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EUROPEAN FRIT FLY IN NORTH AMERICA

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INTRODUCTION

The investigations reported in the following pages were made at La Fayette, Ind., except as otherwise indicated, in the years 1914–1916. They relate to the European frit fly, an insect which attacks both winter and spring wheat every year over the whole geographical range of the crop and at times has done considerable damage. This fly has received little study in this country on account of its minute size, the difficulty of carrying it through its life cycle in cages, and the confused and uncertain condition of its classification, which made it impossible to tell how many species were involved. The similarity of its attack to that of the Hessian fly has also, no doubt, in many cases prevented its recognition as a grain pest.

HISTORY AND SYNONYMY

In 1750 a paper was presented by Linnaeus (*13*),[1] the celebrated naturalist, to the Swedish Academy of Sciences, in which he described the injury caused to barley in Sweden by the larvæ of a small black fly which he found was destroying the immature kernels of the grain to a serious extent, in many heads eating out almost every kernel. Such light and worthless kernels the Swedes called "frits." The species was not given a scientific name until 1758, when the same writer (*14, p. 598*) described it as *Musca frit.* Fabricius (*7, p. 216*) in 1805 included the species under Oscinis, and it has generally been known as *Oscinis frit* since that date.

A century after the species had been described, it was found that the larvæ of the late fall brood winter as stem miners in winter grain, chiefly rye, in Europe, and that spring grain, especially rye and oats, is attacked in the same way by the spring brood. The summer brood was found to attack the kernels of oats more commonly than those of barley. These differences were for a long time supposed to indicate that several, at

[1] Reference is made by number (italic) to "Literature cited," pp. 472–473.

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least two, species were involved; but finally a substantial agreement has been attained in the belief that the damage is the work of the single species, *Oscinis frit.*

In the United States the first biological observations on the species were made by H. Garman (*10*) in Kentucky in the fall of 1889, when he found the stems of young wheat infested. James Fletcher (*8; 9, p. 158*) made the same observation at Ottawa, Canada, at about the same time, and also reared the fly from larvæ in stems of several grasses. Both of these entomologists mention the insect as *Oscinis variabilis* Loew, a species described from North America.

In 1896 Lugger (*17*) reported the insect as *Oscinis variabilis* Loew, injuring spring wheat in Minnesota.

In 1898 Coquillett (*4*) reported various rearings of what he identified as *Oscinis carbonaria* Loew (*15, 16*) and *O. soror* Macquart. F. M. Webster (*21*) also reported rearing the same two species from various plants in 1903, his specimens having been identified by Coquillett.

Tucker (*19*) described a dark form from Colorado in 1908 as *Oscinis nigra*, without reference to its habits.

In 1912 a monograph on the Oscinidae (or Chloropidae, as he called them) of North America was published by Theodor Becker (*2*), of Liegnitz, Prussia, one of the most eminent specialists on this group. His work was based almost entirely on material furnished from this country by Prof. A. L. Melander, of Pullman, Wash., and the writer. Becker identified *Oscinis frit* from North America for the first time, with its variety or color form *O. pusilla* (see Meigen *18, v. 6, p. 157*, and *p. 160* for *Chlorops pusilla* and *C. frit*). What had been called *O. carbonaria* he made a synonym of *O. nitidissima*, a European species described by Meigen (*6, p. 388*) in 1838, which he regarded as distinct from *O. frit.*

Criddle (*6*) in 1913 discussed the larval habits in Manitoba, believing that he had detected three summer broods.

Starting with North American material identified by Becker as *Oscinis frit, O. pusilla*, and *O. nitidissima*, and with European material identified as *O. frit* by Prof. M. Bezzi and by Rev. Gabriel Strobl, the writer has made a study of the North American forms. This has extended to: (a) An examination of the type material of *O. variabilis, O. carbonaria, O. nigra*, and many other more or less related species; (b) a study of reared and collected material in most of the larger collections of the United States and Canada, including numerous rearings by members of the Bureau of Entomology staff and nearly 16,000 specimens of the species swept from vegetation in various parts of the United States and Canada; (c) the rearing of more than 300 specimens from several different food plants; and (d) a comparative study of the male genitalia in North American and European material, including some bred from oats in England.

This study has led to the conclusion that *Oscinis pusilla*, *O. nitidissima*, *O. carbonaria*, *O. variabilis*, *O. nigra* Tucker, and *O. soror* Macquart are all synonyms of *O. frit*. The multiplicity of names has arisen from the variability and wide distribution of the species. The long-continued confusion has existed mainly because the taxonomists since Linnaeus who have classified the adults have paid little or no attention to the habits, while the biological workers have been uninformed as to the characters used in classification and have applied whatever name was given them.

Typical *Musca frit* as defined by Linnaeus has the femora and tibiæ wholly black; *Oscinis nigra* Tucker is precisely this, as described from Denver, Colo. This extreme form apparently does not occur east of the Rocky Mountain region but is common westward. *O. frit* as recognized by Becker, however, includes eastern and western forms with a small amount of yellow on the tibiæ, at base and tip. When the yellow portions are more extensive, so that the front and middle tibiæ are merely ringed with black, the form *O. pusilla* is reached, of which *O. carbonaria* is an exact synonym. From this form *O. variabilis* differs only in having a more shining thorax and is the same as *O. nitidissima* of Europe, North American specimens having been so identified by Becker. All gradations from the somewhat shining dorsal surface of *O. frit* to the highly shining one of *O. nitidissima* can be readily found. Coquillett separated some specimens with shorter frontal triangle as *O. soror* of Macquart, but this is also a variable character; moreover, Macquart in describing it said nothing about the species having a short triangle.

NATURE OF INJURY

In the commonest form of injury minute maggots occur in young stems of wheat close to the ground. They are easily distinguished from the larvæ of the Hessian fly (*Phytophaga destructor* Say) from the fact that the larva is in the center of the stem and crawls actively when removed, whereas the Hessian-fly larva is between the bases of the leaves and is extremely inactive. The *Oscinis frit* larva often causes the central leaf to die and turn brown, those about it remaining green; this the Hessian fly larva never does.

