BEHAVIOR OF PHYTOPHAGA DESTRUCTOR SAY UNDER CONDITIONS IMPOSED BY EMERGENCE CAGES[1]

By Walter H. Larrimer

Entomologist, Office of Cereal and Forage Insect Investigations, Bureau of Entomology, United States Department of Agriculture

INTRODUCTION

The Hessian fly, *Phytophaga destructor* Say, has long been recognized in America as a wheat pest of primary importance, and even before its scientific description by Thomas Say in 1817 it had attracted considerable attention and was referred to under the popular name of Hessian fly. Naturally such an insect pest has been the subject of much published discussion as well as almost every conceivable type of investigation. Many excellent accounts of the life history, food habits, natural enemies, control, and other interesting phases in the life of this insect are readily available and therefore need not be repeated. Osborn (*7*)[2] has given a very comprehensive treatise on the Hessian fly in America, with a complete bibliography of all important papers up to 1898. For contributions appearing since that time full references will be found in the Bibliography of American Economic Entomology (*1*, *8*).

The determination of the time and extent of the emergence of adult flies from flaxseeds under varying conditions has always been an important factor in the study of this phase of the life history of the Hessian fly, and particularly in reference to various schemes for control. The present discussion deals with the design of a number of emergence cages, and the determination of the relative efficiency both as to approach to natural conditions and ability to recover emerged flies.

EMERGENCE CAGES

Although many types of cages have been suggested from various sources, the selection of type, actual design of cages, and accomplishment of results may be considered as original. The six types of emergence cages selected were as follows:

Type A.—Cone-shaped, frame of sheet tin covered with 18-mesh pearl screen wire. Base circular, of diameter sufficient (40.6 inches) to make it inclose 1 square yard. Altitude 30 inches, and top terminating in a sheet-tin cone with 0.5-inch hole at the small end. Over this hole is fitted a small screen trap for catching flies that emerge from the cage through the hole in the top (fig. 1, A).

Type B.—Square, base inclosing 1 square yard. Height, 18 inches. Frame of 1 by 2 inch cypress, covered with 18-mesh pearl screen wire. Top is painted with thin tanglefoot and made to open upward to facilitate counting of flies caught on the tanglefoot (fig. 1, B).

[1] Received for publication Oct. 7, 1924; issued October, 1925.
[2] Reference is made by number (italic) to "Literature cited," p. 574.

Journal of Agricultural Research, Washington, D. C.

Vol. XXXI, No. 6
Sept. 15, 1925
Key No. K-151

Type C.—Square, base inclosing 1 square yard. Height, 18 inches. Frame of 1 by 2 inch cypress, covered with 18-mesh pearl screen wire. Top is made to open upward to facilitate counting of flies. The entire cage is lined with cheesecloth. Four single sheets of tanglefoot fly paper are fastened to the lower side of the top (fig. 1, C).

Type D.—This is a light-proof box of 0.5-inch pine, with base inclosing 1 square yard. In later experiments this type was made of a wood frame covered with tar paper. Two 29-millimeter glass vials were inserted through holes bored in the south side of the box (fig. 1, D).

