceremoniously beneath her at any alarm, pushing the young about and picking them up in her mandibles regardless of whether or not they are in process of hatching.

Nymphal Instars

A total of 136 earwigs have been reared from egg to adult, but it should be pointed out before the results of this work are discussed that these laboratory records bear little relation, in some respects, to what would be obtained in nature.

Egg masses deposited in the soil were dug up with the female and buried in small ointment jars containing earth. Two or three days after they had hatched the young earwigs were brought into the laboratory and fed singly in small tin boxes. The food consisted of dandelion blossoms and a mixture of meat meal, bone meal, and dried pulverized grass. The room temperature ranged daily between 60° and 70° F., varying occasionally 1° or 2° above or below these temperatures. In the room the relative humidity ranged between 40 and 50 percent, but the humidity in the boxes is not known.

Forty-seven percent of the reared insects were females, 50.8 percent were males, and 2.2 percent apparently were gynandromorphs. The average period from hatching to maturity for males was 51.18 days and for females 49.86 days. The average period from hatching to maturity was 51.2 days for nymphs from winter eggs and 47.1 days for nymphs from spring eggs. The time spent in various instars was as follows:

Nymphal instar:	*Extremes (in days)*	*Average period (in days)*
First	11 to 15	12.92
Second	8 to 14	10.23
Third	9 to 15	11.24
Fourth	14 to 19	16.23

As has been stated, these laboratory results do not agree very closely with what is found in nature. This is particularly true of the first nymphal instar. In nature this instar usually is spent in the soil, and under favorable conditions about 18 to 24 days are required for its completion, and nymphs under normal conditions have been known to continue in the first instar for at least 43 days, whereas this instar was completed in from 11 to 15 days in the laboratory. The field records for the duration of the second nymphal instar indicate a period of 14 to 21 days, while the third instar seems to require about 15 to 20 days in the field and the fourth about 21 days. Thus about 68 days or more are req ıred from hatching to maturity in the field, whereas about 51 days were required in the laboratory.

The young nymphs are attended by the mother earwig and remain in or near the original cell in the soil until they have spent a few days in the second nymphal instar, whereupon the parent relinquishes her responsibility for them. During this early period the young may be found in the soil with much plant material in their stomachs, but no food has ever been found in the cells, and it is not known whether the young sally forth at night to feed or whether the mother earwig brings food into the cell.

The Adults

The females care for their eggs with the greatest devotion (fig. 12, *C*), and in these investigations eggs were never known to hatch in the absence of the female, probably because it is necessary for them to be kept in a moist situation, and yet protected from mold. The care of the eggs includes licking, turning as is done by a hen, and frequent shifting of their position, now in a layer on the side of the cell and now, perhaps, in a heap at the bottom. In spite of her solicitude for them, the female will eat her eggs readily if conditions become too unfavorable or even if she is disturbed too much.

If a female earwig with her egg mass is taken from the soil and placed in a suitable container in which the eggs have been mixed with a quantity of soil, she at once sets about retrieving the eggs. An egg will be seized in the mandibles and then a search begins for a suitable place in which to store it. The mother earwig may shove her way into the earth and emerge again still with the egg in her mandibles; the cavities on the surface are canvassed and finally the egg is tucked away. The process is immediately repeated with a second egg although the earwig seldom finds the first egg but may blunder over it and secrete another egg half an inch away. This is continued until all the eggs, at least to a depth of 1 inch in the soil, have been recovered and placed in scattered caches. A little later the eggs are brought together in one cell. If a number of females with their eggs are brought together in this way they fight viciously for possession of the eggs until finally some will have no eggs at all. After the successful ones in this warfare have reared their brood they will no longer take an interest in eggs, but the defeated earwigs accept and care for any eggs at this late date. After the young have hatched (fig. 17) the females no longer attack other earwigs.

The earwig seems to prefer to return to a place in which it has sojourned before. Females with eggs were confined singly in tin boxes half filled with moist earth. After the eggs hatched the lids were lifted slightly at one side to allow egress, and the boxes were placed among debris on the ground. The mother earwig walled up the crevice with earth, and the colony was always present in the morning; but the young were well filled with food, indicating that the mother or the entire colony had made nightly foraging expeditions. When a little moisture was supplied to these colonies from time to time some of them remained intact for as much as 6 weeks, but the gregarious habit at this time is usually not confined strictly to the family group.

FIGURE 17.—Female of the European earwig with eggs and recently hatched young.

USE OF THE FORCEPS

The reason for the peculiar shape of the male forceps is not known, since the forceps apparently do not perform any function in copulation but are essentially a piercing instrument in this sex, whereas in the female the forceps have a shearing action. In the present experiments it was observed that the predaceous ground beetle *Pterostichus vulgaris* (L.) frequently was frustrated in its attempts to seize a mature earwig owing to the nips delivered by its intended victim. On one occasion a small short-forceped male, held between the index finger and thumb, laid hold of the tough inner part of the finger. There was a slight pain, and when the earwig was removed two droplets of blood marked the points at which the forceps entered. This was a very unusual occurrence, but it indicated the defensive value of the forceps when the earwig is able to apply leverage to the best advantage. On one occasion a female earwig squeezed a disabled fly repeatedly with the forceps until the fly was dead, but most information on use of the forceps has been obtained by observing the tactics of females in the presence of eggs.

When a number of female earwigs are confined together and their eggs are strewn on the surface of the soil, a vicious fight ensues whenever two of the females meet. Owing to the flexibility of the abdomen, the forceps are brought into play in several ways in these contests. (1) The abdomen may be turned toward the adversary and twisted until the forceps are in a vertical plane after which the earwig walks sidewise toward the adversary. (2) Occasionally when free and frequently when in the grip of the enemy the insect brings the abdomen forward directly over the head until the forceps extend beyond the head, and attacks her foe in this position. (3) With the abdomen straight the female sometimes walks backward until contact can be made. When the forceps are closed about the neck, the victim is dragged about, and this seems to be the most effective hold; but when the abdomen is caught there is only a brief struggle unless the attacker is large and the victim small, in which case the victim may be held and visibly crushed as the body of the attacker pulsates with the powerful periodic applications of pressure.

Under laboratory conditions which preclude the escape of the male there is good evidence that females sometimes kill the males when the time for oviposition approaches.

When earwigs are thrown into the web of a large spider the males rarely escape, but about half the females escape. When the spider begins swathing the female in silk she seizes the spider which at once becomes quiescent, she then cuts the binding threads with her mandibles, and, with a sudden movement, is away.

FLIGHT

Very few people have seen the European earwig in flight; but this must not be a rare occurrence under certain conditions, as the writers have seen as many as 20 flights in 1 day. Oddly enough, this nocturnal insect seems to fly most readily in bright, warm sunshine.

It seems necessary for the earwig to take off from an elevated object. The wings are opened very quickly, this action being accompanied by a slight, quick, upward movement of the abdomen, and flight may follow immediately, or there may be a brief delay before taking off. The earwig is able to rise and fly at least 30 feet, going around corners of buildings and making rather rapid progress even when quartering with the wind. Upon alighting, the earwig folds the wings very quickly in most cases, and it assists this process occasionally by a quick, twirling flirt of the abdomen, and in rare instances uses the forceps to tuck in the wings. Most flights have been seen in July and hence have been made by recently matured earwigs.

DISPERSION

In July 1929 an experiment with marked earwigs was performed at a race track one-third of a mile in circumference. Inside the track was a field of uncut grass that was very dry at the time of the experiment, and earwigs were abundant in the board fence enclosing the track. At one point on the periphery of the track 75 marked earwigs were liberated, and traps (fig. 22, p. 48) were placed at each fence post around the track. Three days later the marked earwigs were recovered at various points entirely around the track. The food of the earwigs in this area was largely moss which had become shriveled owing to the hot, dry weather.

In July 1931, 176 marked earwigs were liberated on a lot, and receiving traps were placed at various distances. Only 2 marked earwigs were recovered (20 feet away) in the receiving traps. Marked earwigs were found at the point of liberation up to September 8. A year later 252 earwigs marked with silver paint and 265 marked wtih gold paint were placed in separate hiding traps (fig. 22) beside 2 trees 25 feet apart on a lawn, and 50 earwigs marked with yellow paint were liberated in a thicket 50 feet from the margin of the lawn. Receiving traps were placed at various distances from those containing the marked earwigs, and these were kept under observation from July 19 to October 6. The earwigs tended to stay in their original traps, only a few being found as much as 30 feet away. The maximum observed distance of travel was about 75 feet.

In August 1932 a total of 1,000 earwigs were marked and liberated in a tree beside a paved alley, and 25 traps were placed at various distances away on the opposite side of the alley. No marked earwigs were taken in the 25 traps, but this does not indicate that the alley acted as a barrier, as no earwigs were taken in a trap 20 feet from the point of liberation on the same side of the alley.

During the same month 794 earwigs were marked and liberated in an unsprinkled vacant lot, and traps were placed at various distances on an adjacent sprinkled lot, the margin of which was about 50 feet away from the point of release. Fourteen days after the liberation 2 marked earwigs were found in the traps on the sprinkled lot, and these were at distances of 80 and 100 feet. A great many marked earwigs were still present at the point of liberation.

Again in the same month 180 marked earwigs were placed in a hiding trap beside a building where the temperature within the trap reached 80° F. on some occasions. Receiving traps of similar design were placed opposite, across a gravelled alley. In the course of a month 8 marked earwigs were taken in traps across the alley.

These experiments with marked earwigs confirm conclusions drawn from examination of the stomach contents of field-collected earwigs that, when conditions are favorable, the earwig tends to confine its wanderings to a small area. When conditions are unfavorable, however, as in the race-track experiment, or when the equilibrium of the population is disturbed, as when a single lot in the midst of an infested area is baited, the earwig may wander extensively.

EARWIG PARASITES AND PREDATORS

PARASITES

In Europe the earwig is attacked by two tachinid parasites, *Bigonicheta setipennis* (Fall.) and *Rhacodineura antiqua* Meig., of which the former is much the more important (*59*). Much work with *B. setipennis* has been done in Oregon by the Oregon Agricultural Experiment Station [20] and others (*40*). The Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture is conducting extensive experiments in the State of Washington to determine the economic status of this parasite, and work on the problem also is under way in British Columbia under the auspices of the Dominion Entomological Branch.