DISTRIBUTION IN NORTH AMERICA

The region of greatest abundance of the frit fly in North America corresponds rather closely with that in which winter wheat is grown, from the Great Lakes to the Ohio River, and westward about as far as the Missouri. But outside this area it is often common locally from the Atlantic to the Pacific and from Ottawa, Canada, to the Gulf of Mexico. The fly occurs generally wherever grass is abundant and remains green for a considerable part of the year. So in the arid West it occurs in spots, along streams or in irrigated pastures, or in the higher altitudes where

the humidity is greater. Sweepings by the writer in 1917 gave numerous specimens at Pass Christian, Miss., and Lake Charles, La. A few were found at Marfa, Tex., Las Cruces, N. Mex., and Tucson, Ariz.; but none at Yuma, Ariz. Other species replace this one on grass at San Diego and Los Angeles, Calif., but it extends from San Francisco as far south as Santa Barbara. In Canada *Oscinis frit* occurs but sparingly in Manitoba, Saskatchewan, and Alberta but is much more numerous in the more southern latitude of Ontario and Quebec. No records are available for the extreme East. It has been reported from Juneau, Alaska, latitude about 58°. This is the farthest north of all existing North American records.

The accompanying map (fig. 1) has been dotted to indicate the distribution and approximately the abundance of the species, although in

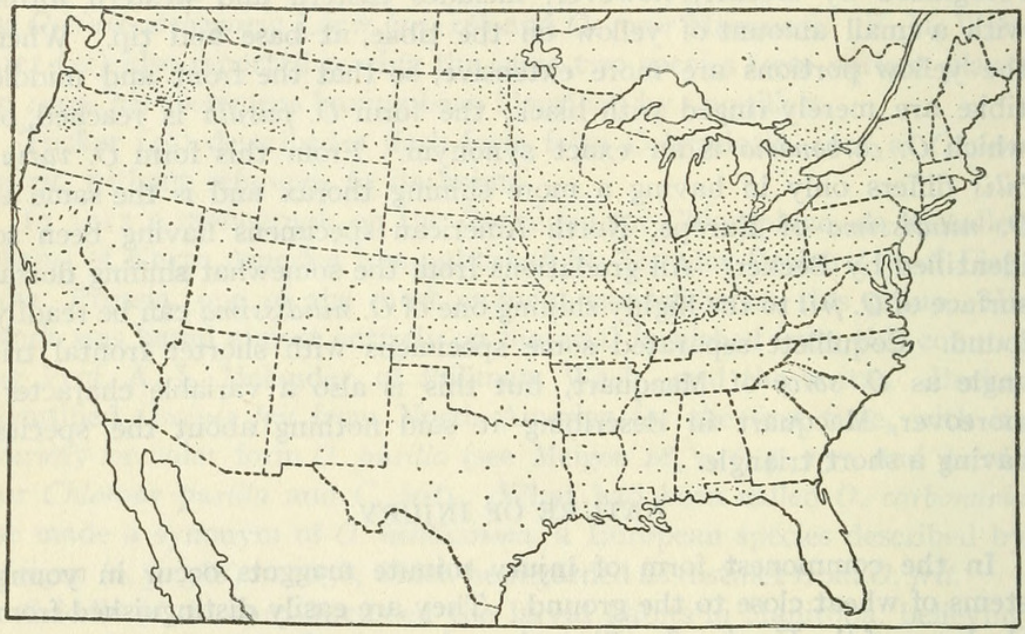

FIG. 1.—Map showing distribution of *Oscinis frit*.

many parts it is marked more from analogy than from definite information.

DESCRIPTION OF INSTARS

EGG

The eggs (fig. 2) are pure white, measuring 0.7 mm. in length and 0.178 mm. in greatest diameter, approximately straight on one side, the other more curved. The surface bears nearly 20 fine ridges, running lengthwise, which are occasionally broken.

NEWLY HATCHED LARVA

The larva (fig. 3) upon emerging from the egg measures 1.06 mm. in length and 0.14 mm. in greatest diameter. It is whitish and semitransparent in color, without head, rather pointed in front and truncate behind. A pair of very minute, soft, 2-jointed antennæ are present. The

only firm structures are the two mouth hooks and the frame to which they are attached. The hooks are clear reddish brown in color. The frame is black at their attachment and becomes gradually less chitinized and paler farther back, and more concealed by the mass of muscles surrounding it. Figure 3 shows one-half of this double structure. The hooks work on a pivot at the point marked *x* in the figure. The larva has 11 segments, the sutures between them, except the first three, bearing transverse rows of very fine teeth below, which extend up the sides in a narrowing series. The first segment is encircled by several rows of these minute teeth, evidently of use in entering crevices. At this stage there appear to be no anterior spiracles, the only ones being a pair at the posterior end; these are on raised protuberances bearing a circle of branched hairs standing at right angles to the axis, the opening into the air tube being on the inner side, not the tip, of the protuberance. From each spiracle a conspicuous air tube extends forward along the side of the body.

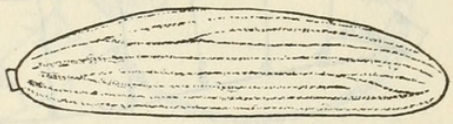

FIG. 2.—Egg of *Oscinis frit*. × 65.

FULL-GROWN LARVA

The full-grown larva (fig. 4) measures about 3 mm. in length and 0.4 mm. in greatest diameter. It is distinctly yellow in color on account of the accumulation of fat under the integument, for use during transformation. The antennæ and mouth hooks (fig. 5)) are relatively smaller than

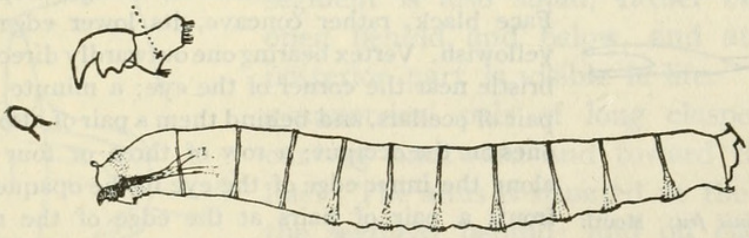

FIG. 3.—Newly hatched larva of *Oscinis frit*. ×65. Antenna and mouth-hooks more enlarged, the latter showing fulcrum at *x*.

in the first stage. The mouth hooks are strongly curved, black, with several microscopic teeth on the under side. Anterior spiracles occur on the first segment, consisting of a protuberance bearing a half dozen soft lobes in a vertical row. The posterior spiracles appear to occupy a median position on their protuberances, with less distinct circles of hairs.

Intermediate larval stages were not made out.

PUPA

Like many Diptera, this species forms the pupa within the hardened larval integument, called the puparium. The pupa is never visible unless this shell-like covering is removed. It is white at first, becoming black

as the time of emergence draws near. It shows the organs of the adult in rough outline, the wings, however, being represented by very small rudiments.

