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KANSAS STATE AGRICULTURAL COLLEGE
MANHATTAN, KANSAS

THE HESSIAN FLY IN KANSAS

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SUMMARY.

1. Since 1871 eight outbreaks of the Hessian fly have occurred in Kansas, each outbreak occupying from two to six years, and generally each more severe than the previous one. The fly now occurs in 82 counties in the state, and during the period from 1912 to 1917 its ravages on wheat caused a loss of at least *$55,000,000.*

2. The fly is distributed principally by the wind carrying the adults. Little danger is experienced in spreading the fly by the use of threshed straw as a top dressing for wheat.

3. The principal food plant of the Hessian fly is wheat, but it may develop on rye, barley, emmer, spelt, and several wild grasses.

4. Recent experiments indicate that certain varieties of wheat exhibit an apparent resistance to fly injury.

5. The principal injury due to the fly is caused by the second-stage larvæ feeding between the leaf sheath and the stalk. These larvæ suck the juices of the plant, depriving it of necessary food, and causing it to have a stunted appearance. Severe injury usually results in the death of the plant, or the latter is so weakened that the heads do not fill, and the straw may break over just before harvest.

6. The life cycle of the Hessian fly is extremely variable, ranging from 20 days to 49 months. While some variation occurs in the egg and larval stages, the greatest difference is noted in the flaxseed stage, where the extremes are 7 days and 1,461 days.

7. As many as five distinct broods may be present during the year, the number varying on account of such factors as temperature and moisture. These broods are known as the first spring brood, the second spring brood, the midsummer brood, the main fall brood, and the supplementary fall brood. During the period covered by this paper (1913-1917) the first and second spring broods and the main fall brood have been present each year, the midsummer brood was noted in 1915, and the supplementary fall brood in 1914, 1915 and 1916. Dry weather and low temperatures appear to be the limiting factors in the number of broods.

8. A study of the source of the various broods indicates that the adults of any generation may be the progeny of any brood of the previous two years; that no brood is complete in itself; and that some flaxseed always hold over to later generations.

9. A number of factors enter into the natural control of the fly. Some evidence is at hand to indicate that the structure of the plant has an important bearing on the successful development of the fly on the plant. Climatic conditions are also of great importance in the life economy of the fly. With the exception of the flaxseed stage, the fly is more or less susceptible to either high or low temperatures, low humidity, and a combination of high temperature and low humidity. The flaxseed, however, is able to withstand the greatest extremes of temperature and moisture recorded in Kansas.

10. Five parasites have been reared from flaxseed collected in the state, three species of which have been rather numerous each year. A summary of the field observations indicates that the parasites are only one factor in the biologic complex of the fly, and cannot be relied upon to effect a control.

11. There are several impractical methods of control which are revived by the farmers during every outbreak, such as rolling, pasturing, spraying, mowing, and planting trap crops. The futility of these measures is readily seen when they are associated with the life economy of the fly.

12. Among the measures of control that might be recommended under certain conditions are the intermittent growing of wheat, burning of stubble, planting resistant varieties, the use of fertilizers, and rotation of crops. Each of these has some merit under exceptional conditions, but should not be advocated for general practice.

13. A practical system of control has been developed for Kansas, based on a thorough study of the life history of the fly under various conditions encountered in the state. The important steps in this method of control are: (1) Early, deep plowing of the stubble; (2) proper preparation of the seedbed; (3) destruction of all volunteer wheat; (4) delaying the sowing until the fly-free date; and (5) cooperation.

TABLE OF CONTENTS.

THE HESSIAN FLY IN KANSAS.[1]

JAMES W. MCCOLLOCH.

During the 46 years that the Hessian fly *(Phytophaga destructor* Say) has been present in this state, but one bulletin has been published (Headlee and Parker, 1913) which treats of it from a Kansas standpoint. The last Hessian-fly outbreak, extending from 1912 to 1917, was the most severe yet experienced by the state, and a large amount of new and important data were secured which is herein discussed.

In a state like Kansas, producing an enormous wheat crop that may equal one-fifth of the total production in the United States,

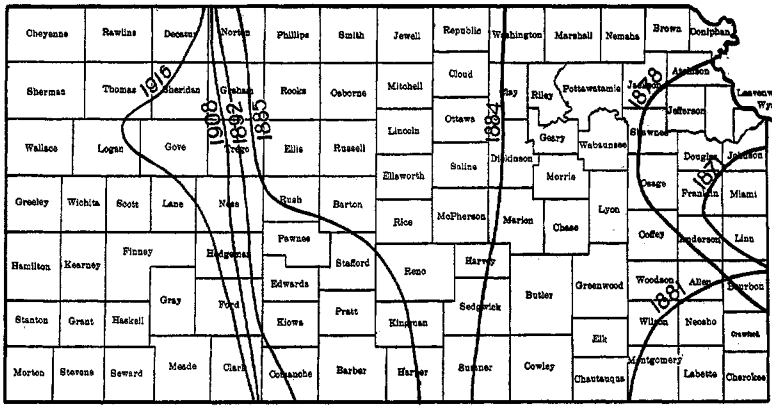

FIG. 1. Map of Kansas showing the westward spread of the Hessian fly.

as in 1914, the Hessian fly is a serious problem. Probably no other state suffers a loss from the fly equal to that of Kansas, where, in 1915, it amounted to $16,000,000.