Among 17,500 earwigs received from England, 2 were found to contain a roundworm coiled in the thorax and abdomen (fig. 18). These worms were determined by G. Steiner as either *Mermis nigrescens* Dujardin or *M. subnigrescens* Cobb.

Always present in the digestive tract of earwigs, often to the number of fifty or more, is a white gregarine with a body apparently divided into a small anterior and a much larger posterior portion, the whole oval in outline. A gregarine, *Clepsidrina ovata* (Dufour, 1828), is said to occur in earwigs in Europe.

In wet, chilly weather a heavy mortality due to the fungus *Entomophthora forficulae* is observed among nymphs of the earwig. The adults are attacked by this fungus much less frequently than the nymphs, and no earwigs affected by it have been found in cells in the soil, females so affected having deposited and hatched at least one lot of eggs before being attacked. The external growth of *E. forficulae* (fig. 19, *A*) consists of a coarse meshwork of white threads often adhering to the body of the insect, which has a noticeably wet appearance, and bearing clear, round bodies like droplets of water. The hyphae seem to develop principally within the body of the host, which becomes distended, the white hyphae protruding between the segments.

The muscardine fungus (*Metarrhizium anisopliae* Sorokin) occasionally infests earwigs (fig. 19, *B*) and Barss and Stearns (*2*) have found a fungous disease, probably due to *Oospora destructor* (Metschni) Delacroix, attacking earwigs at Portland, Oreg.

The migratory nymphs of a species of mite of the family Tyroglyphidae, which are merely riders (fig. 20) and not parasitic, according to H. E. Ewing, of the Bureau of Entomology and Plant Quarantine, sometimes so burden earwigs that death ensues.

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[20] ATWELL, H. C., and STEARNS, H. C. REPORT OF WORK DONE, SEASONS OF 1925 AND 1926 AT THE PORTLAND INSECTARIES WITH PARASITES OF THE EUROPEAN EARWIGS, DIGONOCHAETA SETIPENNIS AND RHACODINEURA ANTIQUA. [Mimeographed.] Rpt. to Oreg. Bd. Hort. 23 pp. 1926.

PREDATORS

In experiments with the introduced ground beetle *Pterostichus vulgaris* it was found that in confinement each beetle ate an average of about one earwig every 2 days. It also was observed that, even in confinement, the earwig often was able to ward off the attack of the predator. Ormerod (*49*) and Walton and Kearns (*64*) report that

FIGURE 18.—A roundworm, *Mermis* sp., emerging from a European earwig.

P. vulgaris feeds on strawberries in England, and the present writers have found that this beetle not only will eat strawberries but also will attack the berries immediately after having been confined with an abundance of earwigs for several days, indicating that a certain quantity of vegetable food is required. The procedure used in determining the earwig population in baiting experiments was followed in two areas in Seattle, Wash., in which this beetle was said to have controlled the earwig, but no appreciable difference was observed between the earwig population of these areas and that of comparable areas in which *P. vulgaris* was very rare or absent. A colony of a polyphagous predatory species could hardly be expected to exercise any appreciable control when introduced among a relatively enormous population of active insects endowed with considerable means of defense.

Pterostichus algidus Lec., a native predator, is common everywhere in the Puyallup, Wash., area, as many as 65 having been found in 1 earwig trap. In confinement these beetles ate an average of 1 earwig per beetle every 5 to 7 days. Evidently this ground beetle is not very

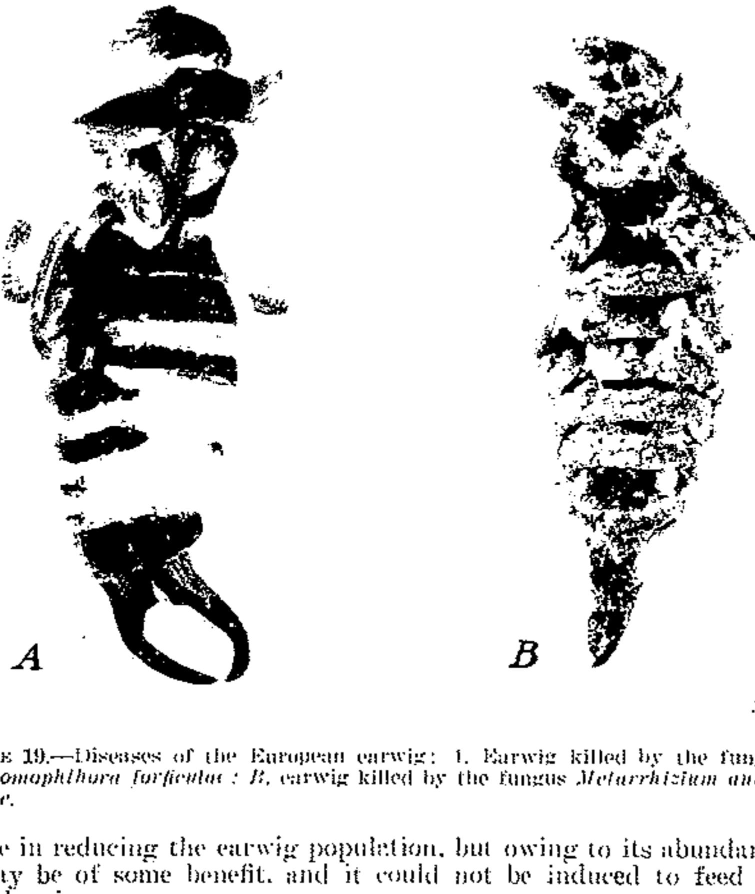

FIGURE 19.—Diseases of the European earwig: *A*, Earwig killed by the fungus *Entomophthora forficulae*; *B*, earwig killed by the fungus *Metarrhizium anisopliae*.

active in reducing the earwig population, but owing to its abundance it may be of some benefit, and it could not be induced to feed on strawberries.

In confinement a specimen of *Carabus nemoralis* Müll., an introduced species, ate 3 mature earwigs in 14 days. In a note kindly supplied by M. C. Lane it is recorded that 5 beetles of this species ate 23 earwigs in 4 days. Lane also observed that 3 adults of *Calosoma tepidum* Lec. ate 26 earwigs in 4 days. E. A. Chapin has determined 3 species of Staphylinidae that have fed on earwigs. These include *Ocypus ater* (Grav.) and *Staphylinus tarsalis* Mann., which attacked earwigs in confinement, and an abundant black species, *Philonthus nitescens* Horn, which has been taken on several occasions feeding on earwigs in the field. The tiger beetle *Omus dejeani* Reiche also has attacked earwigs in confinement.

Earwig remains are found in the feces of toads, snakes, and a gallinaceous bird, presumably the Chinese pheasant. Baiting of premises sometimes results in the death of many snakes, which are protected about gardens in the Pacific Northwest, apparently from their eating poisoned earwigs.

FIGURE 20.—European earwig bearing numbers of mites.

Many persons place much faith in the ability of poultry, and particularly bantam chickens, to control earwigs. In baiting experiments, however, no correlation has been observed between the presence of poultry and reduced numbers of earwigs, and, in fact, the heaviest infestation observed under rural conditions was in a chicken yard. Earwigs are expert at hiding in inaccessible places and are active only after dark, hence it seems probable that chickens are of negligible value in the control of earwigs, although they eat the insects readily when they find them.

CONTROL EXPERIMENTS

Baiting

The habits and wide range of food of the earwig have indicated the use of poisoned baits as being the most likely if not the only practical method of control, and most of the experiments have been with various mixtures for such baits and with methods and times of application.

Figure 21.—Pans used in laboratory experiments with European earwig.

EXPERIMENTAL PROCEDURE

LABORATORY EXPERIMENTS

In each laboratory test two graniteware pans of 2-quart capacity were used (fig. 21). Each pan was covered with a closely fitting pie tin, and 10 earwigs were put in each pan. A bait was divided between the two pans, made up, unless otherwise stated, of 24 gm. of wheat bran, 2 gm. of poison, and 4 cc. of fish oil. When various other bait ingredients were compared with these, the materials were exposed simultaneously in an open insectary and earwigs of the same stage of development were used in each test. A daily record of the mortality was made for 6 days.

FIELD EXPERIMENTS

In field experiments a number of hiding blocks, or traps, consisting of two grooved boards placed upright, groove to groove (fig. 22), were put out on each lot of a city block. After these had been in place for a week the number of earwigs in them were either counted or estimated. If the earwigs were quiet and not too numerous they were counted, otherwise an estimate was made. This population record was taken by the same man in all cases, and the estimates were checked occasionally by counting. The bait was put out as soon as the population had been recorded for the whole block. and additional records were taken in the same way at weekly intervals thereafter, and as the earwig population decreased it became more and more possible to obtain exact counts. Materials to be compared were applied the same day unless otherwise noted.

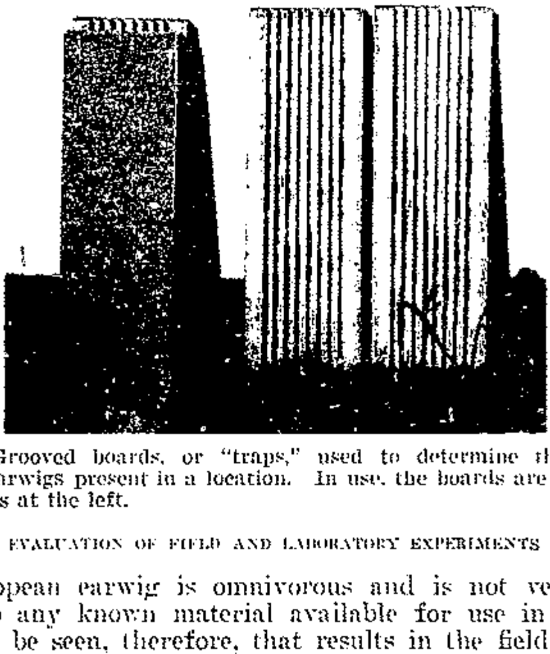

FIGURE 22.—Grooved boards, or "traps," used to determine the number of European earwigs present in a location. In use, the boards are placed groove to groove, as at the left.