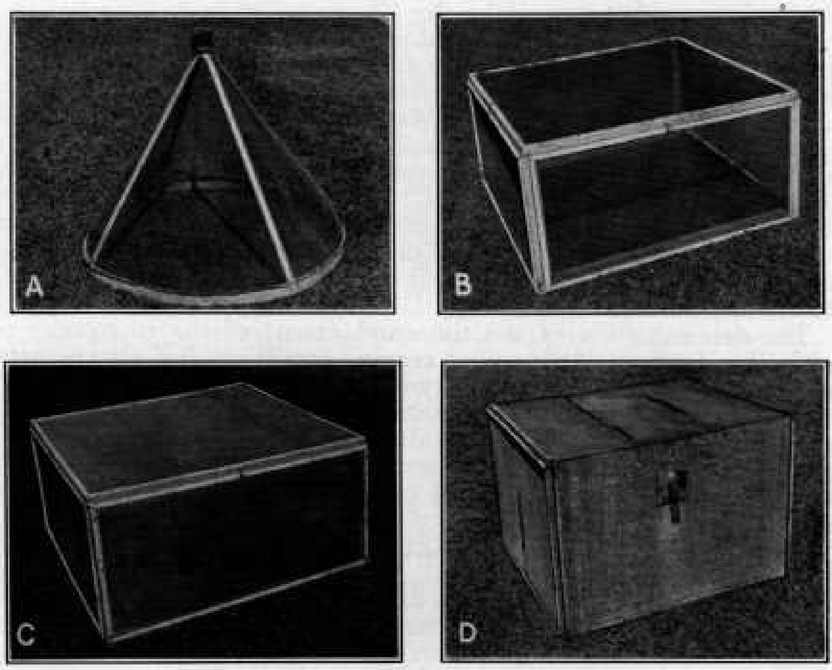

Fig. 1.—*A*, emergence cage for the Hessian fly, type A, having cone-shaped frame of sheet tin, covered with screen wire; B, emergence cage, type B, having square frame of cypress, covered with screen wire; *C*, emergence cage, type C, having square frame of cypress, covered with screen wire and lined with cheesecloth; *D*, dark emergence cage having frame of wood, made light-proof with tar-paper covering

Type E.—May be described as A-shaped, with square base inclosing 1 square yard. The two sloping sides are 1 yard square each and the ends A-shaped. Frame of 1 by 2 inch cypress, covered with 18-mesh pearl screen wire. Door, made by hinging one of the sloping sides at the top, is painted with thin tanglefoot, and the cage set so that this door faces south (fig. 2, A).

Type F.—This may be described as A-shaped with base square, inclosing 1 square yard; the two sloping sides 1 yard square each, and the ends A-shaped. Frame of 1 by 2 inch cypress, covered with 18-mesh pearl screen wire, with the exception of the door, which is made by having one of the sloping sides hinged at the top. This door is covered with 12-mesh pearl screen wire and painted with thin tanglefoot. The cage is set so that this door faces south (fig. 2, D).

FIRST TRIAL, NASHVILLE, ILL., APRIL 10 TO 30, 1917

The cages just described were arranged in a row extending east and west. Each covered 1 square yard of heavily infested winter wheat. There was reason to believe that each square yard was as nearly uniformly infested as was possible to obtain. However, there is some question as to whether an approximately equal number of flies might be expected to emerge in each cage. The cages were set in position April 9. During the 21 days of the experiment the total number of flies taken from each cage was as follows: A, 65; B, 63; C, 8; D, 134; E, 54; F, 61; total for all six cages, 385.

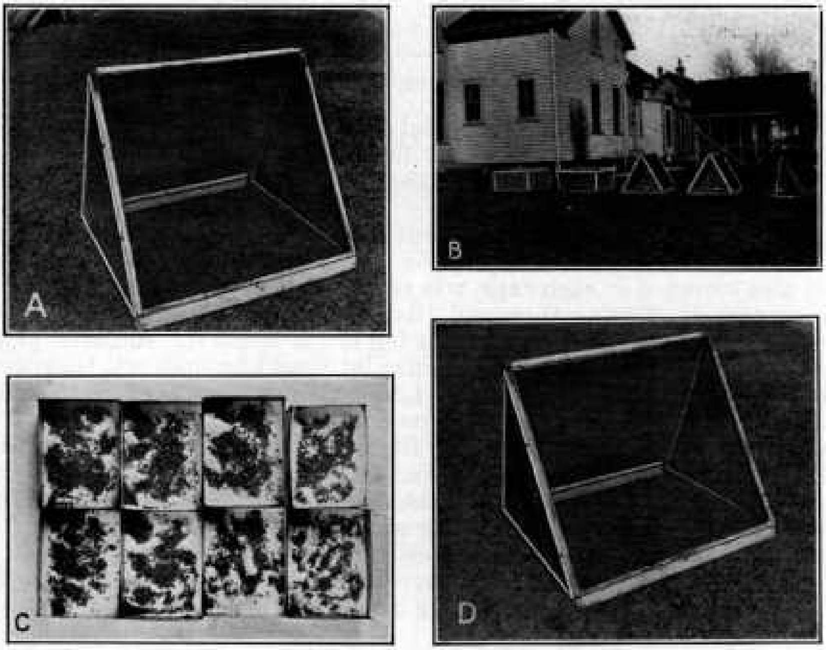

FIG. 2.—*A*, emergence cage for the Hessian fly, type E, having A-shaped frame of cypress, covered with 18-mesh screen wire; *B*, emergence cages in place for outdoor experiment; *C*, 12,000 "flaxseeds" or puparia used in indoor experiment; *D*, emergence cage, type F, having A-shaped frame of cypress covered with 18-mesh screen wire, except door, which is 12-mesh