PUPARIUM

This is at first yellow in color, turning to brown, and is usually opaque. It is 2.7 mm. in length by 0.9 mm. in breadth, bearing the minute larval spiracles anteriorly on each side of its tip and the posterior ones behind.

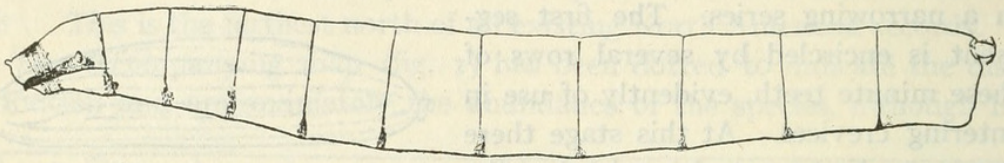

FIG. 4.—Full-grown larva of *Oscinis frit.* × 36.

Neither of these is functional, since they do not connect with the spiracles of the pupa. (Pl. 57, B.)

ADULT (PL. 57, A)

The following description of the adult has been drawn up with the aim of including all common variations.

MALE AND FEMALE

Length 1.1 to 2 mm. Head, thorax, and abdomen black. Front in well-matured specimens wider than one eye, usually a little narrower in specimens not completely hardened before killing. Frontal triangle shining black, reaching usually almost to the root of the antennæ, but shorter in many specimens, at shortest only a little over half the length of front; the remainder of the front outside the triangle is opaque black.

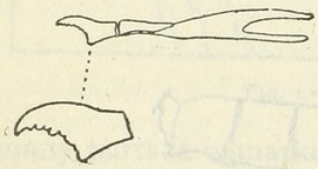

FIG. 5. — *Oscinis frit:* Mouth hooks of full-grown larva. More enlarged than in figure 4.

Face black, rather concave, its lower edge sometimes yellowish. Vertex bearing one outwardly directed, minute bristle near the corner of the eye; a minute, convergent pair of ocellars, and behind them a pair of also convergent ones on the occiput; a row of three or four small hairs along the inner edge of the eye in the opaque part of the front; a pair of hairs at the edge of the mouth also. Antennæ black, third joint rather large, round; the arista with very minute pubescence, beyond its basal fourth often lighter in color, rarely almost white when viewed against a dark background. Proboscis and palpi black. Bucca (side of head below eye) usually about one-sixth the height of the eye, but varying from one-fourth to one-tenth or less, the cause of this variation being usually the greater or less drawing up of the under part of the head in drying.

Thorax with length, breadth, and height about equal; dorsum subshining to shining, with minute dark hairs usually arranged in rows lengthwise. One pair of minute dorsocentral bristles before the scutellum, far apart; one supra-alar, two or three notopleural, one humeral, all small. Scutellum of ordinary form, neither flattened nor elongated. Pleuræ shining black, without bristles. Halteres yellow.

Abdomen black, subshining, rarely the first segment yellowish; the black color extending underneath to the soft part, which is usually paler. Male genitalia often protrude, showing a pair of distinct claspers curved backward, but these may be retracted and invisible. Abdomen of female pointed, ending in a minute pair of palpus-like organs, at tip of the telescopic, 3-jointed ovipositor when the latter is extended (fig. 6), but ordinarily so retracted as to be barely visible.

Legs of ordinary structure; coxæ and femora black, the trochanters and knees often yellowish; tibiæ rarely entirely black, usually paler at base and tip, the fore and middle tibiæ often wholly yellow, hind ones, however, always with at least a black ring. Tarsi yellow, darkened toward tips.

Wings subhyaline, sometimes a little brownish, varying moderately in width; costa extending to fourth vein; the costal segment between the tips of the first and second veins about 1½ times as long as the following one; fourth vein ending very slightly behind the apex; anal angle well developed.

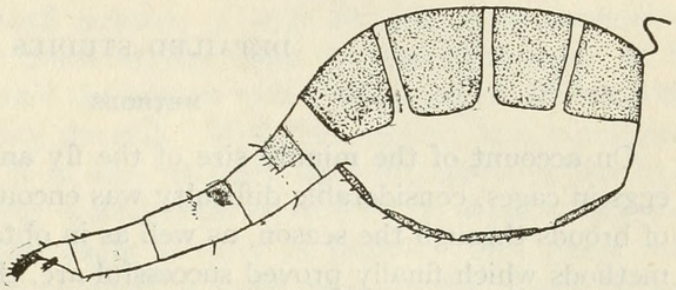

FIG. 6.—*Oscinis frit:* Female abdomen, distended with eggs and ovipositor protruded. (From alcoholic specimen, highly magnified.)

MALE GENITALIA

Since these organs in many insects throw a great deal of light on the limits of species, the genitalia of about 25 males were mounted for study after being boiled for from 5 to 10 minutes in 10 per cent caustic potash; among these were 5 specimens of the oat fly from Garforth, England, kindly furnished by Prof. T. H. Taylor, of Leeds University; others were from Missoula, Mont., Sioux City, Iowa, and La Fayette, Ind. No appreciable difference was found in any of these. The general features are shown in figure 7, drawn from a specimen taken at Missoula, Mont.

The fifth abdominal segment in the male is very small and normally retracted so as to be invisible. The sixth segment is also small, rather cup-shaped, open behind and below, and at least its posterior part is visible in life. It bears a symmetrical pair of long claspers below, curving backward and toward the middle line. The anus is situated at the middle of the segment behind; and on each side of this is a protruding, strongly chitinized lobe, which is produced forward inside both above and below; the upper arm keeps close to the side of the cavity and joins the produced upper margin of a curved plate with a thickened edge, which extends forward so as to form a trough, almost a tube, through the open anterior end of which the penis projects. This organ arises in the ventral part of the sixth segment in the median line and is supported in part from the ventral forward extension of the lobe beside the anus.

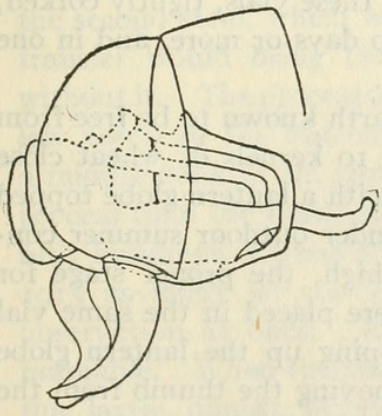

FIG. 7.—*Oscinis frit:* Male genitalia, highly magnified.

LIFE HISTORY

SUMMARY

At La Fayette, Ind., *Oscinis frit* winters in the larval stage in winter wheat. Following the emergence of this brood as adults in the spring, there are four summer broods.