HISTORY AND DISTRIBUTION.

The Hessian fly was first reported in Kansas in 1871, when it was found infesting wheat in a few of the eastern counties. Since that time it has gradually worked westward across the state (fig. 1), until at the present time it has been found in 82 of the 105 counties.

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1. Contribution No. 316 from the Department of Entomology. This publication was prepared in 1918 and reports the work on the Hessian fly at the Kansas Agricultural Experiment Station for the six-year period, 1912-1917, inclusive.

ACKNOWLEDGMENT.—The author wishes to acknowledge the kindly aid and criticism of Prof. Geo. A. Dean in conducting the experimental work and in the preparation of this bulletin. Various other members of the Department of Entomology have rendered valuable assistance at different times. Special credit is due Mr. H. Yuasa for his careful and painstaking studies of many points in the life history.

Beginning with the first outbreak in 1871, eight distinct periods of fly abundance have occurred, each period occupying from two to six years and generally covering a wider area (fig. 2) than the preceding one. The first appearance of the fly was apparently confined to a few counties in the eastern part of the state, the principal injury being reported from Linn and Franklin counties. The second outbreak began in 1875 and reached its maximum about 1878. The area of infestation in this case included that of the first outbreak and extended north to Atchison county and west to Osage county. In 1881 a small amount of injury occurred in southeastern Kansas, involving about nine counties. The first serious invasion of the fly into the state began in 1883 and reached its

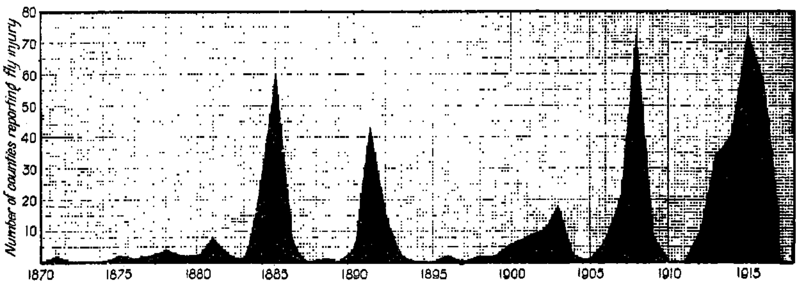


FIG. 2. Chart showing the number of Kansas counties reporting Hessian-fly injury each year, 1870-1917.

maximum in 1885, when 60 counties reported its presence. Snow (1885) in commenting on this outbreak says: "The most conspicuous entomological event of the year 1884 was the successful entrance within our borders of the far-famed Hessian fly." Some estimates of the loss to the wheat crop of 1884-'85 due to the fly are as high as 27 per cent of the crop.

The fifth outbreak began in 1889 and was at its height in 1891-'92. when 43 counties reported damage. The area of infestation seemed to be inclosed on the east by a line from the southeast corner of Nemaha county to the southeast corner of Sumner county, and on the west by a line from the northeast corner of Washington county to the northwest corner of Rush county and from the southwest corner of Rush county to the southwest corner of Harper county.

The sixth appearance of the fly was apparently of minor importance and was confined to the central part of the state. It began in 1899 and reached its maximum in 1902-'03. The records in this case with regard to the area involved and the amount of injury are meager.

The seventh period of abundance started in 1905 and reached its maximum in 1908. This outbreak was brought to a sudden termination in the spring of 1909 by a period of excessive dry, windy weather following the emergence and oviposition of the first spring brood. The area involved at this time included all the counties in the eastern three-fourths of the state, with the possible exception of a few counties in the northeastern part. Headlee and Parker (1913, p. 113) estimate that the fly reduced the crop of 1908 by at least ten million bushels.

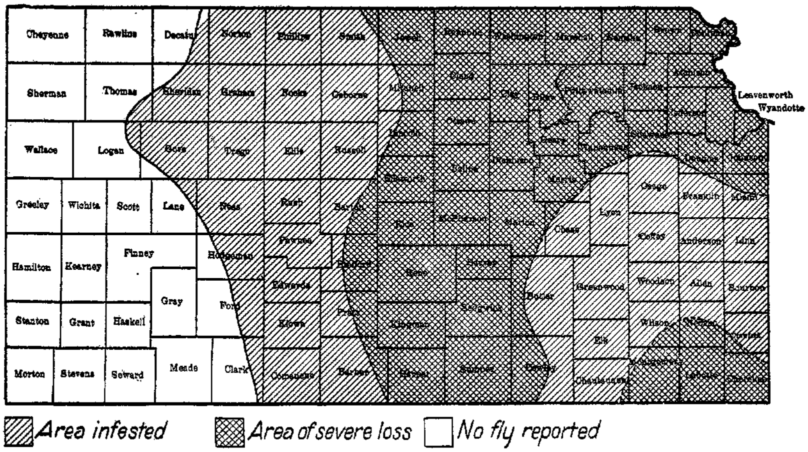


FIG. 3. Map of Kansas showing the area involved during the last outbreak of Hessian fly, 1912-1917.