EVALUATION OF FIELD AND LABORATORY EXPERIMENTS

The European earwig is omnivorous and is not very strongly attracted to any known material available for use in a bait. It will readily be seen, therefore, that results in the field where free choice of food may be exercised are likely to be quite different from those obtained under the restricted conditions of laboratory experiments.

Not only is the earwig limited as to choice of food in the laboratory but it also has access to a practically unlimited quantity of bait, whereas in the field the quantity of bait available in any one place is limited. Furthermore, the bait in the laboratory is not subjected to deteriorating influences, such as sprinkling, under which it must operate in the field. It is very unsafe to base conclusions as to the effectiveness of a bait on laboratory experiments alone unless the bait gives markedly inferior results.

A large number of laboratory experiments were conducted in which the same bait was tested both with and without the presence of green food. In most cases there were no great differences between the two series. These results and the results of examination of the stomach contents of field-collected earwigs lead to the conclusion that the earwig is an inveterate nibbler of whatever comes in its way. This habit probably accounts in large measure for the success of baits in the field.

The earwig is highly gregarious, is attracted by the earwig odor, and the grooved boards used in field experiments form a very satisfactory hiding place for the insect. For these reasons there is a strong tendency for earwigs to congregate in increasing numbers the longer the traps are exposed. This is illustrated by the following record of the numbers found in the traps put out on an unbaited lot: First week, 852; second week, 4,450; third week, 4,350; fourth week, 4,375; fifth week, 4,485. It can be readily seen that basing the record of performance of a bait on the earwig population in traps at the end of 1 week as compared with that in following weeks, as has been done in the baiting experiments, tends to minimize the actual results. It seems remarkable, therefore, that the recorded mortality has been rather high.

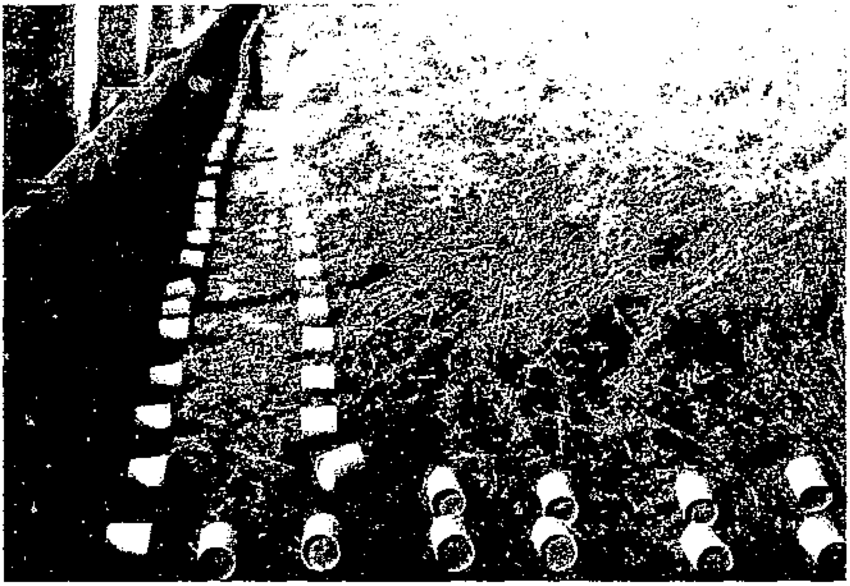

FIGURE 23.—Arrangement of paper containers in experiments with attractants for the European earwig.

LABORATORY EXPERIMENTS WITH ATTRACTANTS

Five hundred and ninety possible attractants for the earwig were tested in a grassy area of 70 by 90 feet surrounded by a metal barrier within which 50,000 earwigs were liberated. These materials included a wide variety of organic chemicals, the benzene series and essential oils being particularly well represented. Solids were dissolved in a suitable solvent before use. The chemicals were numbered, and each number was placed on the side of the lid of three 1-pint paraffined paper cups in each experiment. These cups containing the respective chemicals were exposed at different points in the plot as shown in figure 23, along with 6 to 12 untreated checks, and their positions changed daily. Twenty drops of the chemical (10 drops in some later experiments) were applied to an absorbent-cotton material (referred to as cellucotton) cut in small square pads and attached to the lid of the cup, and 2 small holes were made in the lid for the diffusion of the odor and to provide an entrance for the earwigs (fig. 24). A daily record was kept for 6 days of the number of earwigs in each cup, the examinations being made early in the morning before the cups became sufficiently hot to drive the earwigs out. Nearly all the chemicals were tested 3 times and all those that attracted more earwigs than the average for the checks were tested in 2 additional series.

The earwigs were free to enter and leave the paper cups at will, but it was felt that the number that remained in the containers of

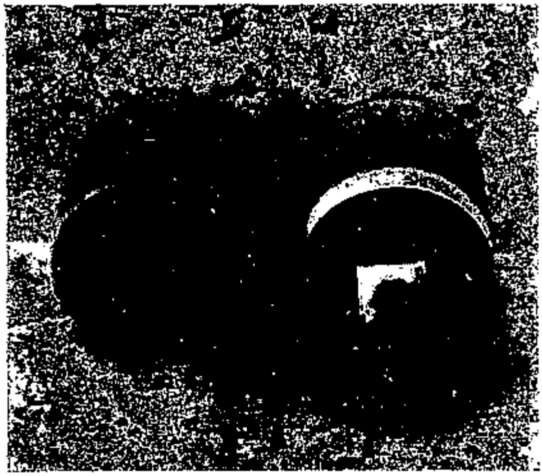

FIGURE 24.—Paper containers used in experiments with attractants for the European earwig, showing, at the right, the piece of cellucotton bearing the odorant.

their own accord would furnish a clue to the types of material that were attractive.

Under the conditions of these experiments 16 substances consistently attracting the most earwigs were as follows, in descending order of apparent attractiveness: Chamomile coctum oil, capsicum oleoresin, hyoscyami coctum oil, oleic acid, egg oil, oil of St. Johns-wort, rapeseed oil, oil of cantharides, *n*-butyl stearate, sesame oil, croton oil, methyl valerate, sperm oil, benzoic acid, honey and brown sugar, and fish oil. It will be noted that the 11 best attractants are of an oily or greasy nature. In addition the following attracted more earwigs than the average of the checks in some experiments: China wood oil, cottonseed oil, citric acid, phenyl hydrazine acetate, capryl butyric acid, levulose, phenyl phthalate, methyl formate, rum ether (imitation), sodium salicylate, methyl propionate, and raw linseed oil.

As the experiments with possible attractants had indicated that oily or greasy substances or sweet materials were most attractive to the earwig, several series of experiments consisting of 373 separate tests were conducted in the laboratory to determine the relative effectiveness of various substances having these qualities when incorporated in poisoned baits. The tests were performed in the manner described for the laboratory experiments under Experimental Procedure (p. 47) and included the following: Oil of St. Johnswort, hyoscyami coctum oil, rapeseed oil, *n*-butyl stearate, oleic acid, chamomile coctum oil, sesame oil, fish oil, glue solution, cod-liver oil, coconut oil, honey, brown sugar, molasses, corn sirup (light), corn sirup (dark), and water.

In one series of experiments 10 of the oily or greasy substances that had attracted the most earwigs in the field experiments involving the use of paper-cup containers were selected and the baits were mixed in the following proportions: Sodium fluoride 2 grams, bran 24 grams, water 1 ounce, and attractant 20 drops. Under the conditions of these tests chamomile coctum oil, *n*-butyl stearate, oleic acid, oil of St. Johnswort, egg oil, and rapeseed oil appeared to be the most effective of the materials tested, and in no case was the average mortality greater than occurred in the pans containing bait without attractant other than water.

In the remaining series of experiments sodium fluosilicate was used as the poison and the amount and kind of oily, greasy, or sweet material as well as the amount of water varied between the several groups of tests. In summarizing the results it was found that oleic acid, *n*-butyl stearate, oil of St. Johnswort, and rapeseed oil were no better than fish oil and also that the mortality was no greater than that which occurred in the pans that contained bait without attractant other than water. Honey was distinctly the best sweet substance tested.

A number of further tests of attractants were conducted, both in the field and in the laboratory, in which grooved-wood hiding blocks were treated with these attractants and exposed. In every case more earwigs were taken in the untreated checks than in any of the treated blocks. Beall (*4*) had the same result in tests with an olfactometer. These results await an explanation.

In 10 series of laboratory experiments a number of baits made up of 12 parts of wheat bran and 2 parts of an attractant, if any, were exposed together in a vessel containing earwigs. Two grams of each bait were used, and weighings were made at intervals of 1, 2, 3, and 4 days to determine the quantity eaten.

There is some evidence that the choice of immature earwigs may not be quite the same as that of mature earwigs, but in all cases dry, untreated wheat middlings was eaten in greater quantity than any other of the 15 materials tested, and bran treated with honey occupied second place. Rapeseed oil appeared slightly more attractive than fish oil to mature earwigs, but this apparently was not true in the case of immature earwigs. Fish oil, in all cases, appeared to be more attractive than coconut oil, castor oil, or oleic acid; and dry, untreated wheat bran and moistened bran treated with salt were among the least attractive materials tested.

A series of laboratory experiments was conducted to determine the relative effectiveness of various quantities of fish oil when added to a bait consisting of 12 grams of carrier and 1 gram of sodium fluosilicate. The results of six sets of simultaneous experiments with mature earwigs are shown in table 6.

TABLE 6.—*Laboratory experiments with various quantities of fish oil in baits for the European earwig, Puyallup, Wash.*

[Six experiments were made with each quantity of oil]

Quantity of fish oil (cubic centimeters)	Mortality by days					
	1	2	3	4	5	6
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	6.6	33.3	53.3	62.5	80.0	88.3
2	12.5	38.3	60.8	75.0	87.5	93.3
4	6.6	45.8	59.1	69.1	80.8	87.5

The bait with 2 cc. of fish oil was more effective than that with 1 and apparently was superior to that with 4 cc. The 2 cc. dosage is approximately equivalent to 1 quart of fish oil to 12 pounds of carrier and 1 pound of sodium fluosilicate, and this formula is hereinafter referred to as the standard bait.