DETAILED STUDIES

METHODS

On account of the minute size of the fly and its disinclination to lay eggs in cages, considerable difficulty was encountered in running a series of broods through the season, as well as in obtaining other details. The methods which finally proved successful are, therefore, believed to be of sufficient importance to justify a rather full description.

Wheat sown in the garden in September, 1915, became infested that fall. On March 30 and April 11, 1916, portions of it were dug up, placed in pans of earth, and covered with glass cylinders 8 inches in diameter with cheesecloth tops. Records of spring emergence were made from these. In removing the adults, advantage was taken of their natural inclination to go to light. The cage was opened in the house close to a south window on which the sun was shining. The flies, as soon as given their freedom, would fly toward the window, alight on a swiss curtain before it, and begin to walk upward. They were then easily secured in numbered homeopathic vials, in each of which a small drop of sirup and one of water had previously been placed. In these vials, tightly corked, adults were kept for some time, frequently 20 days or more, and in one instance 49, by changing the vial occasionally.

Breeding cages were prepared by placing earth known to be free from insects in 6-inch flowerpots, planting about 10 kernels of wheat close together in the middle of each, and covering with a lantern globe topped with cheesecloth. In seven or eight days under outdoor summer conditions the wheat was from 1 to 2 inches high, the proper stage for introducing the flies. A male and female were placed in the same vial and introduced into the cage by simply tipping up the lantern globe and setting the vial upright in the earth, removing the thumb from the mouth of the vial just as the globe was replaced. This method was not quite satisfactory, but only a few flies escaped. Their inclination to walk upward caused them to leave the vial at once if it was upright, but if it was horizontal they sometimes remained in it a long time, and even failed entirely to find their way out.

In the cage the flies were inactive most of the time, usually resting on the cloth at the top but occasionally visiting the plants, where they appeared to lick up a nutritious exudation. The addition of sirup did not lengthen their lives, and they soon died in cages without plants.

Eggs were obtained in a small proportion of cages, in from 20 to 40 per cent, as a rule. Many flies laid only 1 or 2 eggs, and the maximum was about 10. Since the normal number of eggs maturing in the ovaries of a female at one time is about 30, it is evident that the conditions were far from satisfactory; but they were the only ones under which any eggs were obtained.

On account of the small number of eggs secured, each successive generation in cages was much smaller than the preceding one. It is therefore necessary to start the season with a large supply of material to avoid running out before the end. With this species, though perhaps not with related forms, it is easy to stock up with adults of the first summer brood by placing considerable quantities of already infested garden winter wheat under cages as early as June 1. This wheat will yield adults in the desired numbers to stock cages for the second brood. Wheat taken from the fields is likely to be much less infested than that sown in gardens; the latter therefore should be used for cages.

Larvæ on hatching from eggs in cages immediately entered the young wheat stems and in most cases were allowed to develop there, the pot being watered and kept under observation to see when the adults made their appearance. For early larval stages, eggs were taken from leaves and placed in a vial, where they could be examined more frequently and closely than in the cage. In this way the newly hatched larvæ were obtained before they had fed. For later stages, larvæ were dissected out of wheat stems they had entered, placed on a fresh piece of young stem, and corked up in a vial. Larvæ so handled readily entered the second stem, which would keep fresh for four or five days; a second transfer would bring the larva to maturity—some, in fact, matured without it. The process of dissecting the larva out was performed under a low power of the binocular dissecting microscope, using a needle with a minute hook at tip and slitting the stem carefully. This is a simpler process than the description might indicate and was performed successfully hundreds of times with only a few mishaps. During the summer of 1915 as many as 100 vials containing transferred larvæ were under observation at once. The vigor and endurance of the larvæ are remarkable. When the stems were left too long in the vials and decayed, the larvæ almost always survived. In several cases they endured starvation for several days; one fasted a week and then when given the opportunity entered a wheat stem and in due time reached maturity. They do not survive drying up, however, but require a moist atmosphere. This is true also of the adults.

WINTER BROOD: DATES OF SPRING EMERGENCE

Records were kept in the spring of 1916 on four cages containing garden wheat that had wintered outdoors where it grew. The emergence is shown in Table I.

TABLE I.—*Emergence of winter brood of Oscinis frit*

Date of emergence.[a]	Cage No. 2, caged Mar. 30.	Cage No. 3, caged Mar. 30.	Cage No. 4, caged Apr. 11.	Cage No. 5, caged Apr. 11.	Total by days.
Apr. 26	1	0	0	0	1
29	0	0	0	0	0
30	0	0	1	5	6
May 3	5	3	0	10	18
6	2	0	2	9	13
9	0	1	1	4	6
15	1	0	1	3	5
19	0	0	0	0	0
25	0	0	1	0	1
31	0	0	0	0	0
June 12	0	0	0	0	0
Total by cages	9	4	6	31	50

[a] Dates on which no observations were made are not entered in the table.

From Table I it appears that emergence in 1916 extended over a period of 29 days (April 26 to May 25) and that 85 per cent of the flies emerged in 11 days, from April 30 to May 10. It would appear, however, that these dates were retarded by keeping the cages too much in the shade, since sweepings made outdoors at frequent intervals in early April gave the first adult for 1916 on April 13 and for 1915 on April 14.

SUMMER BROODS

Four complete summer broods were reared in 1916, as reported in Table II. Each cage was started at the time indicated by the cross, using flies that had emerged a few days before. Cages 23, 24, and 26 were exceptions, being stocked with garden wheat already heavily infested outdoors, This explains their large yield of flies. The wheat in cage 26 was taken up so late (June 16) that there was a possibility of its containing eggs of the second brood; and this probably accounts for the single fly which emerged in it on July 28, 16 days after the last preceding one. The negative observations for each cage are omitted up to the first positive one, after that both positive and negative are included up to the time that the use of the cage was discontinued. All cages that produced no positive results are omitted; they were more numerous than those included.

Flies of the first summer brood began to emerge on June 12 and continued to do so until July 13 (32 days), the heaviest emergence being from June 25 to 30.

Flies of the second summer brood began to emerge July 16 and continued to do so until July 26 (only 11 days). Flies emerged in 10 cages. July 21 gave the largest record.

Flies of the third summer brood emerged from August 10 to August 28 in 5 cages, a total, however, of only 21 flies.