The eighth and last appearance of the fly had its inception in 1911, when a few scattering reports of injury were received. This outbreak increased with great rapidity, and in 1915 the fly was reported in damaging numbers in 73 counties in the state. (Fig. 3.) This was the most disastrous outbreak yet recorded in the state, and a conservative estimate of the loss due to the fly during the years 1912 to 1917 is about $55,000,000.

DISPERSAL.

NATURAL.

The natural dissemination of the Hessian fly takes place by flight in the adult stage. The fact that migration does occur has long been recognized, but has been given little attention and apparently has not been taken into account in devising methods of control. Osborn (1898, p. 11), Marlatt (1900, p. 2), Roberts, Slingerland, and

Stone (1901, p. 256), Garman (1903, p. 220) , Webster (1902, p. 795), and Headlee and Parker (1913, p. 135), all mention the fact that the fly may be carried limited distances by the wind. The concensus of opinion, however, seemed to be that this migration did not exceed a mile, and then not in sufficient numbers to warrant any consideration. During the last few years this point has been given some study in Kansas, and it has been found that wind migration is of considerable importance. A preliminary report of these investigations has been published (McColloch, 1917), and a brief résumé of this paper is given here.

In one instance, at Paxico, flies were carried in sufficient numbers to heavily infest a field of wheat planted after the fly-free date on new wheat land located one and one-fourth miles from any fields of wheat or stubble. At McFarland the migration of flies from early-sown and volunteer wheat was so large as to heavily infest and greatly reduce the yields in fields prepared according to the most approved methods for the control of the fly. In both cases the diffusion was in a northeasterly direction and the wind at the time that the flies were abroad was from the southwest.

In order to gather more definite data on wind dispersal of the Hessian fly and the distance they are carried, observations were made on the number of flies caught on screens set up at varying distances from infested fields. The results of these observations show that the flies may readily be carried from two to five miles without any apparent injury. It is interesting to note that a large per cent of the migrating flies were females and that fertilization had taken place before flight.

The fact that fertilized females may be carried considerable distances by the wind has an important bearing on the control of the fly. It means that cooperation must be practiced over large areas, and that the individual grower cannot be promised immunity from injury even if he does prepare a good seedbed and sows late. It means that all stubble fields and volunteer wheat fields must be plowed under early in the fall, since they are the greatest sources of infestation.

ARTIFICIAL.

Distribution may also occur through the transportation and scattering of infested straw. In the life-history studies it has been found that the second spring brood of flies may infest the plant at any joint on the stalk as well as at the crown, and at harvest flaxseed may occur at any of these joints. In harvesting wheat, then, any flaxseed occurring above the first joint may be removed with the crop. The subsequent use of this straw for packing or as a cover on wheat land may aid in the distribution of the fly.

This point has been given considerable attention during the last few years. Counts of the number of larvæ and flaxseed found at the different joints have been made at various seasons of the year, and the pertinent data thus secured are given in Table I.

TABLE I.—Location of larvæ and flaxseed on the plant.

Date.	Place.	Number of larvæ and flaxseed.						Remarks.
		Crown.	1st joint.	2d joint.	3d joint.	4th joint.	Total.	
7- 4-'13......	Manhattan.....	10	101	......	......	......	111	Stubble.
11-11-'13......	McFarland.....	3	154	88	3	0	248	Stub le.
11-28-'13......	McFarland.....	8	525	282	4	0	819	Stubble.
12-10-'13......	McFarland.....	0	10	2	0	0	12	Stubble.
3-14-'14......	McFarland.....	0	124	33	0	0	157	Stubble.
4-13-'14......	McFarland.....	0	160	107	4	0	271	Stubble.
5- 9-'14......	McFarland.....	1,267	163	0	0	0	1,430	Regular crop.
5-13-'14......	McFarland.....	710	329	33	1	0	1,073	Regular crop.
5-18-'14......	St. Marys......	240	46	5	0	0	291	Regular crop.
5-19-'14......	Bern............	223	112	4	0	0	339	Regular crop.
5-21-'14......	Marysville......	367	119	11	0	0	497	Regular crop.
6- 9-'14......	McFarland.....	57	55	21	7	2	142	Regular crop.
6-22-'15......	Winfield........	179	303	214	682	146	1,524	Regular crop.
6-29-'15......	Wellington.....	62	179	101	40	0	382	Regular crop.
6-22-'16......	Newton.........	367	114	133	196	23	833	Regular crop.
	Totals.....	3,493	2,494	1,034	937	171	8,129	

This table shows that of 8,129 larvæ and flaxseed found, 5,987, or 73.6 per cent, occur at the crown and first joint, where they will not be disturbed in harvesting. At the second joint 1,034 larvæ and flaxseed, or 12.7 per cent, were found. These are often left in the stubble at harvest time. While the per cent of flaxseed removed in harvesting is small, it is of interest to know what becomes of them. Large amounts of threshed straw from badly infested fields have been examined without finding a single living flaxseed. Several bushels of the same straw have been placed in rearing boxes, but so far no flies have emerged. It seems that the process of harvesting, threshing, and stacking is destructive to the flaxseed remaining in the straw and that the possibility of distribution by transporting the straw is almost negligible.

It has been found also that the per cent of parasitism is often higher in the flaxseed occurring above ground, and that many of those removed in harvesting have already been killed by their natural enemies.

FOOD PLANTS.