The laboratory experiments, as a whole, indicated that baits containing vegetable or animal oils, water, and honey should be tested in the field, and there was some evidence that salt might prove a satisfactory bait ingredient.

FIELD EXPERIMENTS WITH ATTRACTANTS

EXPERIMENTS WITH OILS

To study the value of the attractants in the field a similar bait was used in all the experiments recorded in table 7 except that different attractants were used, but the results are not strictly comparable since more experiments were conducted with some material than with others and hence the experimental conditions were not entirely uniform.

TABLE 7.—*Field experiments with baits containing various ingredients as attracting agents for the European earwig, Puyallup, Wash.*

Nature of test	Material used	Blocks treated	Mortality by weeks			
			1	2	3	4
		Number	*Percent*	*Percent*	*Percent*	*Percent*
Experiments with oils	Cod-liver oil	3	76.4	90.8	92.6	
	Fish oil	9	85.1	90.4	90.4	
	Rapeseed oil	9	85.1	85.0	89.6	
	Coconut oil	9	83.4	90.5	92.1	
Comparison of honey with fish oil	Honey	6	90.1			
	Fish oil	6	87.2			
Comparison of water with fish oil	Water	5	66.5	71.3	66.9	65.8
	Fish oil	5	78.4	88.3	86.6	87.1
Comparison of salt with fish oil	Salt	5	71.5	82.6	81.8	79.8
	Fish oil	5	89.6	91.5	90.0	88.3

The differences in mortality in the experiments with different oils probably are within the limits of experimental error, indicating that none of these oils has a marked superiority over the others as an ingredient in earwig bait insofar as effectiveness is concerned, but physical characteristics and cost render some more satisfactory than others. Coconut oil is solid at normal temperatures and must be melted before it can be incorporated properly in a bait, and rapeseed oil has a ropy consistency and does not mix well. Fish oil and cod-liver oil are liquid and hence most satisfactory from a physical standpoint. Fish oil is one of the cheapest oils, and field experiments have shown that a crude, foul-smelling grade of this oil is just as effective as a refined grade. When a crude fish oil is used the odor is perceptible about the premises for a few hours but soon disappears. In packaged baits exposed for sale in stores the crude oil probably would be objectionable.

EXPERIMENTS WITH HONEY

A bait made up 12 pounds of bran, 1 pound of sodium fluosilicate, and 3 pounds of honey was compared in six paired field experiments with a similar bait in which 1 quart of fish oil was substituted for the honey. In all but two cases the compared baits were applied on nearly the same dates. These experiments, which were conducted for only 1 week, indicated a mortality of 90.1 percent for the honey bait and 87.2 percent for the bait containing fish oil (table 7). It seems probable that honey, at the above dosage, would be satisfactory as an attractant in earwig bait.

EXPERIMENTS WITH WATER

The bait used in the experiments with water (table 7) was made up in the proportions of 12 pounds of bran, 1 pound of sodium fluosilicate, and 1 gallon of water, whereas in the oil bait with which it was compared, 1 quart of fish oil was substituted for the water. The dates of application for the compared experiments were the same. Fish oil was distinctly superior to water in the mortality obtained (table 7).

EXPERIMENTS WITH SALT

In laboratory experiments it had been found that bait flavored with 1 pound of salt to 12 pounds of carrier was eaten very sparingly by earwigs, but in spite of this fact mortality was high in laboratory experiments with salted poisoned bait.

In field experiments the results obtained with the standard earwig bait were compared with those obtained with the same bait except that 1 pound of salt was substituted for the fish oil (table 7). The dates of application for the two baits were the same. The substitution of salt for fish oil in field experiments resulted in a distinctly lower mortality.

EXPERIMENTS WITH CARRIERS

Wheat bran, because of its general availability, physical characteristics, and acceptability to earwigs, as shown in a number of tests, was selected for use in earwig bait. Dissection of earwigs from experimental areas and weighings of food offered to earwigs in confinement have shown that they prefer middlings to the bran husk. It also has been found that but little of the poison adheres to the husk unless some adhesive such as oil is added, and that the earwigs lap the oil from the husk in such cases.

Laboratory experiments were conducted (table 8) in which various proportions of flour were added to a "health bran" which had been washed to remove most of the middlings. The washed bran was dried before the flour was added. The addition of 25 percent of flour to the bran carrier increased the effectiveness of the bait, but a carrier made up of 50 to 75 percent of flour was less effective. It is probable that a bran deficient in middlings could be improved for use in earwig bait through the addition of a small proportion of middlings or flour, but ordinary bran has been used in all the regular field experiments.

TABLE 8.—*Laboratory and field experiments with various carriers used in baits for the European earwig at Puyallup, Wash.*

Experiment	Carrier	Mortality by days					
		1	2	3	4	5	6
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Laboratory comparison of flour added to a "health bran."	Bran alone	63.8	93.1	98.3	100.0		
	Bran 75 percent, flour 25 percent.	67.8	100.0				
	Bran 50 percent, flour 50 percent.	57.6	91.5	98.3	100.0		
	Bran 25 percent, flour 75 percent.	60.0	90.0	95.0	100.0		
Laboratory comparison of bran and sawdust.	Bran	22.0	64.0	79.0	91.0	98.0	99.0
	Bran plus 1/6 middlings	14.0	70.0	86.0	96.4	100.0	100.0
	Sawdust	6.0	48.0	66.0	85.0	93.0	97.0
	Sawdust plus 1/6 middlings	23.4	82.6	93.8	98.9	100.0	100.0
		Mortality by weeks					
Field comparison of bran with sawdust and middlings.	Bran	78.4	88.3	86.6	87.1		
	Sawdust-middlings	70.8	64.5	57.1	58.0		

In five sets of simultaneous laboratory experiments with mature earwigs the results obtained with wheat bran were compared with those with fir sawdust, both with and without addition of wheat middlings (table 8). Both the bran and sawdust showed increased mortality where middlings was added; sawdust alone showed fairly good results, and with the addition of middlings this material gave the highest early mortality.

In examining the stomach contents of earwigs killed in the experiment with plain sawdust it was found that only traces of sawdust were present, but that much oil was included, indicating that the earwigs had lapped the oil from the sawdust, thus ingesting the poison. The high mortality obtained in the sawdust-and-middlings experiments may have been due to concentration of the poison in the middlings.

A carrier made up of a mixture of 10 pounds of fir sawdust and 2 pounds of middlings was compared with the usual bran bait in five pairs of simultaneous experiments in which city blocks were baited. The results as given in table 8 show that sawdust and middlings used as a carrier in earwig bait gave very poor results.

Apple pomace, consisting of desiccated peelings and cores obtainable from canneries, with and without fish oil, was compared with bran as a carrier in a series of laboratory experiments in which all other conditions were the same. The results of 15 sets of simultaneous experiments, recorded in table 9, indicate little difference in the results obtained with the three baits except that the apple pomace without fish oil appears to be slightly less satisfactory in producing an early mortality. This material was not tested in the field; and its physical characteristics are not so satisfactory as those of wheat bran, since, owing to its coarseness, much more bait would be required to cover a unit area with apple pomace than would be required if bran were used.

TABLE 9.—*Laboratory experiments with apple pomace, with and without fish oil, as a bait for the European earwig, Puyallup, Wash.*

Carrier	Attractant	Mortality by days					
		1	2	3	4	5	6
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Bran	Fish oil	6.7	44.4	61.5	75.3	84.3	89.3
Apple pomace	None	3.7	36.3	58.0	71.8	81.6	89.2
	Fish oil	7.7	42.4	59.7	75.5	85.2	91.2

EXPERIMENTS WITH POISONS

Fifty-four poisons were tested in earwig baits in laboratory experiments at from three to five different dilutions. Thirty of them killed less than half of the earwigs in 6 days at a concentration of 1 pound of poison to 12 pounds of carrier. These poisons, listed in descending order of effectiveness are as follows: Sodium fluosilicate, potassium fluosilicate, barium fluosilicate, lithium fluoride, lead fluosilicate, sodium fluoride, magnesium fluosilicate, chromium fluoride, paris green, lead fluoride, ammonium bifluoride, calcium arsenate, antimony fluoride, ammonium arsenate, arsenic oxide, calcium arsenite, arsenous trichloride, cuprous cyanide, sodium arsenite, rotenone, cupric fluoride, sodium arsenate, arsenic acid, barium fluoride, zinc arsenite, strontium arsenite, arsenous oxide, antimony arsenate, zinc fluoride, cryolite (synthetic), potassium bifluoride, zinc cyanide, ammonium arsenite, antimony arsenite, potassium antimonius tartrate (tartar emetic), copper arsenate, arsenious sulfide, antimonic tartrate, iron arsenite, aluminum fluoride, antimony pentoxide, strontium fluoride, sodium methyl arsenate, lead arsenite, potassium arsenate, potassium arsenite, arsenic disulfide, london purple, zinc arsenate, calcium fluoride, mercuric cyanide, lead arsenate, lead antimoniate, magnesium fluoride.

Table 10 indicates the results of 10 laboratory experiments with each of the 10 best poisons, with the exception of sodium fluosilicate and sodium fluoride, which were tested 25 times. Earwigs of the same stage of development were used in the compared experiments. Of the 25 arsenicals tested, paris green was the only one to appear among the 10 best poisons, the remainder of the 10 being fluorides and fluosilicates.

TABLE 10.—*Results obtained in laboratory experiments with various poisons*[1] *in baits for the European earwig, Puyallup, Wash.*

Poison used	Mortality by days					
	1	2	3	4	5	6
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Sodium fluosilicate	6.1	54.5	84.2	93.7	96.8	98.4
Potassium fluosilicate	13.0	64.0	82.5	92.0	96.0	97.5
Barium fluosilicate	10.0	56.3	73.9	83.4	92.4	94.9
Lithium fluoride	2.1	42.1	66.8	78.4	89.4	93.6
Lead fluosilicate	4.0	32.2	62.3	80.9	89.4	93.4
Sodium fluoride	4.4	31.1	58.9	80.6	88.0	92.8
Magnesium fluosilicate	6.5	27.0	58.0	77.0	88.0	93.5
Chromium fluoride	4.0	28.2	56.8	74.4	87.9	92.4
Paris green	8.0	37.7	58.6	72.9	80.4	82.5
Lead fluoride	4.2	17.5	45.4	70.1	82.5	88.1

[1] 1 part of poison was used for 12 parts by weight of the carrier.