TABLE II.—*Record of adults of Oscinis frit reared in cages at La Fayette, Ind., in the summer of 1916*

[The sign × indicates dates on which flies were introduced into cage. Observations were then made daily until the first fly emerged and thereafter only on dates indicated]

Date of observation.	Brood I. Cage No. —										Brood II. Cage No. —										Brood III. Cage No—					Brood IV. Cage No. —	
	11	13	14	15	19	20	21	23	24	26	27	28	29	31	36	39	43	44	45	52	73	74	75	82	84	87	92
May 6	×																										
9		×	×	×																							
15					×	×	×																				
31								×	×																		
June 12		2																									
13		1																									
14		1																									
15		0																									
16		1								×																	
18	2	1	1	1																							
19		0	0	0				1			×	×	×														
20		1		2																							
21	0			1					4																		
22	0	2	0	0					3					×													
23	2	2	2	1				1	5	4	2																
26	0	6	0	0	1		8	26	41	1																	
27	0	1	0	0	0		0		21	2					×	×	×	×	×								
29	0						0	31	20	16										×							
July 2	0	1	0	0	0	1	0	9	0	7																	
5	0	0	0	0	0	0	0	10	3	13																	
6								1																			
7	0	0	0	0	0	0	0	1	7	8																	
10	0	0	0	0	0	0	0	0	1	7																	
13	0	0	0	0	0	0	0	1	1	4																	
16	0	0	0	0	0	0	0	0	0	0	1																
17								0	0	0	0	4	1														
19								0			0	0	3	1	4	1			1								
21									0	0	0	0	0	1	4	3	3	2	1	2	×	×	×	×			
24											0	1	0	0	0	1	0	0	2	0							
26											0	0	0	0	1	0	1	1	1	1							
28										1	0	0	0	0	0	0	0	0	0	0					×		
29										0																	
30											0	0	0	0	0	0	0	0	0	0							
Aug. 1											0	0	0	0	0	0	0	0	0	0							
3											0	0	0	0	0	0	0	0	0	0							
7											0	0	0	0	0	0	0	0	0	0							
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6																										0	0
10																										0	0
13																										0	0
15																										0	0

Only two flies of the fourth summer brood were obtained. These emerged in cage 87 on September 24 and 25. The small number was due to the rapid dwindling of the broods in cages, as explained under "Methods" p. 459. When a possible failure to get the fourth brood in lineal descent was anticipated, a supplementary series of cages was started, stocked with flies obtained by sweeping a bluegrass lawn. One of these, cage 92, gave adults, and they correspond very well with those of cage 87, the first fly appearing on the same date in both. Cage 92 gave two adults on September 26 and one, the last of the season, on October 3.

Cages started the last of September with flies swept from the lawn and with the few reared flies gave no results, no eggs being obtained. The weather was cool, and the flies were almost continuously dormant. Afterthought would suggest that in spring and fall the cages need a good deal of direct sunlight. No indications, however, of a fifth summer brood were observed. Flies emerging in September probably live longer than those of midsummer, having long dormant periods in cool weather; so they merely lay eggs on winter wheat in October for the winter brood.

The record here given covers too few flies, and those kept under too uniform conditions, to exclude the possibility that a portion of the representatives of this species, under natural conditions, might have a brood more or less. It does indicate, however, that four is the normal number of summer broods; and, allowing for the effect of a slight retardation in the cages in spring and fall, it is probable that five broods in the season will occur oftener than three.

LENGTH OF INSTARS

The number of days from adult to adult in each of the summer broods is shown by Table III.

In this table there were 8 individuals in brood II and 3 in brood III whose parents emerged two days apart, the intermediate day being taken as the date for both. One of these cases in brood III gave the minimum record of 22 days. The actual minimum period for the season was for the male of this pair. He was 21 days from emergence when his offspring emerged; but since his mate was 23 days old the number 22 was recorded as the average. The period covered in this case for the male was July 21 to August 11, in which there were two hot waves separated by a few somewhat cooler days—on the whole, an excessively hot period.

The table shows an average period from adult to adult in the first summer brood of 49.7 days for 35 individuals; for the second brood, 30.3 days for 41 individuals; for the third brood, 28.5 days for 21 individuals; and for the fourth brood, 45.5 days for 2 individuals.

TABLE III.—*Variation in the time of emergence of adults of Oscinis frit in each brood, with reference to the number of days from emergence of their parents*

Number of days since emergence of parents.	Brood number.				Total by days.
	I.	II.	III.	IV.	
22			1		1
24		1	4		5
25			1		
26		10			10
27		3			3
28		4	3		7
29		5	1		6
30		1	5		6
31		4	2		6
32		3	2		5
33		1	1		2
34			1		1
35		4			4
36		1			1
40		3			3
42		1			1
44	3				3
45				1	1
46	3			1	4
47	3				3
48	2				2
49	6				6
52	16				16
53	1				1
58	1				1
Total by broods	35	41	21	2	99
Average	49.7	30.3	28.5	45.5	

The period from adult to adult may be considered as consisting of: (a) The preoviposition period; (b) the egg instar; (c) larval instars; and (d) the pupal instar. Since the sum of these (adult to adult) varied from 21 to 58 days, naturally the components would vary accordingly—not, however, in strict proportion, because all periods become successively accelerated while approaching the heat climax of summer and are retarded after passing it. Making the best approximation possible, the records obtained seem to bear out the following division of the entire period:

PERCENTAGE OF TIME IN LIFE CYCLE

Preoviposition	14
Egg	11
Larva	50
Pupa	25
Total	100

It would be more logical to count this period from egg to egg, but oviposition is very difficult to observe and the data upon that subject are very meager. The emergence of the adult is the easiest point to note, and is the one on which the record is most complete.

HABITS AND FOOD PLANTS

As indicated in the introduction, the fly deposits its eggs on grains and grasses, usually on the very young and tender shoots, but sometimes upon or within the glumes just after heading. In the former case the larva enters the shoot and feeds downward in the middle; in the latter, it eats out the soft young kernel

Oviposition was not observed, although eggs were found that had been laid only an hour or two. In one instance, a female was seen to protrude the three terminal segments of her abdomen into a sort of ovipositor (see fig. 6, from an alcoholic specimen). With this she explored the crevices along the stem formed by overlapping of leaves but finally discontinued the operation without laying. Eggs were found both on the stem close to the ground and on the leaves, the latter, however, always within 3 or 4 inches of the ground. One or two lots were laid in crevices, but most of them were in plain sight. In about 5 days after the emergence of the female her eggs are fully developed and can be seen through the thin side walls of the abdomen. There are normally about 30 of equal size contained in the two ovaries. No indication was seen that other series might develop later, but such may be the case under outdoor conditions.