Wheat is the principal food plant of the Hessian fly, although it is able to develop on a number of other plants. Occasionally injury is noticed on rye, barley, emmer, and spelt, but the fly does not thrive so well on these crops as it does on wheat.

A study of the number of eggs laid, and the number of flaxseed developing in a variety test of small grains conducted in 1916, gives the relative degree of infestation of the principal small grains. (Table II.)

TABLE II.—Average number of eggs and flaxseed per plant on the principal small grains (1916).

Grain.	Number of varieties in test.	Average number per plant.	
		Eggs.	Flaxseed.
Hard wheat	26	27.3	3.9
Soft wheat	40	19.6	1.7
Australia wheat	8	10.7	1.2
Spring durum wheat	1	4.1	.5
Einkorn	1	2.2	.0
Spelt	1	4.6	.5
Spring emmer	1	4.6	.0
Winter emmer	1	15.0	.1
Winter oats	1	.4	.0
Winter barley	2	1.7	.04
Rye	1	24.0	.0

During the winter of (1915-16) experiments were conducted under greenhouse conditions to determine the ability of the fly to develop on various small grains. In one series of tests about 12 plants were grown in a cage and several females were allowed to oviposit on the plants. Another series of experiments was conducted in which a female was allowed to deposit a few eggs on a single plant, and the plant was then isolated. The pertinent data are summarized in Tables III and IV.

TABLE III.—Summary of cage experiments with food plants.

Kind of plant.	Number of tests.	Number pupating.	Remarks.
Turkey wheat	29	98	Large numbers of eggs laid.
Illini Chief wheat	2	0	Large numbers of eggs laid.
Rye	5	80	Large numbers of eggs laid.
Barley	2	24	No adults emerged.
Oats	1	0	90 eggs laid on 11 plants.

TABLE IV.—Summary of the individual food plant experiments.

Kind of plant.	Number of plants.	Number of eggs laid.	Number pupating.	Per cent pupating.
Turkey wheat	182	1,012	191	18.8
Illini Chief wheat	24	288	24	8.6
Rye	6	26	3	11.5
Barley	5	24	15	62.5
Oats	21	120	0	.0

A field of rye growing on the agronomy farm was examined November 11, 1914, and 20 per cent of the plants were found to be

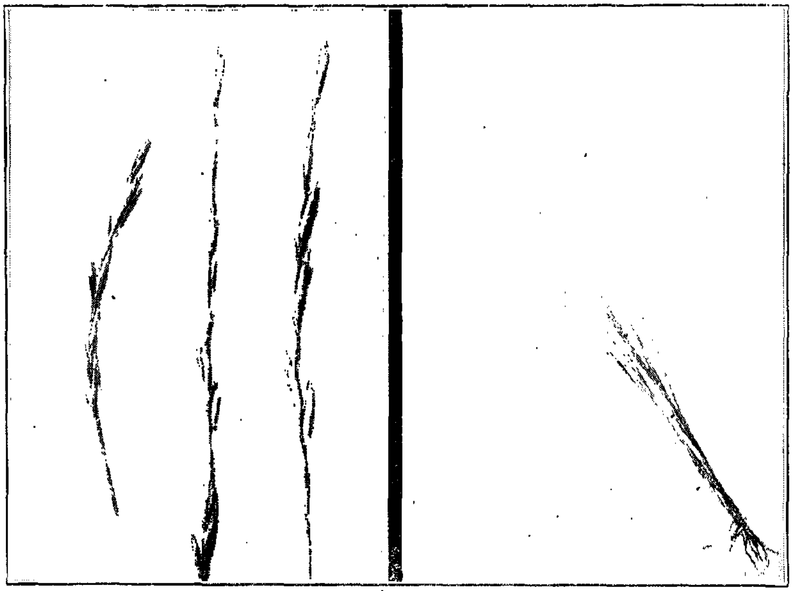


FIG. 4. Mature heads and young plant of couch grass (*Agropyron repens*).

infested by the fly. Another field of rye at McFarland had about 25 per cent of the plants infested.

Hendlee and Parker (1913, p, 94) cite an instance of the fly developing on *Agropyron smithii* at Wellington in 1908. During the season of 1914 all stages of the fly were found frequently on couch grass *(Agropyron repens)* and wild rye grass *(Elymus canadensis)* (figs. 4 and 5) at McFarland. In one instance flies bred in sufficient numbers in these grasses during the fall to seriously injure a late-sown field of wheat in the spring. Twenty-one adults were reared from a few clumps of rye grass collected at McFarland, April 3,

1916. Eggs have been found also on foxtail, einkorn, and Culberson winter oats, but repeated examinations have failed to show larvæ or flaxseed.

The period when food is present in the field has an important bearing on the number of broods and the methods of control. Marchal (1897) was able to rear six successive generations by planting plots of wheat about the time each generation should emerge. Osborn (1898, p. 21), in commenting on Marchal's work, says: "The

FIG. 5. Mature heads and young plant of wild rye grass (*Elymus canadensis*).

conditions necessary to such a continuaus series of broods are of course not present in nature."