The results obtained indicate that cage D was approximately twice as efficient in recovering flies as the best of the other cages. Cage C shows up very poorly, whereas the other cages are so close together in number of flies recovered that other considerations might be allowed to influence the selection of one of these cages for any particular purpose. A comparison of temperature, evaporation, and rainfall in each cage with that of natural conditions outside, or normal, was made. Temperature variations were determined by radiation thermometers placed close to the soil surface, and are shown in degrees plus or minus from the normal. Variations in evaporation were determined by compensating atmometers, and are shown in cubic centimeters plus or minus from the normal; the evaporation for each preceding 24 hours being recorded at 8 a. m. Variations in rainfall were determined by especially adapted standardized rain gauges and are shown in inches plus or minus from the normal, the amount for each preceding 24 hours being recorded at 5 p. m. Readings for each factor were made, and the accumulated variations are given in Table I.

TABLE I.—*Accumulated variation 19-day period, April 12 to 30, 1917*

Factor	Cage A	Cage B	Cage C	Cage D	Cage E	Cage F	Time
Minimum temperature (°F.)	+34.5	+32.0	+22.5	+51.5	+26.0	+31.5	
Temperature (° F.)	+9.5	−5.0	−26.0	−25.0	−2.0	−2.5	8 a. m.
	−21.5	−33.0	−103.0	−141.5	−39.5	−17.5	12 m.
	−8.0	−15.0	−51.0	−65.0	−26.0	−24.0	4 p. m.
Evaporation (c. c.)	−80.4	−110.4	−223.2	−282.1	−118.8	−104.9	8 a. m.
Rainfall (inches)	−.49	−.16	−1.57	−3.24	−.53	−.59	5 p. m.

SECOND TRIAL, LA FAYETTE, IND., MARCH 15 TO 24, 1920

In order to make an extra trial, it was decided to run the cages indoors, thus forcing the adult flies to emerge by artificial heat. The cages were arranged in the laboratory under conditions as nearly uniform as possible.

The disadvantage pointed out in the first trial, namely, the existence of an uncertainty as to whether about the same number of flies emerged in each cage, was recognized, and an attempt made to eliminate it. Twelve thousand "flaxseeds" (fig. 2, C) were taken from wheat plants killed by the regular fall brood of the fly, and after being thoroughly mixed so that the entire lot would be uniform, they were divided into smaller lots, and 1,500 each were placed over moist soil in small rectangular tin boxes, and then exposed, one box in each cage. An additional 1,500 flaxseeds were placed in tin parasite boxes, and the adult flies allowed to emerge into glass vials. By counting these daily, and also those in the boxes, a suitable control was obtained on the total number which could reasonably be expected to emerge from each 1,500 flaxseeds in each of the cages.

Flies were counted and removed from the cages daily, as in the preceding trial, except that the record of males and females was kept separate, as follows:

Cage A, 205 females, 539 males, total 744; B, 127 females, 453 males, total 580; C, 21 females, 32 males, total 53; D, 307 females, 355 males, total 662; E, 195 females, 527 males, total 722; F, 136 females, 435 males, total 571; control, 512 females, 601 males, total 1,113.

No attempt is made to consider this trial as being conducted under any other than extremely unnatural conditions; however, it does give considerable information on the subject. It brings out the fact that although moisture and temperature may be the controlling factors in the emergence of adult flies, wind is certainly of some importance in the determination of cage efficiency. Indeed, the percentage of recovery is very remarkable in most cases, the exception being cage C, which will undoubtedly prove to be too inefficient to merit further consideration. Another remarkable point brought out in this experiment is the fact that from 1,500 flaxseeds used in the control, 1,113 adult flies were obtained, thus indicating that the very high rate of 74 per cent of the flies survived the winter, parasitism, and other fatalities. Of the total number of flies emerging in the control, 601, or 54 per cent, were males, and 512, or 46 per cent, were females, in this case indicating a very fair degree of equality in the proportion of sexes. Another interesting point, although to be expected, is that of the recovery of the greater percentage of males in comparison with the females in each cage except the dark cage D. Excepting the cage C, there does not seem to be any choice indicated by the percentage of efficiency when the cages are run indoors.

A hygrothermograph was run in cage A, and temperature and humidity charts (Table II) were kept.