Earwig baits are used chiefly in places that are frequently sprinkled with water from a hose. Because of the sprinkling and the accumulation of dust and dirt on the bait, together with the drying action of the sun, a bait often does not remain effective for much more than 3 days after it is put out. Hence it is advantageous to use a quick-acting poison which at the same time is not too soluble in water. Sodium fluosilicate is one of the least expensive of the materials tested, it ranks high in the mortality produced both on the third and sixth days, and also it is not very soluble in water. For these reasons it has been used in nearly all the field experiments.

Since sodium fluoride has been used extensively in earwig baits, 25 paired laboratory experiments were conducted with this poison and with sodium fluosilicate. The pairs of baits were exposed simultaneously; earwigs of the same stage of development were used in both; and the baits were made up in the proportions of 12 pounds of wheat bran, 1 pound of poison, and 1 quart of fish oil. On the basis of these experiments (table 10), sodium fluosilicate is superior to sodium fluoride as an earwig poison, particularly in acceleration of kill, which is very important in a bait which must be subjected to sprinkling.

The standard bait and one of the same formula except that sodium fluoride was substituted for sodium fluosilicate were also compared in five pairs of simultaneous experiments in which city blocks were baited. Results are given in table 11.

TABLE 11.—*Outdoor experiments comparing the effectiveness against the European earwig of sodium fluoride and sodium fluosilicate in baits distributed over five city blocks, Puyallup, Wash.*

Poison used	Mortality by weeks			
	1	2	3	4
	Percent	*Percent*	*Percent*	*Percent*
Sodium fluoride	82.7	89.1	86.2	83.9
Sodium fluosilicate	89.6	91.5	90.0	88.3

The difference in effectiveness indicated in table 11 is in favor of sodium fluosilicate, but it is not very marked. The lesser solubility of this poison, however, and the greater acceleration in mortality should render it more generally satisfactory than sodium fluoride.

EXPERIMENTS WITH DIFFERENT PROPORTIONS OF POISONS

A great many experiments with different proportions of poison and carrier have been carried out in the laboratory; but these indicate little with the better poisons, since the insect, in the presence of a practically unlimited quantity of bait in a small container, ingests sufficient poison with a proportion of 1–96 to produce about the same mortality as is obtained with 1–12.

The standard bait has been compared, however, in entire city blocks with one containing one-half the standard quantity of poison in five pairs of simultaneous experiments. The results are shown in table 12. It is evident that the bait containing only half the recommended quantity of poison gave very poor results.

TABLE 12.—*Experiments with different proportions of sodium fluosilicate in baits for the European earwig exposed in five city blocks at Puyallup, Wash.*

Proportion of poison to carrier	Mortality by weeks			
	1	2	3	4
	Percent	*Percent*	*Percent*	*Percent*
1–24	77.8	82.3	59.7	49.3
1–12	89.6	91.5	90.0	88.3

COMPARATIVE TOXICITY OF POISONS TO MATURE AND IMMATURE EARWIGS

Twenty-four paired laboratory experiments were conducted to compare the relative toxicity of the standard earwig bait against mature and immature earwigs. The results as given in table 13 coincide with those in an additional 48 pairs of experiments with various dosages of poison. The early mortality is higher in the case of the immature earwigs, but the reverse tends to be true at the end of 6 days.

TABLE 13.—*Laboratory experiments comparing the toxicity of the standard European earwig bait to mature and immature earwigs, Puyallup, Wash.*

Stage of earwigs	Mortality by days					
	1	2	3	4	5	6
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Mature	8.3	44.8	62.1	76.9	90.6	96.2
Immature	11.7	54.1	69.5	79.3	88.5	95.4

EXPERIMENTS WITH OTHER RECOMMENDED BAITS

Seventeen sets of laboratory experiments were conducted to compare the effectiveness of two baits previously in extensive use on the Pacific Coast with that of the standard bait which is referred to in table 14 as bait No. 3. The formulas of the other two baits are as follows:

Bait No. 1

Wheat bran ____ pounds__	5
Sugar ____ do____	2.5
Meat meal ____ do____	2.5
Paris green ____ ounces__	10
Water to moisten.	

Bait No. 2

Wheat bran ____ pounds__	16
Molasses ____ quarts__	2
Sodium fluoride ____ pound__	1
Water ____ gallons__	2

TABLE 14.—*Laboratory experiments comparing the effectiveness of three baits for the European earwig, Puyallup, Wash.*

Bait No.	Mortality by days					
	1	2	3	4	5	6
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	0.9	10.0	25.1	39.5	56.6	60.0
2	.5	14.7	42.2	59.4	74.8	85.7
3	6.5	50.3	70.0	85.0	93.8	97.4

It will be noted that bait No. 2 is much more effective than No. 1, and that No. 3 is distinctly superior to both the others.

EXPERIMENTS WITH DIFFERENT QUANTITIES OF BAIT

Ten city blocks baited in July and August 1931 were baited again in July and August 1932 with a smaller quantity of bait. July 1931 was warmer and drier than usual and August 1931 was one of the driest on record. Only one light rain fell which might have affected the results of the baiting. In 1932 July was unusually cool and rainy, whereas in August the temperature was about normal, but the weather was unusually cloudy and rainy. Three of the experiments begun in 1932 gave very poor results, which were definitely traceable to rain falling shortly after the bait was put out. Table 15 indicates the results obtained, excluding in both years the three blocks in which the experiments were invalidated by rain in 1932.

TABLE 15.—*Field experiments to determine the relative efficiency of different quantities of bait for the European earwig, Puyallup, Wash.*

Year	Average quantity of bait per block	Average area per pound of bait	Earwigs before baiting	Mortality by weeks		
				1	2	3
	Pounds	*Square feet*	*Number*	*Percent*	*Percent*	*Percent*
1931	107	626	109,517	86.6	93.7	94.7
1932	61	1,071	22,348	79.5	91.6	83.1

Under the conditions of the experiments reported in table 15 the smaller quantity of bait gave distinctly poorer results than were obtained with the larger quantity. At the heavier rate of application it would require 8 pounds of bait to treat a lot 50 by 100 feet in area.

METHODS OF PUTTING OUT THE BAIT

Two series of experiments were conducted in one of which the bait was broadcast over the entire area, whereas in the other it was applied in a strip about 1 foot wide along walks, flower beds, and buildings and about trees, posts, and all other objects offering hiding places for earwigs. In both series the forks of trees also were baited if they could be reached. The mortality obtained in treating five city blocks by each method is indicated in table 16.

TABLE 16.—*Field experiments to determine the relative efficiency of the broadcast and spot methods of baiting for the European earwig, Puyallup, Wash.*

Method of application	Mortality by weeks			
	1	2	3	4
	Percent	*Percent*	*Percent*	*Percent*
Broadcast	78.4	88.3	86.6	87.1
Spot	71.3	81.1	78.8	74.9

Evidently the broadcast method of application gave considerably better results than the spot method, but the broadcast application required four times as much bait. For best control a broadcast application would seem to be required, but a moderate degree of control may be obtained through the spot method of application.

BAITING SINGLE LOTS

In early experiments to determine what constituted reasonably satisfactory barriers against earwigs, 62 single building lots were baited. Most of the lots selected were bordered by roads, streets, or adjacent property that was also baited, or were surrounded by cultivated areas or dry prairie. In most cases the only mortality record was that taken 1 week after the bait was put out. The average mortality for 12 well-isolated lots was 87.2 percent as compared with 59.3 percent for 12 poorly isolated lots. In the year following these experiments, however, a high mortality continuing for 5 weeks after the bait was applied was obtained on a few lots which seemed to be poorly isolated against reinfestation. Hence it cannot be said that poor results may always be expected when a lot is baited which apparently is poorly protected from infiltration of earwigs from adjacent property. What usually happens, however, when an unprotected lot is baited is illustrated in table 17, in which the fluctuations of the earwig population after the baiting of a single lot are compared with those in an adjacent baited block.

TABLE 17.—*Changes in European earwig population in a baited lot located in an otherwise unbaited block as compared with that in a baited block, Puyallup, Wash.*

Area baited	Earwigs before baiting	Earwigs (weekly) after the spreading of the bait								
		1	2	3	4	5	6	7	8	9
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Single lot	1,748	804	564	433	537	962	1,354	....	1,498	1,633
Entire block	14,490	1,524	714	335	484	410	545	559	572	448

It will be noted that the earwigs decreased in number in the single lot for 3 weeks after the baiting, and then the number increased rather rapidly until at the end of 9 weeks the earwigs were almost as numerous as they were before the baiting. In the baited block the number of earwigs was still low 9 weeks after the baiting.

In the majority of instances, baiting an unprotected lot in the middle of an infested area gives only moderate and temporary relief from earwigs, but where the lot is isolated completely by streets, roads, or cultivated areas baiting should give good control.

TIME OF BAITING IN RELATION TO CONTROL

In 1933, during the period May 31–June 5, when 96 percent of the earwigs were immature, the remaining 4 percent being overwintered adults, 5 city blocks were baited, whereas in 1932 the young had begun to become mature when baiting was begun on July 7 on 23 blocks, and nearly all were mature when the last application of bait was made on August 26. The results of these experiments against mature and immature earwigs are indicated in table 18.

Table 18.—*A comparison of the effectiveness of baiting against mature and immature European earwigs, Puyallup, Wash., 1932 and 1933*

Stage of earwigs	Blocks baited	Earwigs per block	Mortality by weeks					
			1	2	3	4	5	6
	Number	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Immature	5	4,050	96.6	98.0	97.9	97.0	96.5	98.8
Mature	23	2,439	67.8	80.8	89.1	89.9	91.6	...