The writer has watched this point in Kansas in order to determine the time food is present. In 1913, fields under observation at Manhattan and McFarland had no green wheat from the last of June to the middle of September. In 1914, green wheat plants were found in the field at Manhattan until June 25. Harvest occurred at that time and some volunteer wheat appeared about July 5. This grew to about two inches in height and then died during a period of dry weather. Volunteer wheat again appeared the last of August and food was present throughout the rest of the year. The following year, 1915, was an exceptionally wet year; and with the possible exception of the first week in July, wheat was present at all times.

SUSCEPTIBILITY OF DIFFERENT VARIETIES OF SMALL GRAIN TO FLY INJURY.

It has long been recognized that certain varieties of wheat are less susceptible to Hessian-fly injury than others. Packard (1883, p. 227) states that of the different varieties of "fly-proof" wheat, the Underhill variety has for nearly a century been highly recommended.

Devereaux (1878, pp. 376, 377) noted the abundance of Hessian fly when Clawson's, Soule's and similar wheats were raised. Lancaster and most of the red wheats were proof against fly injury.

Woodworth (1891) made some observations during 1886, 1887 and 1889 on the variation in Hessian-fly injury on 125 varieties of wheat grown at the California agricultural experiment station. He found Volo and Washington Glass to be the only varieties free from fly injury. Forelle; bearded wheat from Missoyen, Palestine; Blue grass; Polish; Diamond; Common March; and Egyptian Imported were practically free from injury.

Roberts, Slingerland, and Stone (1901, p. 252), in summarizing their observations in New York of fly injury on different varieties of wheat, draw the following conclusions: "The resisting power of varieties varies greatly. Those with large, coarse, strong straw are less liable to injury than weak-strawed and slow-growing varieties. There were at least six varieties grown in the state [New York] this season that were not appreciably affected by the fly, though numerous other varieties in the same neighborhoods were much injured. Of these only Dawson's Golden Chaff has been tested at the station, and this has been found to be a superior wheat for general culture. The other resistant varieties are Prosperity, No. 8, Democrat, Red Russian, and White Chaff Mediterranean." In the same paper (pp. 250, 251), however, they quote two cases where Dawson's Golden Chaff was seriously injured in Canada.

Gossard and Houser (1906, pp. 10-12) made careful observations on 76 varieties of wheat grown on the grounds of the Ohio agricultural experiment station during the years 1904, 1905 and 1906. In their work they determined the per cent of stalks infested and the per cent of fallen straws. In summing up their results they found that there was little support for the idea that there are so-called resistant varieties, and attributed apparent resistance to some other hypothesis.

Numerous other workers have noted the apparent resistance of some particular variety of wheat, but have not conducted investigational work to determine the degree of fly resistance.

Recent claims of resistance to fly injury put forth by growers of certain varieties of wheat, general observations by farmers in eastern and central Kansas, who claim that hard wheat is more susceptible to injury that the soft varieties, and experiments at the Kansas Agricultural Experiment Station, show that the subject is worthy of further investigation. Experiments have been outlined to determine (1) the relative infestation and injury of different kinds, varieties, and strains of various small grains; and (2) why certain kinds and varieties are resistant or immune, or if not, why they escape injury in some cases where others are badly injured. Considerable data have been secured on the first point, and a preliminary report has been published (McColloch and Salmon, 1918). The data are here summarized (Table V) to show the number of eggs laid on each variety and the subsequent infestation.

TABLE V.—Number of eggs laid on different varieties and the subsequent infestation.