During the seasons of 1915 and 1916, sweepings were made on various grains and grasses, both by the writer and by a number of voluntary assistants,[1] to ascertain the distribution and preferences of the adult. Usually 200 sweeps with a 12-inch net were made. An examination of 240 lots was made in 1915 and of 310 lots in 1916, in order to sort out the various species of oscinids and related families. In both years *Oscinis frit* led all others in numbers, with totals of 4,677 and 11,235 out of grand totals of 23,416 and 40,187.

In the course of this work it soon became manifest that adults of *Oscinis frit* are rare on grain after it has begun to shoot up to head, or on grasses that are approaching maturity; but they are abundant on wheat and grass that is in an earlier stage, stooling or producing fresh shoots. Bluegrass lawns that are kept sprinkled and mowed yield large records of *O. frit* practically all through the season. Roadside bluegrass kept grazed yields large numbers before the dry weather of summer, but the records decrease rapidly at this time. Evidently the fly seeks grain or grass that is producing new shoots. They seem to be attracted by an exudation from the fresh epidermis, which they greedily lick, and not by the desire to lay their eggs on the plants. In no case was any appreciable number of specimens obtained from sweeping on dicotyledons, unless the stand was noticeably mixed with grass. The maximum record for 1915 was 365 flies in 200 sweeps with a 10-inch net on a blue-

[1] Among these should be mentioned Mr. Norman Criddle, Field Officer for Manitoba of the Dominion Entomological Branch, C. N. Ainslie, Sioux City, Iowa, and Dr. C. F. Adams, Atherton, Mo.

grass lawn at Elk Point, S. Dak., by C. N. Ainslie. This was on September 7.

This was exceeded five times in 1916, when the highest record was 486 flies in 200 sweeps with a 13½-inch net on bluegrass lawn at the Central Experiment Farms, Ottawa, Canada, by Mr. Germain Beaulieu, on August 17. Both of these records indicate a great concentration of the flies upon this food plant in late summer. However, an earlier record stood second in 1916, when Dr. C. F. Adams swept 401 flies in 200 sweeps of a 12-inch net at Atherton, Mo., on bluegrass lawn, on May 17.

INFESTATION OF WHEAT

Almost all the infestation observed by the writer has been upon wheat. Eggs are laid on fall wheat soon after it comes up, and the larvæ winter in the stems. Wheat was sown at weekly intervals from September 12 to October 17, and in November it was noted that the infestation was great in the earliest sowing and decreased regularly to the latest one or two sowings, in which none could be seen. In the spring the wheat is attacked by the first summer brood. Spring wheat is not a farm crop at La Fayette, but experimental sowings, especially the later ones, were heavily attacked.

A very characteristic symptom of infestation in young shoots of all kinds is the dying of the central leaf while the others around it remain green. The observer readily notices this when once his attention is directed to it. In the cooler and moister periods of the year, however, the insect may be abundant and yet only a few of the plants show this symptom. Since the larva does not usually cut the central leaf entirely off, in periods of low transpiration the leaf will still keep green for some time, whereas the same injury in hotter and dryer weather would kill the leaf at once. So the damage may be greater than it appears and can be calculated for the cool part of the year only by placing a known number of plants in a cage and counting the flies that emerge, every one of which may be considered to have destroyed a shoot.

At a meeting of Russian economic entomologists in Kiev in 1913, Mr. N. V. Kurdjumov (*1*) advanced the theory that the pruning off of some of the shoots of summer grain by *Oscinis frit* may do it good rather than harm. But the same author (*12*) in the same year mentions the insect as inflicting particularly severe injury upon spring grain. Since several other Russian entomologists have reported it to be doing serious injury, it is likely that its possibly useful character was mentioned in a qualified way.

Although in garden-sown wheat infestation occurred in a considerable percentage of the stems, the writer was never able to find in fields of winter wheat any appreciable infestation in late fall or early spring, such as was reported by Garman. For a while this was explained apparently by the fact that at these seasons of the year the characteristic

symptom of infestation (the dying of the central shoot) does not appear so quickly. In the spring of 1917 the point was further tested by transplanting wheat from fields to pots under cages, to compare it with rye and several grasses treated in the same way. Glass cylinders were placed over several grasses outdoors without transplanting, and several lots of wheat and grass were taken into the laboratory and all the stems slit up to find larvæ. The net result was that the fly was found to winter in timothy and meadow fescue, but not in wheat, rye, or several other grasses. The explanation which best harmonizes this result with other observed facts is that the insect has a rather wide range of habits and may concentrate upon any one of several food plants, just as it sometimes severely attacks the young, unripe grains while ordinarily it does not affect them.

INFESTATION OF RYE

A small percentage of infestation was obtained in rye sown in the garden rather late in spring. The European literature contains frequent references to *Oscinis frit* as a pest of rye, but the crop is so little raised in the United States that the insect heretofore has escaped notice in this connection.

INFESTATION OF BARLEY

Linnaeus (*13*) in his classic first paper on *Musca frit* described the infestation of barley kernels on an extensive scale, beyond anything that has been seen since. He estimated that one-fifth of the barley crop was annually destroyed by the insect. A few years later in another paper he reduced the estimate to one-tenth, indicating that further observation had not shown so great infestation as in the first instance. The insect also attacks barley stems in the spring, as indicated in European literature and confirmed by the writer.

INFESTATION OF OATS

The oat fly is a term used in England for *Oscinis frit.* Wilhelm (*24*) published a 40-page pamphlet in Germany on it, using the same name (die Haferfliege). In both countries it has often been noted mining the young shoots and destroying the ripening kernels. Westwood (*22*, *23*) reports a striking instance of infestation of oat kernels in England, attributing it to *O. atricilla* Zett. A farmer had thrashed 25 quarters of oats and stored them in a loft. The following account was written to Westwood by J. B. Yonge, Esq.

> A few days afterwards a stratum of flies was seen on top of the Oats, coming up among them, and passing away through the window. The stratum was about 4 feet long, 1 broad, and 3 inches thick, and being continually renewed from below as those above passed off, an immense number must have gone through during the four days it was observed.

This case compares very well with the immense infestation of barley kernels reported by Linnaeus in 1750 (*13*); no doubt both represent extreme instances of this sort of damage.