The baiting experiments against mature earwigs probably were more adversely affected by rains than was the case in the experiments against immature earwigs, and this may account for the low mortality for the first week in experiments with the mature insects.

Young earwigs are apparently more readily controlled by baiting than the mature insects. The two series of experiments are not strictly comparable, however, and the writers would merely draw the inference that both mature and immature earwigs are amenable to control by baiting. The appearance of young earwigs from the second egg laying in June and the early part of July does not seem to have depressed the percentage of mortality appreciably in either series of experiments and, hence, it would appear that baiting at any time after the majority of the young have appeared in the spring should give satisfactory results.

PERIOD DURING WHICH ONE BAITING AFFORDS PROTECTION FROM EARWIGS

In a series of experiments conducted in 1931 a total of 27 city blocks were baited and kept under observation for various periods up to 9 weeks. The mortality recorded, beginning with the end of the first week and noted at each week end for the first 3 weeks and in alternate weeks thereafter, ran 83.2, 85.7, 88.4, 91.0, 94.0, and 97.3

percent, 6 blocks having been observed for the entire period. At the end of the 9 weeks there was an average of less than 200 earwigs per block in the 6 blocks, whereas there had been originally in the 27 blocks an average of 8,965.

The reduction in number of earwigs was not due to natural mortality, since the baiting was begun on July 7 after all the old, overwintered earwigs had died.

The gradual increase in mortality over a period of 9 weeks very probably was due to the living earwigs eating the poisoned dead ones, since earwig remains were abundant in the stomachs of earwigs taken from the baited areas, and observation indicates that the bait probably does not remain effective in most cases for more than a week owing to the watering of lawns, the accumulation of dirt on the bait, the evaporation of the oil, and other deteriorating factors.

The bait applied early in July kept the area practically free of earwigs for the remainder of the year.

EARWIG POPULATION THE YEAR AFTER BAITING

Several series of field experiments have been conducted to determine the effect of baiting on the earwig population during the year following. The results are indicated in table 19. With a smaller number of traps covering the same area, the average number of earwigs per trap preceding the baiting in 1932 was only 32.8 percent of that in 1931. On the basis of these experiments it would appear that baiting in 1931 resulted in a reduction of 67.2 percent in the earwig population at the same period in the year following. That this difference is not due to a general reduction in the earwig population is indicated in the prebaiting counts made in 1932 on 14 blocks not baited in 1931.

TABLE 19.—*Effect of baiting on earwig numbers in July and August the following year, Puyallup, Wash.*

Year counted	Blocks	Traps	Total earwigs	Average earwigs per trap	Treatment previous year
	Number	*Number*	*Number*	*Number*	
1931	14	348	89,328	256	Not baited.
1932	[1] 14	291	24,447	84	Baited.
1932	14	285	62,018	217	Not baited.

[1] The same blocks as those examined in 1931.

EFFECT OF SPRINKLING ON THE EFFECTIVENESS OF BAIT

A series of laboratory experiments were carried out in which baits were mixed, spread on pieces of cheesecloth on a lawn, and sprinkled with a hose until puddles of water stood on the turf as would occur in a thorough sprinkling of the lawn. The baits were made up in the proportions of 12 pounds of bran, 1 pound of poison, and 1 quart of fish oil. After the sprinkling, the materials were allowed to dry until they were only slightly moist, after which they were tested simultaneously in pan experiments with immature earwigs. The results of 11 sets of experiments are indicated in table 20.

TABLE 20.—*Effect of sprinkling with a hose on baits for the European earwig, Puyallup, Wash.*

Poison used	Condition	Mortality by days					
		1	2	3	4	5	6
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Sodium fluoride	Sprinkled	0.9	20.6	34.9	45.9	62.2	76.5
Sodium fluosilicate	do.	4.6	41.8	56.4	70.9	81.8	90.
Do	Not sprinkled	5.7	64.0	79.2	80.4	94.9	98.6

Both sodium fluoride and sodium fluosilicate in baits that had been sprinkled were distinctly less effective than sodium fluosilicate in an unsprinkled bait, but sodium fluosilicate was decidedly more effective than sodium fluoride under the same conditions. Sodium fluosilicate is only about one-sixth as soluble in water as sodium fluoride.

A number of experiments with various quantities of fish oil indicated that the proportion of fish oil used was not important in relation to the effectiveness of sprinkled baits. In other experiments an effort was made to incorporate the poison into the carrier by adding water and boiling the mixture to dryness before the fish oil was added. This bait, after it had been sprinkled, was less effective than the untreated bait.

In additional experiments the results obtained with fish oil, with a mixture of fish oil and glue, and with glue alone in sprinkled baits were compared. The baits were made up in the proportions of (1) 24 gm. of wheat bran, 2 gm. of sodium fluosilicate, and 4 cc. of fish oil, (2) 4 cc. of fish oil and 16 cc. of glue, and (3) 16 cc. of glue, respectively. The glue was made by dissolving 4 ounces of crude glue in 1 gallon of water.

The results obtained in five sets of simultaneous experiments with these materials against immature earwigs are indicated in table 21.

TABLE 21.—*Laboratory experiments with various attracting ingredients in earwig baits sprinkled and unsprinkled, Puyallup, Wash.*

Attractant used	Condition	Mortality by days					
		1	2	3	4	5	6
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Fish oil	Not sprinkled	5.1	76.5	86.7	94.5	94.8	96.0
Do	Sprinkled	4.0	49.0	71.0	81.0	86.0	90.0
Glue and fish oil	do	3.0	55.0	80.0	84.0	86.0	91.0
Glue	do	4.1	51.0	71.8	85.4	86.4	89.5

All the sprinkled baits were inferior to the unsprinkled one in mortality obtained, and none of the attractants was much superior to the others in resisting the deterioration caused by sprinkling.

Fish oil is a drying oil, and it was thought that baking the bait might form an insoluble coating over the poison, thus causing less loss when the bait was sprinkled. In six sets of simultaneous experiments the usual fish-oil bait was tested, baked and unbaked, in sprinkling experiments. The baked bait was distinctly less effective than the unbaked one.

TREES IN RELATION TO EARWIG CONTROL

Other things being equal, the earwig prefers to hide about some object above the ground rather than on the ground itself. Trees satisfy this preference and, in addition, may provide satisfactory food, in which case the insect becomes independent of the ground. In a heavily infested spot every curled leaf, every crevice under a loose flake of bark, and every suitable hole may be occupied by one or more earwigs, and several hundred may find concealment in a small tree.

For several years, in baiting experiments, the location of each trap and the number of earwigs taken have been recorded. The number of earwigs trapped in several situations and the mortality in these situations brought about by baiting are indicated in table 22, which is based on results in 30 traps from each type of location, all taken from the same baiting experiment.

TABLE 22.—*Hiding places of European earwigs with reference to the mortality produced by baiting, Puyallup, Wash.*

Location of trap	Average earwigs per trap	Mortality by weeks		
		1	2	3
	Number	*Percent*	*Percent*	*Percent*
In a tree	170	77.4	85.4	89.6
At base of tree	152	81.7	88.0	88.9
Adjacent to house, fence, or post	111	92.9	96.7	97.1

More earwigs per trap were taken in or adjacent to a tree than beside a house, fence, or post. Bait was placed in the forks of trees when these were accessible, yet mortality was lower in the trees or in traps at the base of trees than in traps beside buildings, fences, or posts. It seems probable that many of the tree-frequenting earwigs, particularly in large trees, never come in contact with a bait and that they are an important factor in the reinfestation of premises after the bait has become ineffective. Banding trees with a sticky material before the earwigs have climbed them may be necessary where the highest degree of control is desired. Mortality in trees may be increased through the use of bait traps as discussed on p. 65 in this bulletin.

THE BAIT RECOMMENDED AND ITS APPLICATION

In view of the experiments that have been performed the following formula is recommended for earwig bait:

Wheat bran	pounds	12
Sodium fluosilicate (silicofluoride)	pound	1
Fish oil	quart	1

The bran and poison should be mixed thoroughly either by hand in a tub or other suitable vessel or in a bait mixer (fig. 25). The fish oil should then be added and the bait mixed thoroughly again. No water should be used.

The following materials may be substituted for those recommended: In place of bran, dried apple pomace probably would be satisfactory; but, being coarser, much more bait per unit area would be required to obtain the same distribution. In place of sodium fluosilicate, sodium fluoride is the best substitute generally available, but this is less effective than the poison recommended. Substitutes for fish oil include cod-liver oil, rapeseed oil, coconut oil, and honey, but some of these have objectionable features.

The bait should be scattered thinly over the entire area in which control is sought, but special attention should be given to distributing the bait along board fences and walks and about trees, telephone poles, wood piles, the foundations of buildings, and other places where earwigs are known to lurk in numbers. The quantity of bait made up in the foregoing formula is sufficient for one application to an area of from 5,000 to 8,000 square feet, depending on the special baiting necessary on account of trees, fences, etc. Lawns should not be sprinkled until the bait has been out for two nights. The bait rarely causes any noticeable damage to grass, but it should not be applied to ornamental plants.

When a single city lot is baited in an infested area it may become reinfested very soon, but where whole city blocks are baited one thorough application should control the earwigs for the remainder of the season.

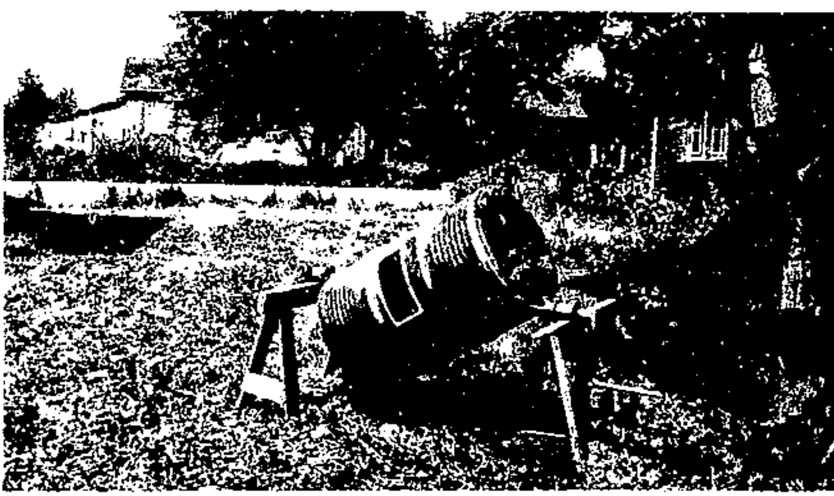

FIGURE 25.—Bait mixer used in preparing baits for the European earwig.