TABLE II.—*Temperature and humidity, La Fayette, Ind., March 15 to 24, 1920*

Date	Temperature			Humidity		
	Minimum	Maximum	Average[1]	Minimum	Maximum	Average[1]
	° F.	*° F.*	*° F.*	*Per cent*	*Per cent*	*Per cent*
Mar. 15	65	75	70.5	38	49	43.8
Mar. 16	60	72	65.8	35	40	38.4
Mar. 17	58	70	64.4	34	36	34.7
Mar. 18	58	68	64.2	36	39	37.5
Mar. 19	62	68	64.6	37	44	39.7
Mar. 20	58	74	68.1	35	38	36.2
Mar. 21	62	77	71.4	33	36	34.2
Mar. 22	65	77	71.1	33	37	35.[illegible]
Mar. 23	68	76	73.5	31	37	34.2
Mar. 24	69	78	72.4	36	44	40.6

[1] The average is the arithmetical mean of readings at 2-hour intervals.

THIRD TRIAL, LA FAYETTE, IND., APRIL 22 TO MAY 12, 1920

The third trial was made in the same manner as the second, with the two main exceptions that the cages were placed under natural conditions outdoors and arranged in a row, as shown in Figure 2, B. Flaxseeds for this trial were collected and kept under as nearly natural conditions as possible until placed in the cages. One thousand flaxseeds were placed in each cage and protected from the sun's rays by small canopies of cheesecloth over each box. The results obtained are as follows: Cage A, 78 females, 191 males, total 269; B, 74 females, 88 males, total 162; C, 20 females, 12 males, total 32; D, 130 females, 233 males, total 363; E, 49 females, 100 males, total 149; F, 39 females, 55 males, total 94; control, 524 females, 240 males, total 764.

Cage D is again indicated to be the most efficient, and it is unfortunate indeed that this cage should impose conditions which are further from natural conditions than those of any of the variously devised cages of the experiments. Although in this trial, as proved by the control, the emergence was heavy, the number of flies recovered by the cages falls far below the indoor records. From 1,000 flaxseeds of the control 764 flies were obtained, a yield of 76 per cent. This comes very close to the indoor record, which was 74 per cent.

Attempts at further trials of these cages on May 11 and again on June 18, 1920, were made by placing flaxseeds in refrigeration to retard their development until after the natural emergence had occurred in the field. For some reason a sufficient emergence was not obtained from these two lots of flaxseeds, and the scattering results will not be included.

Again, on September 15, 1920, another lot of flaxseeds was started in the cages, but owing to the freakish circumstance that adults emerged about 20 days later in the season than usual the number finally recovered by the cages was too small to give any data worth recording. In a faithful daily examination of the cages made throughout the period, it was discovered that ants were attacking and carrying away the flaxseeds; because of the unforeseen and extremely unusual delay in emergence, they were able to destroy quite a large number of them. This is a condition likely to occur whenever the cages are used, and it can not be considered other than a disadvantage.

DISCUSSION

Of a total of 38,500 flaxseeds used in these experiments, records were made on 17,500, from which one may expect 13,125 flies to have emerged, and of these 6,278 were recovered by the various cages. An additional 385 were recovered by the cages in the first trial, making a total of 6,663 flies recovered and counted during the experiment.

Probably the best arrangement of the information obtained in the preceding experiments, and one by which a comparison can be made for selection of a cage for any special purpose, is that of a tabulation of the relative efficiency of the cages used. Table III shows, on a percentage basis, the conditions in each cage as compared to natural conditions—the natural temperature, evaporation, and rainfall being taken as 100 per cent. Efficiency in recovering flies is shown by the average per cent recovered from the number reasonably supposed to have emerged in each cage. The results from the indoor trial were not included in this rating, since conditions under which this particular experiment was run were unique.

TABLE III.—*Cage efficiency, on percentage basis*

Cage	Temperature				Evaporation	Rain	Flies recovered
	Minimum	8 a. m.	12 m.	4 p. m.	8 a. m.	5 p. m.	
A	95	99	99	99	76	85	35
B	96	99	97	90	66	95	21
C	97	97	92	96	33	58	4
D	94	97	89	95	15	00	48
E	97	99	97	98	64	84	20
F	96	99	99	98	68	82	12
Control	100	100	100	100	100	100	100

It is found that cage A comes the nearest to being suitable for the determination of the date when flies are emerging in the field. For the actual recovery of flies, the dark cage D was the most efficient. For counting the flies, cages B, E, and F have their advantages, whereas cage C seems to be entirely impractical, as is shown in Table III.