Professor T. H. Taylor, of the Department of Agriculture, Leeds University, England, has kindly given the following summary of his observations on the oat fly in England in a letter dated October 6, 1915.[1]

The chief attack is made upon the oat crop. I have seen crops very seriously damaged by the pest. The attack that injures the oat plants most seriously is caused by the first brood appearing in early summer. These flies lay their eggs on the leaves of the young oat corn and the larvæ bore in the heart of the plant and destroy the stem. The plant thereupon tillers and produces a stunted bunch of young shoots which are practically worthless. The farmers call this condition of the oats "segging." The second brood of flies remains mostly—but perhaps not altogether—upon the oat crop, and the larvæ attack the *grains* between the glumes. These larvæ pupate *in situ* and the flies (third generation) migrate from the oats to wild grasses, upon which they spend the winter, pupating the following spring and giving rise to the first brood of frit-flies for the new season, thus completing the vicious circle. I have come across isolated examples of frit-fly attacking the stem of wheat and barley, but as I have paid very little attention to these outside attacks I can only say that they appeared to be due to the ordinary *frit*. I do not remember to have seen the grains between the glumes of either wheat or barley attacked.

When the writer's studies early revealed the fact that the American species has a marked distaste for the oat, several lines of investigation were carried out in order to test this relation as fully as possible.

(1) Wheat, rye, emmer, barley, and oats, sowed in rows in the garden in late spring, were infested in the order given, wheat much the worst, oats hardly at all. Oats sowed in the garden on August 25 were taken up and placed in a cage on September 20, when they were about 10 inches high and very thrifty. They had occupied a rather dense row about 25 feet long. In this cage only one specimen of *Oscinis frit* emerged, on October 16. A control cage of wheat sowed at the same time and caged at the same time yielded 68 adults of *O. frit*—12 on October 5, 20 on October 13, 8 on October 16, 20 on October 22, 3 on October 27, and 5 on November 1.

(2) Eight cages were started in which pairs of *Oscinis frit* were confined on young oat plants. Three eggs were laid in two cages, but no adults developed.

(3) In order to learn whether the American species is able to feed upon the oat stem at all, on September 10 and 13, 1915, 29 larvæ were dissected out of young wheat stems and placed on similar young oat stems in vials, as described under "Methods," p. 459, except that the food plant was changed. The results are shown in Table IV.

In most instances the larvæ which did not enter lived about a week, crawling actively on the glass much of the time.

[1] Professor Taylor disclaims any attempt to identify the species of the insect; specimens sent by him at the same time, however, seem indistinguishable from *Oscinis frit* as identified by Professor Bezzi and G. Strobl.

TABLE IV.—*Results of transferring larvæ of Oscinis frit from young wheat stems to young oat stems*

Larva No.	Result.
176	Died without entering oat stem.
177	Do.
178	Do.
179	Do.
180	Do.
186	Do.
187	Do.
188	Do.
189	Do.
190	Do.
199	Do.
200	Do.
201	Do.
202	Refused to enter oat stem, and after 7 days the nearly starved larva was placed in a vial with a wheat stem, which it entered and in due time emerged as a normal adult, Oct. 15.
203	Refused to enter oat stem, and after 10 days the nearly starved larva was placed in a vial with a wheat stem; it was however too weak to enter, and soon died.
204	Entered oat stem and fed; pupated normally; its emergence was not noted in the record.
205	Died without entering oat stem.
206	Do.
207	Do.
208	Entered and fed normally, and adult emerged Oct. 15.
209	Entered and fed, but left stem to wander on glass; however pupated and emerged Oct. 14.
210	Died without entering oat stem.
211	Do.
212	Entered and fed, but died without pupating.
213	Died without entering oat stem.
214	Do.
216	Larva was nearly full-grown and pupated without entering oat stem.
217	Died without entering oat stem.
218	Larva was nearly full-grown, and pupated apparently without feeding.

Thus it appears, disregarding larvæ 216 and 218, that out of 27 larvæ transferred, only 4 (204, 208, 209, and 212) accepted the oat as a food plant, and 1 of these did not reach pupation; 2 of the 4, however, emerged as adults and showed no differences from specimens reared entirely upon wheat.

A control series on the same dates, in which larvæ were dissected out of wheat stems and placed in vials on other wheat stems, gave the results recorded in Table V.

Of the 13 larvæ transferred in this test, only 3 died without entering the wheat stem, 7 went through their transformations normally, while the failure to get an emergence record for the remaining 3 probably is not due to the transfer. It may be presumed that in both series some larvæ suffered unnoticed injuries while they were being removed from the stems. The net result of the two series shows that larvæ of the American species, when they have once begun to feed in wheat, are very loath

to accept the oat, usually preferring starvation, whereas they can be transferred to new wheat stems with comparative ease.

TABLE V.—*Results of transferring larvæ of Oscinis frit from wheat stems to other wheat stems*

Larva No.	Result.
181	Fed normally, and adult emerged.
182	Do.
183	Do.
184	Fed and developed to pupation, but pupa became moldy and adult never emerged.
185	Died without entering.
191	Fed normally, and adult emerged.
192	Do.
193	Fed normally and developed to pupation, emergence not noted.
194	Died without entering.
195	Entered stem normally but was accidentally killed later while being transferred to fresh stem.
196	Fed normally, and adult emerged.
197	Died without entering.
198	Fed normally, and adult emerged.

(4) To determine whether specimens of *Oscinis frit* that had been reared in wheat would breed in green oat kernels, a bunch of newly headed oat plants was transplanted into a pan and arranged so that the heads only would project up through a slot in a horizontal wide board; an 8-inch glass cylinder, topped with cheesecloth, was placed over the heads, and the slot in the board was filled up and chinked with cotton batting. Into this cage with the oat heads 28 specimens of both sexes of the fly were introduced on July 2. On the next day 4 more pairs were introduced. None of the flies lived in this cage more than a week. On August 10 a single adult emerged, the only offspring of the 36 specimens confined.

(5) To test whether *Oscinis frit* or any other oscinid normally lives in oat kernels in the United States, it was planned to strip the green oats from 50 heads (estimated to be at least 1,000 kernels) and place them in a lantern-globe cage to see if any flies would emerge. The cooperation of economic entomologists was obtained, and in all 79 lots of 50 heads each were placed in cages. Twenty-two lots were from various places in northern Indiana; 2 from Madison, Wis.; 10 from Minnesota, sent by Professor Ruggles; 3 from South Dakota, sent by Mr. Severin; 7 from places in Montana, sent by Messrs. Cooley, J. R. Parker, and Larrimer; 4 from Washington, sent by Professor Melander; 5 from Utah, sent by Professor Titus; 13 from Colorado, sent by Director Gillette; 4 from Sioux City, Iowa, sent by C. N. Ainslie; and 9 lots received without data, but apparently from the West. The material was in various stages, but none fully ripe. It represented numerous varieties of oats, some being almost

pure wild oats. In only 2 lots did any flies emerge. One of these was taken at Manchester Siding, Ind., near Crawfordsville, on July 13 and yielded one specimen of *O. frit* on July 26. The other lot was taken on the edge of Crawfordsville the same day, and on July 26 it was found that two specimens of *O. frit* had emerged, together with one of *O. umbrosa* Loew and two of *Elachiptera nigriceps* Loew, a member of the same family.