TOXICITY OF SODIUM FLUOSILICATE TO HIGHER ANIMALS

To determine the toxicity to poultry of the earwig bait containing sodium fluosilicate, six young chickens weighing 1.3 pounds each were confined in a coop and provided with water. These chickens were given nothing but the usual earwig bait as food except that a small portion of meat meal was added. One chicken was removed each day and fed thereafter on unpoisoned food. One died after 94 hours and another after 114 hours. The surviving fowls, which had been exposed to the food for 22, 46, 70, and 114 hours, respectively, were kept under observation for 2 months and apparently became entirely normal except that one, that had been fed for only 22 hours, remained a runt. Even in 24 hours these chickens consumed far more bait than would be eaten by fowls when bait is distributed thinly on the ground. Hence it would seem that very little injury to poultry should be expected from the usual application of earwig bait. The findings of Hauck and others (*31*) indicate, however, that it would be best to keep chickens away from baited areas. These writers, in experiments with sodium fluoride, found that when this poison constituted as much as 1.2 percent of the ration it was highly toxic to chicks of all ages and that a proportion of 0.96 percent markedly reduced egg production in pullets.

De Eds (*13, p. 16*), in discussing acute fluorine intoxication, says:

> No reliable information exists as to the minimum lethal dose of fluoride or fluosilicate for human individuals. The reports mentioned above show that recovery has followed the ingestion of 0.45 gram of sodium fluoride, and that 4 grams (0.5 teaspoonful) of sodium silicofluoride proved fatal.
>
> More accurate information on dosage and symptoms exists when the experimental data on animals are considered. In 1867 Rabuteau published data obtained on dogs and rabbits. When 0.5 gram was given to dogs by mouth, symptoms were produced but 0.25 gram by mouth produced no demonstrable changes. One gram injected intravenously caused serious symptoms, but was not fatal. In rabbits, 0.25 gram by mouth caused symptoms and the same amount injected intravenously proved fatal.

From this it will be seen that sodium fluosilicate is quite definitely poisonous to higher animals, and unconfirmed reports indicate that dogs and cats may have been killed as a result of baiting for earwigs with sodium fluosilicate.

BAIT TRAPS

The writers have devised a bait trap (fig. 26) consisting of two grooved boards, with the hiding block thus formed enclosed at one end in a galvanized-iron box, fitting closely to the block on one side and offset on the other to provide a compartment for a bait that is accessible to earwigs from within the hiding block, and provided with a sliding cover. Bait exposed in the trap remains in good condition indefinitely, but the hiding block becomes filled with frass and shed skins of earwigs, necessitating an occasional cleaning.

Experimental procedure was not very satisfactory with these traps, since they could not be taken apart without killing many of the earwigs. To estimate the numbers of earwigs previous to putting out the bait, the usual procedure for baiting experiments was followed, the hiding blocks used being placed in or beside trees. One of the bait traps was then placed above the hiding block in each tree, and the mortality record was based on the number of earwigs in the hiding blocks below the bait traps as compared with the number in the same hiding block before the baiting. One of several objections to this method is that many of the earwigs from the hiding blocks took up their abode in the bait traps, rendering the mortality record based on fluctuation in the population in the hiding blocks very unreliable.

Four experiments have been conducted with these bait traps in each of two locations. Only one mortality record, 7 days after the traps were exposed, was made in each experiment. The apparent reduction in the number of earwigs in one case was 41.6 percent, with the untreated checks showing an increase of 35.3 percent; whereas in the other the apparent decrease was 64.4 percent, with an increase of 12.9 percent in the checks.

Bait traps are not recommended for control, but they may be of some service where there is objection to scattering poisoned bait.

FIGURE 26. Bait trap for European earwigs. An assembled trap is shown hanging on a tree, and the separate parts of another are shown lying on the metal barrier at the base of the tree.

EARWIG-BAITING CAMPAIGNS

Baiting campaigns for the general control of earwigs have been undertaken in a number of cities on the Pacific Coast, particularly in Seattle, Wash., and at Portland, Oreg. These campaigns were conducted under the auspices of some agency of the city, county, or State, The areas to be baited were determined through a board of survey or through petition of 50 percent of the property owners in a block, after which baiting in these areas became compulsory. Those in charge of such campaigns often found themselves involved in a host of difficulties, and no baiting campaigns have been conducted during recent years.

The essentials of such a campaign are that a reliable bait should be used, the distribution of the bait should be under the supervision of the agency in charge, a city block should be taken as the unit, and all property in the block should be baited the same day.

Experiments With Inert Dusts

Mote and others (*47*) have called attention to the pronounced "cleaning-up" habit of the earwig, and H. C. Atwell brought to the attention of the senior author some experiments he had conducted in which earwigs died when confined with ground stone. In the present experiments earwigs were confined in graniteware pans having the bottoms partly or completely covered with a dust and provided with a grooved hiding block for the earwigs. In some cases the insects were allowed to settle in the hiding block, which was then placed in the pan, whereas in others they were dropped upon the dusty bottom of the pan. The results were the same in both cases, and likewise it made no difference whether the pan was completely or only partly covered with dust. The materials tested, in descending order of effectiveness, were plaster of paris, air-slacked lime, ground stone, talcum powder, dry field earth, and powdered sulfur. All the earwigs confined with plaster of paris or lime were dead within 3 days.

Death was not due to stoppage of the spiracles but to the ingestion of large quantities of the dust in "cleaning-up" operations. It seemed to be essential that the dust be spread on a smooth surface. When earwigs were dusted with talcum powder from a sieve and became coated with dust without walking in it and were then placed in a clean vessel mortality was very low. It also was found that when large numbers of earwigs were liberated in a pan containing talcum powder mortality was low, probably because they milled about in masses, thus freeing themselves of the powder.

Two series of experiments were conducted in metal barriers about 3 feet square (fig. 16) in which conditions more nearly approached those found in nature. Each enclosure contained moss, lichens, aphids, and dandelion, and was supplied with 100 earwigs. A hiding block was provided in one series of experiments and omitted in the other. This caused no important difference in the mortality obtained. The dust was spread as a thin layer on the bottoms of a series of shallow paper cups (fig. 27) with lateral entrance holes for the insects, and one cup was placed in each enclosure. Mortality obtained at the end of 7 days with dust boxes is compared below with that obtained with boxes containing the usual bran bait:

Material in box:	*Percent mortality*
Poisoned bran bait	81.1
Plaster of paris	2.5
Air-slacked lime	6.0

It seems evident that inert dusts are useless for the control of the earwig in the field. The earwigs disliked coming in contact with the dusts and seldom visted these boxes long enough to pick up a lethal quantity of the powder.

Experiments With Poisonous Dusts

In another series of experiments similar paper cups (fig. 27) with lateral entrance holes for earwigs and a thin layer of poison on the bottom were placed within similar galvanized-iron barriers containing moss, algae, dandelion, and aphids. One hundred earwigs were put within each barrier, and a hiding block made of two grooved boards placed groove to groove (fig. 22) was provided. A

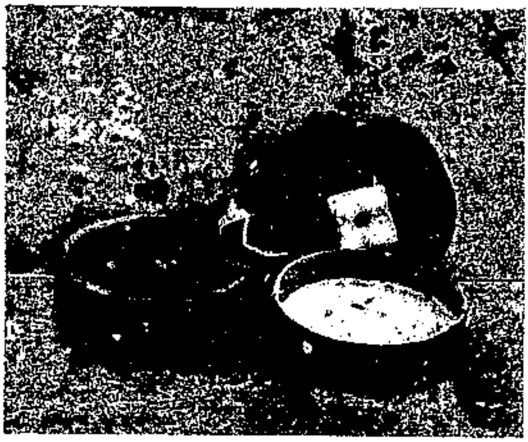

Figure 27.—Paper boxes used in experiments with dusts for the control of the European earwig.

piece of cellucotton on the lid of the cup was treated with fish oil in some cases. Mortality within the barrier at the end of 8 days was as follows:

Material tested:	*Percent mortality*
Sodium fluoride, fish oil on the cotton	74.0
Sodium fluosilicate, fish oil on the cotton	96.0
Sodium fluosilicate, no fish oil	83.0

These experiments indicate that earwigs, in a situation in which they had some little choice, entered the boxes for a sufficient period and in sufficient numbers to bring about a high mortality in 8 days, and that the addition of fish oil may have been advantageous.

One field experiment was carried out along a board fence in which a thin layer of sodium fluosilicate was applied over the bottom of the cups and a piece of cellucotton in the lids was scented with fish oil. The standard procedure in bating experiments was followed to determine the earwig population before the poisoning. The earwigs were then emptied from the traps, the traps removed, and a poisoned cup placed at each of 20 fence posts. After the cups had been out a week they were removed and the traps replaced for 1 night. The difference in earwig population before and after exposure of the poison indicated a mortality of 37.67 percent, but the removal of the traps before the poisoning and their replacement after the experiment for only 1 night was not considered as furnishing a satisfactory basis for estimating the mortality. Hence all the earwigs from along the treated part of the fence were collected in a bucket, and from this lot a sample was taken and brought to the laboratory, where the earwigs were given unpoisoned food. The accumulated percentages of mortality were 15.2, 25.4, 47.3, 74.3, 82.0, and 84.6, respectively, for a 6-day period. Much of this mortality may have been due to the live earwigs eating the poisoned dead; but this of course would also occur under natural conditions, although probably to a lesser extent. The mortality could not be ascribed to lack of places for concealment other than the cups, since the board fence provided many situations in which the earwigs were accustomed to hide.