Variety (a).	Kind.	Total number eggs on 20 plants.	Total number flaxseed on 100 plants.	Average number per plant.	
				Eggs.	Flaxseed.
King's Early	Common white wheat	161	183	9.4	1.8
Bunyip	Common white wheat	116	123	5.8	1.2
Bobs	White spring wheat	89	114	4.4	1.1
Hugenot	Durum wheat	24	34	1.2	.3
Cleveland	Durum wheat	28	118	1.4	1.2
Cedar	Hard red wheat	119	68	6.0	.7
Indian Runner	Durum wheat	43	28	2.1	.3
Tuscany solid straw	Common white wheat	128	157	6.4	1.6
Kubanka	Durum wheat	22	35	1.1	.3
Marquis	Hard red spring wheat	72	71	3.6	.7
Poulard wheat		116	35	5.8	.3
Polish wheat		102	46	5.1	.5
Einkorn		14	0	.7	.0
Spelt		48	55	2.4	.5
Spring emmer		38	0	1.9	.0
Winter emmer	Black winter	101	144	5.0	1.4
Culberson	Winter oats	2	0	.1	.0
Tennessee barley	Winter barley	11	1	.5	.0
Michigan barley	Winter barley	8	13	.4	.1
Rye		129	0	6.4	.0
Kanred	Hard red winter wheat	110	140	5.5	1.4
Crimean select	Hard red winter wheat	271	124	13.5	1.2
Turkey	Hard red winter wheat	303	258	15.1	2.5
German	Soft red winter wheat	82	71	4.1	.7
Malakof	Hard red winter wheat	161	172	8.0	1.7
Jones Winter Fife	Soft red winter wheat	244	55	12.2	.5
Kharkof	Hard red winter wheat	144	280	7.2	2.8
Ghirka	Hard red winter wheat	123	157	6.1	1.5
Turkey	Hard red winter wheat	249	191	12.4	1.9
Turkish Type	Hard red winter wheat	96	158	4.8	1.5
Mealy	Soft red winter wheat	207	165	10.3	1.6
Malakof	Hard red winter wheat	192	219	9.6	2.1
Turkey Hybrid	Hard red winter wheat	94	289	4.7	2.9
Pesterboden	Hard red winter wheat	86	203	4.3	2.0
Beardless Hard Winter	Hard red winter wheat	134	60	6.7	.6
1443 Kharkof	Hard red winter wheat	93	121	4.6	1.2
Turkey	Hard red winter wheat	165	151	8.2	1.5
Turkey	Hard red winter wheat	116	173	5.8	1.7
Hard Red Winter	Hard red winter wheat	95	171	4.7	1.7
Bearded Fife	Hard red winter wheat	116	185	5.8	1.8
Red Winter	Hard red winter wheat	101	285	5.0	2.8
Alberta Red	Hard red winter wheat	124	228	6.2	2.3
Defiance	Hard red winter wheat	143	268	7.1	2.7
Defiance	Hard red winter wheat	71	158	3.5	1.6
Red Winter 2132	Hard red winter wheat	154	30	7.7	.3
Champanka	Hard red winter wheat	144	141	7.2	1.4
Red Hussar	Soft red winter wheat	67	93	3.3	0.9
Hungarian	Hard red winter wheat	115	103	5.7	1.0
Nigger	Soft red winter wheat	119	17	6.0	.2
Fulcaster	Soft red winter wheat	106	19	5.3	.2
Beechwood Hybrid	Soft red winter wheat	86	3	4.3	.1
Miracle	Soft red winter wheat	96	12	4.8	.1
Marvelous	Soft red winter wheat	172	59	8.6	.6
Washington Hybrid	Hard red winter wheat	65	73	3.2	.7
Binkel	Hard red winter wheat	93	161	4.6	1.6
Michigan Bronze	Soft white winter wheat	85	15	4.2	.2
Improved Turkey	Hard red winter wheat	77	201	3.8	2.0
Bucanera	Soft red winter wheat	63	246	3.1	2.5
North Allerton	Soft red winter wheat	100	150	5.0	1.5
Currell P. 1092	Soft red winter wheat	114	3	5.7	.1
Harvest Queen	Soft red winter wheat	74	42	3.7	.4
Harvest Queen	Soft red winter wheat	98	44	4.9	.4
Alabama Bluestem	Soft red winter wheat	91	184	4.5	1.8
Hybrid	Soft white wheat	53	24	2.6	.4
Hybrid	Soft white wheat	94	46	4.7	.5
Valley	Soft red wheat	43	8	2.1	.1
Rudy	Soft red winter wheat	65	6	3.2	.1
Dawson's Golden Chaff	Soft white winter wheat	159	3	8.0	.1
Dietz	Soft red winter wheat	191	15	4.5	.2

TABLE V.—*Concluded.*

Variety (a).	Kind.	Total number eggs on 20 plants.	Total number flaxseed on 100 plants.	Average number per plant.	
				Eggs.	Flaxseed.
Currell Prolific	Soft red winter wheat	84	38	4.2	.4
Bearded Purple Straw	Soft red winter wheat	121	23	6.0	.2
Gipsy	Soft red winter wheat	100	157	5.0	1.6
Jersey Fultz	Soft red winter wheat	72	71	3.6	.7
Hybrid	Soft white winter wheat	93	87	4.6	.9
Hybrid	Soft white winter wheat	97	90	4.8	.9
Hybrid	Soft white winter wheat	116	52	5.8	.5
Washington Hybrid	Soft white club wheat	93	53	4.6	.5
Illini Chief	Soft red winter wheat	118	0	5.9	.0
Zimmerman	Soft red winter wheat	67	207	3.3	2.1
Sibley New Golden	Soft red winter wheat	113	202	5.6	2.0
Fultz	Soft red winter wheat	99	132	5.0	1.3
Currell	Soft red winter wheat	54	65	2.7	.7
German Emperor	Soft red winter wheat	90	298	4.5	3.0
Deihl Mediterranean	Soft red winter wheat	106	48	5.3	.5
Deihl Mediterranean	Soft red winter wheat	95	40	4.7	.4
Poole	Soft red winter wheat	41	133	2.0	1.3

(a) The varieties are given in the order in which they occurred in the field.

The following conclusions are to be drawn from the data presented in Table V:

Eighty-seven varieties of small grains, principally wheat, grown under practically identical conditions, showed a marked difference in the degree of Hessian fly infestation.

With the exception of Hugenot, Cleveland, Kubanka, Einkorn, winter oats and winter barley, eggs were found in large numbers on all varieties. The data indicate that adult flies are capable of distinguishing between wheat and oats, barley and einkorn in ovipositing, and that they also show a slight preference for hard wheat.

An examination of 100 plants of each variety showed that certain varieties escape with practically no infestation, while other varieties were heavily infested. Einkorn, spring emmer, Culberson winter oats, rye, and Illini Chief were entirely free from infestation. Twelve varieties, namely, Tennessee winter barley, Michigan winter barley, Nigger, Fulcaster, Beechwood Hybrid, Miracle, Michigan Bronze, Currell P. 1092, Valley, Rudy, Dawson's Golden Chaff, and Dietz were only slightly infested. Other varieties having a small number of fiaxseed were: Hugenot, Indian Runner, Kubanka, Poulard, Red Winter 2132, Currell Prolific, and Bearded Purple Straw. The standard varieties of hard wheat showed a much higher infestation than did the standard varieties of soft wheats.