A fair conclusion from the five lines of investigation would seem to be that *Oscinis frit*, as we have it in this country, does not normally feed upon the oat at all, but that occasional individuals, when compelled, are able to do so. This conclusion, in view of the marked preference for the oat manifested by *O. frit* in Europe, appeared to the writer to cast a strong doubt upon the identity of the American species; but after reviewing once more that phase of the subject he is of the opinion that there is no ground other than a physiological one for asserting that the species in North America is not *O. frit*. The case appears to resemble those mentioned by Dr. C. Gordon Hewitt (*11*) in his presidential address at the 1916 meeting of the American Association of Economic Entomologists, and others cited in the discussion of the address, in which strains of a species apparently arise which have a special adaptation to a certain food plant.

INFESTATION OF GRASSES

Much remains to be done in studying the relation of *Oscinis frit* to grasses. Only a few definite records of infestation exist, although most entomologists who have studied the insect assume that a considerable proportion of the flies, especially in middle and late summer, must breed in them. As already noted, sweepings made by the writer and by other entomologists who sent the material so obtained to him, show that from early summer onward the fly is much more abundant on bluegrass lawns than anywhere else. But sweepings on bluegrass that has begun to head or is in a later stage yield very few specimens, indicating that the presence of young shoots is the attraction. Sweepings on timothy in unmixed stand yield almost no specimens at any time, indicating that it is a plant unattractive to *O. frit*.

In 1915 five cages were prepared, each containing growing plants of wheat, bluegrass, and timothy. Several individuals of *Oscinis frit* of both sexes were placed in each. The only infestation that occurred was in wheat, from a stem of which a single maggot was taken and brought to maturity in a vial. From bluegrass sods placed in two cages no specimens of *O. frit* emerged, and several examinations of both stems and roots of the same grass gave no indications of infestation. *O. frit* has, however, been reared from this and other grasses, as the list of food plants will show.

KNOWN FOOD PLANTS

The following list of food plants includes those known for the United States and Canada. An asterisk (*) indicates that the fly was reared from this host by the writer. Numbers after authorities refer to the literature cited in this paper. The unpublished references are based on material identified by the writer.

*Wheat (stems). Garman (*10*), Fletcher (*8*), Webster (*21*), and Coquillett (*4*).
Wheat ("roots of wheat"). C. N. Ainslie, Moravia, Iowa (unpub.).
*Oats (stems). Webster (*21*), J. J. Davis, Sheldon, Ill. (unpub.).
*Oats (kernels).
*Barley.
*Emmer.
*Rye.
Corn (green cornstalks). Tucker (*20*).
*Timothy (*Phleum pratense*).
*Meadow fescue (*Festuca elatior*).
Kentucky bluegrass (*Poa pratensis*). Fletcher (*8*) and Webster (*18*).
Slender wheat-grass (*Agropyrum tenerum*). Fletcher (*8*).
Awned wheat-grass (*Agropyrum caninum*). Fletcher (*8*).
Quack grass (*Agropyrum repens*). Fletcher (*8*).
Rye grass (*Elymus canadensis*). Fletcher (*8*), and C. N. Ainslie, Elk Point, S. Dak. (unpub.).
Slough grass (*Spartina michauxiana*). C. N. Ainslie, Elk Point, S. Dak. (unpub.).
Barnyard grass (*Echinochloa crusgalli*). Webster (*21*) and C. N. Ainslie, Elk Point, S. Dak. (unpub.).
Low love-grass (*Eragrostis minor*). Webster (*21*).
Sedge (*Cyperus strigosus*). A. F. Satterthwait, La Fayette, Ind. (unpub.).
Cucumber roots. Webster (*21*).
Strawberry. Webster (*21*).
Ironweed (*Vernonia noveboracensis*). Wintering in seed capsules, Webster (*21*).

The last three records are the only ones on dicotyledons. It should be noted that the determinations were made at a time when the species of Oscinis were but little known, therefore they may be errors of identification or of observation.

PARASITES

Webster (*21*, *p. 56*) mentions having reared *Cyrtogaster occidentalis* Ashm. from either *Oscinis carbonaria*, *O. soror*, or *O. umbrosa* Loew, in Indiana. His uncertainty illustrates a common difficulty in rearing parasites from these forms. When material is taken from garden or field and placed in a cage to get the parasites, it is likely to contain the Hessianfly, Isosoma, Meromyza, Elachiptera, and several species of Oscinis. Although *Oscinis frit* may predominate, it is impossible to say positively that it was the host of the parasites. These are usually abundant. Even to isolate selected larvæ would not entirely obviate the difficulty, since at present no way is known to distinguish those of several species of oscinids. Parasitized larvæ would yield no adults, so there could not be a positive determination. Where cages are started by introducing adults on young wheat plants grown under cover, of course no parasitism is

possible; and this was the principal method used by the writer. Webster says:

Rhyssalus oscinidis Ashm. is parasitic on a species of Oscinis larvæ mining leaves of plantain at Washington;

but the miner referred to is now known to be *Agromyza melampyga* Loew, not Oscinis.

At present it can only be said that *Oscinis frit* appears to be freely parasitized by minute Hymenoptera, but observations have not as yet excluded all doubt in any case.

REMEDIES

The similarity of this insect's attack upon wheat to that of the Hessian fly indicates that a solution of the one trouble may carry the other with it. Unfortunately, the Hessian fly, although it has received a vast amount of attention, continues to inflict serious loss upon agriculture.

As far back as 1777, Bierkander (*3*) made recommendations for the control of *Oscinis frit* by changing the methods of tillage, and down to the present this is the only direction in which a lessening of its injury seems practicable.

Wheat sown early in the fall is more infested than that sown later, so the recommendation of late sowing to escape the Hessian fly will be equally applicable for *Oscinis frit*, but with this difference, that with the Hessian fly the possibility of infestation entirely ceases at a certain date, but with *O. frit* the chances decrease regularly until cold weather.

Wheat sown in the late spring is more infested than that sown early.

Continuous cropping in wheat appears to make no difference with the fly, which migrates freely for considerable distances.

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