PRACTICAL APPLICATION

A discussion of the use that has already been made of this information on emergence cages in investigations that have been conducted subsequent to those of cage development may be appropriate. The dark cage D has been the one adopted in most cases, and many unpublished data on various treatments of stubble as a fly control have been compiled. Although this may be said to be the primary purpose of these cage experiments, it was also desirable to have a cage for use at "emergence stations" in comparison with migration screens and egg counts, as has been described by Gossard and Eastwood (*4*), Gossard and Parks (*5*), and later at "observation stations" as described by Drake, Fenton, and Butcher (*3*). The dark cage has given very satisfactory results in both cases, and when properly manipulated under the immediate direction of a trained entomologist, serves as a good indicator of Hessian-fly emergence.

It might be well to discuss briefly the results of experiments with emergence stations and the part played by emergence cages, the detailed report of which will be published later. Such stations have been in operation at LaFayette, Ind., and Centralia, Ill., during the fall emergence of the fly for the years 1919 to 1923 inclusive, that at the latter location being under the immediate observation of W. B. Cartwright, of the Bureau of Entomology, United States Department of Agriculture.

After this rather extensive use of emergence cages, migration screens, egg counts, and flaxseed examinations, dependence is now placed almost entirely on egg counts and flaxseed examination to give the emergence records which are most closely associated with infestation of wheat. The reasons for this are the advantages of simplicity, high degree of responsiveness, economy, and accuracy. Many midges closely resemble Hessian flies in cages and on migration screens, whereas there is very little chance of mistaking anything for a Hessian fly egg. The flaxseed examination to determine the status of pupation proved to be a very important contribution to the emergence-station activities.

The results obtained by this series of emergence stations have certainly demonstrated their value in the scientific study of this phase of the life history of the fly. Confidence in the ability thus to predict the safe time to sow wheat any one year has not been experienced to nearly the extent that has been the case elsewhere. Without flaxseed examination, a peak of emergence may be obtained, but there is nothing to indicate that there may not be another peak. Even with the status of pupation determined by flaxseed examination, actual emergence must occur before it can be heralded as such. By the time complete pupation and emergence have been determined, the sowing date will have been delayed five to seven days longer than necessary, a very vital matter to the farmer with some sizable acreage to sow. If regular sowing time arrives and passes and still a large proportion of the fly remains in the larval stage in the flaxseeds, just what policy is to be adopted? There can be no assurance that such larvae will remain in that stage until the following spring. They may pupate the very next few days after the safe sowing date has been announced, and thus emerge at exactly the right time to do the most damage to young wheat. Such cases have occurred too

66850—25†——6

frequently (*2*, *6*), and during the last five years in the East Central States have constituted the only really serious factor affecting the reliability of sowing dates determined by observations over a series of years.

Moreover, in years of moderate infestation, when the wave of infestation is on the up-grade, but because of lack of parasites considerable menace exists, it will be extremely difficult, if not entirely impracticable, to find enough flaxseeds for examination. In actual practice, even in years of heavy infestation, when parasitism has been heavy but not sufficiently so to remove the fly menace, considerable difficulty has been met in getting satisfactory records, and in some cases it was not at all practical to get them. Entirely successful cases of emergence have been obtained, but these almost without exception, have occurred in regular years when the emergence fitted in quite nicely with the established and set series of dates.

It would seem, therefore, that the practical application of the emergence cage to Hessian-fly investigations is confined principally to life history and control studies of other than a predictive nature.

LITERATURE CITED

(1) American Association of Economic Entomologists.
1925. Index to the literature of American economic entomology January 1, 1905, to December 31, 1924. 3 v. Melrose Highlands, Mass.

(2) Cartwright, W. B.
1923. Delayed emergence of Hessian fly for the fall of 1922. Jour. Econ. Ent. 16: 432–435.

(3) Drake, C. J., Fenton, F. A., and Butcher, F. D.
1923. Hessian fly control in Iowa. Iowa Agr. Exp. Sta. Circ. 86, 11 p., illus.

(4) Gossard, H. A., and Eastwood, G. R.
1916. County cooperation to control Hessian fly. Ohio Agr. Exp. Sta. Mo. Bul. 1: 230–232.

(5) ——— and Parks, T. H.
1921. Hessian fly prevention. Jour. Econ. Ent. 14: 53–60.

(6) Larrimer, W. H.
1922. An extreme case of delayed fall emergence of Hessian fly. Ann. Ent. Soc. Amer. 15: 177–180, illus.

(7) Osborn, H.
1898. The Hessian fly in the United States. U. S. Dept. Agr., Div. Ent. Bul. 16, n. s., 58 p., illus.

(8) United States Department of Agriculture, Bureau of Entomology.
1889–1905. Bibliography of the more important contributions to American economic entomology. 8 pts. Washington, D. C.