There was no correlation in most cases between the number of eggs deposited on a variety and the subsequent infestation. Varieties bearing few eggs often had a large number of flaxseed, while other varieties bearing a large number of eggs had a light infestation.

The data for rye, Illini Chief, and Dawson's Golden Chaff are especially significant, in view of the fact that large numbers of eggs were deposited on each. The low infestation of Red Winter No. 2132 is also worthy of mention. Illini Chief has been grown in field tests since 1914, and in every case has had practically no infestation. It is a high-yielding variety of soft wheat, but is not adapted to the hard-wheat section of Kansas.

The variety tests were repeated again in the spring of 1917, using the same varieties mentioned in Table V. While the fly infestation was not as great as in the preceding experiment, the results were in accord with those obtained in the fall.

CHARACTER OF INJURY.

The injury caused by the fly is due almost entirely to the feeding of the second-stage larvæ between the leaf sheath and the stalk. During the feeding period of the larvæ they suck the juices from the plant, thus depriving it of the necessary food for a healthy growth. The injury in the fall is characterized by the stunted appearance of the plant and the failure of the central stalk to develop. At first the infested tiller has a deeper color, the leaves appearing broader and somewhat shorter. As the injury increases the tiller loses its green color, and by the time the larvae have completed their growth it may be dead. (Fig. 6.)

(Adapted from Webster.)

FIG. 6. Plant at left infested by Hessian fly. Plant at right not infested by Hessian fly.

FIG. 7. Wheat plants heavily infested with larvæ and flaxseed of the Hessian fly.

The spring broods attack the plants in much the same manner as do the fall broods, but the effect on the plant may be different. If the injury occurs early in the spring the plant may show the same type of injury as in the fall. In most cases, however, the plant has begun to joint and the larvæ may attack it either at the crown or at any of the joints. The plant is stronger and the stem contains more fiber, as a result of which growth continues except at the point of contact with the larva. Development apparently ceases at this point and the rest of the plant grows around it, forming a cell the size of the larva.

As the plant grows it may become so weakened at the place where the fly is developing that it may break over before harvest. In many cases the infested straw does not produce a plump head, but instead the head may fail to fill out or may contain shriveled grain. The heads may appear white, as if blasted, about harvest time, although this characteristic may be due to the attacks of other insects.

The number of larvæ developing on a plant has considerable influence on the amount of injury. The presence of only one or two larva may not seriously injure the plant, but where more occur the injury becomes severe. During the years 1914 and 1915 the number of larva and flaxseed found on a plant was often very large. A field examined at McFarland in June, 1914, had an average of about 30 flaxseed per plant, and many of the plants contained as high as 80 larvæ and flaxseed. (Fig. 7.) Table VI gives some of the more striking cases of heavy infestation.

TABLE VI.—Number of larvæ and flaxseed per plant.

Place.	Date.	Number of plants infested.	Number per plant.		
			Average.	Maximum.	Minimum.
Holton	10- 6-'13	13	10.7	33	4
Toronto	11- 8-'13	19	11.9	21	5
Reno	11-12-'13	119	12.3	39	1
Reno	11-12-'13	13	14.0	29	5
McFarland	11- 6-'13	133	17.2	48	1
Marysville	5-21-'14	25	19.8	47	4
McFarland	5- 9-'14	25	21.5	46	3
McFarland	6- 9-'14	25	29.6	80	5

In addition to the direct injury due to the presence of the larvæ the plant may become so weakened as to be susceptible to disease, In a badly infested field examined at McFarland in the fall of 1914, it was noticed that every infested plant was also heavily covered with the orange leaf rust. Plants containing no flies had little or no rust present. (Fig. 8.)

FEEDING.

It is not definitely known whether the larvæ are capable of feeding before they reach the base of the plant, although it seems to be the feeling among entomologists that they do not. Enoch (1891, p. 334), however, states that "the larva increases in width even before it disappears out of sight, leading one to suppose that it imbibes moisture as it journeys down the furrows of the leaf." He also states that he has kept newly hatched larva alivæ for eight