An additional field experiment was conducted on a city lot in which sodium fluosilicate was exposed as in the preceding experiment except that the fish oil was omitted. The usual procedure for determining the earwig population was followed there, and a dust box containing the poison was placed beside each trap. Three weeks after the poison was exposed there was an apparent reduction of 32.3 percent in the earwig population. A sample of earwigs taken from one of the traps 3 days after the poison was put out showed no mortality when fed further at the laboratory, and the same was true of another lot collected 9 days after the poison was exposed.

Earwigs are not attracted strongly to fish oil, and it seems probable that the experiment along the board fence represented a rather special case and that poison in dust boxes ordinarily will give very poor control of earwigs. Ordinarily but slight and temporary relief from earwigs is obtained when a single unprotected lot is treated in the midst of an infested area, and the provision of sufficient boxes for an entire block would be a considerable task.

On two well-isolated city lots a mixture of 3 parts of sodium fluoride and 1 part of flour was scattered about all trees, posts, and buildings. Two and one-half pounds of the mixture was used on each lot. The standard procedure for determining the earwig population before and after baiting was followed. In one lot a mortality of 59.6 percent was indicated in 1 week after the powder was applied, and in the other a mortality of 52.2 percent was indicated at the end of 1 week, but this had increased to 63.7 percent at the end of 2 weeks. It was noted that the powder absorbed moisture and became encrusted and ineffective within a week. The later mortality probably was due to the live earwigs eating the poisoned dead.

Mortality was low in these experiments, but owing to cannibalism it would probably increase over a period of several weeks. Moreover, the cost of such treatment is low. In using this material it would be necessary to discontinue sprinkling lawns for a week or so after the application, and damage would result if the mixture were placed on grass or too close about plants.

Trapping

Observations made in the course of baiting and trapping experiments indicate that trapping earwigs on a single building lot in the midst of an infested block is almost useless as a means of reducing their number. In table 23 are given the results on two city lots in which trapping was continued for a longer period than usual. The earwigs were trapped and removed at approximately weekly intervals.

TABLE 23.—*Effect of trapping on European earwig populations on single building lots at Puyallup, Wash.*

Lot No.	Earwigs at approximately weekly intervals							
	1	2	3	4	5	6	7	8
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
1	147	642	1,239	1,525	3,359	4,120	4,350	3,383
2	6,305	5,710	3,654	8,611	5,497	8,657	3,260	4,863

Lot No. 2 had been trapped consistently for 3 years previous to this experiment. A total of 46,560 earwigs were removed from this lot in the course of the 8 weeks, but the earwig population in the traps was but little less at the end of the experiment than in the beginning. Beall (*3 p. 238*), in discussing the results of trapping experiments, says:

> In conclusion it may be said that trapping on a single lot caused some lowering of the level of population. However, rapid infiltration from surrounding non-trapped lots nullified these results on the whole.

Experiments with marked earwigs and examination of the contents of the digestive tract of numerous specimens lead to the conclusion that, under favorable conditions, the earwig tends to be sedentary. If this is the case, it seems strange that trapping a single lot apparently does not reduce greatly the number of earwigs present on it. At least two factors probably enter into this situation: (1) The earwig population probably is much greater than observation had indicated, since the insect has an almost magical ability to conceal itself; (2) some factor in the nature of pressure of population apparently tends to equalize the density of population within a unit area such as a city block. Many evidences of this tendency have been encountered in experiments in which single lots have been baited. Traps at the periphery of the baited area often contain as many dead earwigs as there were live ones at the preceding examination, but an equal or greater number of live earwigs have been added to the dead in these traps. In the meanwhile control may remain satisfactory for a time at the center of the lot.

CONTROL IN BALLED NURSERY STOCK

Mackie (*42*) gives a preliminary report on the effectiveness of fumigation of balled nursery stock with a dust cyanide and of treatment with several repellents, of which naphthalene was the best. Steinweden (*54*) shows that 100-percent mortality of earwigs cannot be obtained through fumigation with calcium cyanide without serious injury to balled evergreen plants when the foliage is exposed to the gas, but that when the fumigant is dusted around the ball inside the burlap covering and the ball wrapped tightly in a rubber tarpaulin, fumigation is safe and effective. The dosage recommended is three-fourths of an ounce of calcium cyanide for medium sized plants with a fumigation time of 24 hours. He found paradichlorobenzene and naphthalene ineffective against earwigs in the soil when used as recommended for calcium cyanide.

Fleming and Baker (*22*) have shown that immersion in water at a temperature of 112° F. for 70 minutes was fatal to many dormant evergreen shrubs and trees and to some deciduous shrubs and herbaceous perennials. They describe a tank suitable for treating nursery plants with hot water, give the reaction of a great variety of plants to the treatment, and discuss the proper methods of handling treated material. Results of experiments with earwigs submerged in water at various temperatures have been indicated (p. 37). Whether it would be feasible to free balled nursery stock from earwigs by submersion in water at a moderate temperature has not been determined.

Repellents

Nine repellents have been tested, each in three field experiments and one laboratory experiment. These experiments differed in details.

In experiment No. 1 the usual earwig traps made of two pieces of board placed groove to groove were treated by pouring the liquid on the grooved surfaces of each of three traps for each repellent. Naphthalene and paradichlorobenzene were exposed as solids in small compartments at the centers of the traps and, in addition, these chemicals were dissolved in gasoline and the liquid poured upon the grooved surfaces of the same traps. All the traps were treated again every third day. At each of nine apple trees three traps were placed, all three treated with the same chemical but a different chemical used at each tree. The traps were emptied and moved daily from one tree to the next. Thus the three traps treated with any of the chemicals were placed at each of the nine trees during the 9 days that observations were continued.

In experiment No. 2 one trap was treated with each repellent and the nine traps were all leaned against one tree and moved around one space each day, after being emptied. Paradichlorobenzene and naphthalene were exposed in a small compartment at the center of the trap. The chemicals were not renewed during the 9 days of observation.

Experiment No. 3 was similar to No. 1 except that the chemicals were not renewed and naphthalene and paradichlorobenzene were exposed only as solids in a small compartment at the center of each trap.

Experiment No. 4 was a laboratory experiment in which unused grooved earwig traps were cut into blocks 1½ inches square, 9 blocks each treated with a different repellent and 5 untreated blocks were arranged about the inner periphery of a large graniteware pan containing about 150 earwigs. The pan was greased at the top to keep the earwigs in and was turned daily to offset differences in illumination. Naphthalene and paradichlorobenzene were dissolved in ether and the liquid poured upon the grooved surface of the blocks. The chemicals were not renewed during the 9 days of observation.

The results of these experiments are shown in table 24.

TABLE 24.—*Results of experiments with repellents against the European earwig, Puyallup, Wash.*

Repellent	Earwigs taken in traps							
	Total for 9 days in—				By 3-day periods			Total
	Experiment No. 1	Experiment No. 2	Experiment No. 3	Experiment No. 4	Days 1–3	Days 4–6	Days 7–9	
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Cresol	0	0	385	0	33	76	276	385
Nitrobenzene	109	8	580	14	186	219	306	711
Carbolic acid	79	10	815	0	216	176	512	904
Naphthalene	300	11	646	9	312	292	362	966
Cedar oil	117	2	915	2	154	397	485	1,036
Turpentine	563	27	1,212	38	575	416	849	1,840
Castor oil	593	72	1,400	154	615	742	862	2,219
Paradichlorobenzene	719	64	1,282	214	567	735	977	2,279
Pyroligneous acid	833	95	1,415	89	1,101	605	726	2,432

On the basis of these experiments cresol is the best repellent of those tested. A group including carbolic acid, nitrobenzene, naphthalene, and cedar oil was fairly effective. A third group including turpentine, castor oil, paradichlorobenzene, and pyroligneous acid gave little or no evidence of effectiveness. The earwigs seemed to enjoy resting among the crystals of paradichlorobenzene.

Taking the experiments as a whole it will be noted that cresol gave complete protection for 9 days in three experiments, and that none of the chemicals repelled earwigs entirely in all experiments for as much as 3 days.

SUMMARY

The European earwig has become established in nine States in this country, most of the infestations originating during the period 1910–20 when the earwig was particularly abundant in northwestern Europe.

The survival and abundance of the insect are dependent largely on the degree of dessication to which it is subjected, it being best adapted to cool latitudes and becoming less abundant where the mean temperature for July approaches 75° F. The nymphs, in particular, are subject to fungous diseases in cold, wet weather. Outbreaks occur in Europe only when the period from March to August, inclusive, is distinctly warmer and drier than normal, and when this period in the preceding year was distinctly warmer and at least somewhat drier than normal.

The earwig is omnivorous but prefers low forms of plants such as mosses, lichens, and algae to most higher forms of vegetation. The insect is capable of damaging a wide variety of plants, but this ability is rarely exercised to a serious extent, and the earwig is important mainly as an obnoxious nuisance in and about dwellings. It also feeds to some extent on insects.

The eggs are deposited in cells in the soil (in January and February at Puyallup, Wash.) and hatch during April, the adults beginning to appear in July. A portion of the females enter the soil for a second time about a month after the first eggs have hatched, and deposit a second lot of eggs that hatch in June, the nymphs becoming

mature late in July or early in August. Pairs of earwigs form cells for hibernation late in September and during October. Overwinter survival is highest in loamy soils, the percentage of survival being low in heavy soils or in pure sand.

Eggs usually are deposited within 2 inches of the surface of the soil, the average number being about 30 for each female in the case of the first lot and considerably less than this for the second lot of eggs. The duration of the egg and nymphal stages is influenced strongly by the temperature. The winter eggs require about 72.8 days from deposition to hatching, whereas the spring eggs require only about 20 days. The four nymphal stages require about 68 days or more for their completion in nature. The female watches over her eggs and first-instar young and will fight savagely in their defense.

The earwig rarely flies but is well adapted for transportation by man, since it hides in any available place at the approach of daylight and thus may be carried long distances in merchandise, luggage, or automobiles.

The most important parasite of the earwig is the tachinid fly *Bigonicheta setipennis.*

A bait has been found effective in the control of both young and mature earwigs, but in most cases it is essential that an entire city block be baited at one time for the best results. One thorough baiting of a city block should control the insect for the remainder of the season. Cresol was found to be the best repellent of those tested.

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U. S. GOVERNMENT PRINTING OFFICE: 1940

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