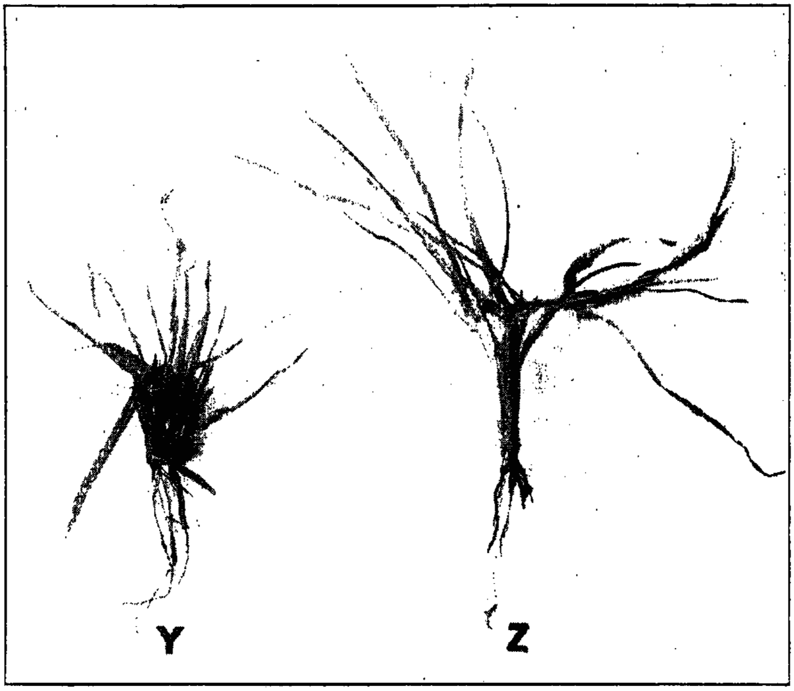


FIG. 8. Comparison of two wheat plants growing side by side in a general field at McFarland. (Y) Heavily infested with fly and leaves covered with orange leaf rust. (Z) Not infested with fly and no rust apparent.

days on blotting paper moistened with starch water. During April, 1913, the writer carried on some experiments to determine whether newly hatched larvæ could be kept alive in water. One larva lived 71 hours in a drop of tap water in a Barber's chamber. Of 75 larvæ submerged in a glass of tap water, 50 per cent lived 56 hours, 20 per cent lived 70 hours, and 1 per cent lived 77 hours. In a third experiment a wheat leaf bearing seven eggs was submerged in water and observations were made on the larvæ as they hatched. Four of these larvæ lived 96 hours, two lived 106 hours, and one lived 123 hours. In each experiment the larvæ showed an appreciable increase in size.

The principal feeding occurs in the second larval stage, when growth and develpment are taking place. In this stage the head is retracted on the ventral side so that the mouth parts are in direct contact with the stem of the plant. The food consists principally of plant juices obtained by rasping the stalk and then sucking the juice, Enoch (1891, p. 336) states that the juices are taken in by a sort of pumplike motion.

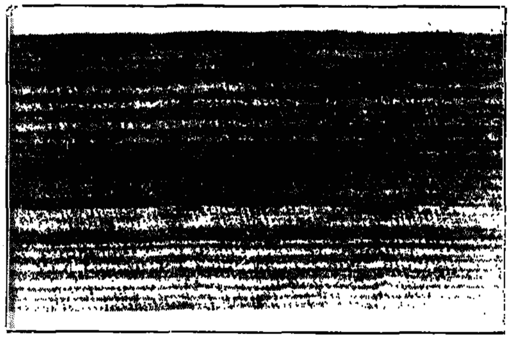
It is doubtful if food is required by the adult fly. In one case in the life-history work a female was observed with her mouth parts in a drop of water. This is the only indication of the adult feeding that has come to the writer's attention. Sweetened water and tap water have been supplied in many of the adult cages, but in no instance was there any appreciable difference in the length of the adult life or in oviposition.

DESCRIPTION AND LIFE HISTORY.

EGG.

DESCRIPTION.

The egg of the Hessian fly (fig. 9) is very minute, being from 0.40 to 0.50 mm. in length, cylindrical, obtusely rounded from ends,



(After Headlee and Parker.)

FIG. 9. Eggs of Hessian fly in natural position on wheat blade. (Magnified about eight times.)

glossy, translucent, and pale yellowish red. This color deepens with the development, so that just before hatching it is distinctly reddish. About the second day after deposition the posterior end of the egg becomes opaque and shows no reddish content. This is very characteristic of the fertilized egg, since the caudal extremity of the embryo is located in this end.

HATCHING.

The exact method whereby the maggot breaks the eggshell has not been definitely ascertained. The shell seems to split along its cephalo-dorsal aspect, and the larva emerges quickly. As the larva leaves the egg it turns sidewise, describing an arc, and finally orients itself in the direction exactly opposite to that in which it had been within the egg. (Fig. 10.) Enock (1891, p. 333) found that the movements of the inclosed larva could be distinctly seen on the third day, and on the fourth day he was able to distinguish

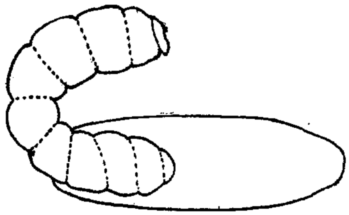


FIG. 10. Larva of Hessian fly leaving the egg.

the muscular efforts of the maggot to burst open the shell, which it succeeded in doing after three or four hours' work.

LENGTH OF STAGE.

The length of the egg stage varies considerably with different temperature and moisture conditions. At Manhattan this variation has been from 3 to 12 days. Under field conditions, 1,318 eggs hatched in an average of 4.8 days, with extremes of 4 and 12 days. When the eggs were held under a constant temperature of 70° or 85° F. and humidity was reduced much below 65 per cent, the egg stage was prolonged and many of the eggs failed to hatch. Moisture is apparently essential for the hatching of the eggs. Tables VII to IX summarize the experiments conducted to determine the length of the egg stage.

TABLE VII.—Length of egg stage under field conditions. (Screen insectary.)

Number of eggs.	Date.		Length of stage, days.	Mean temperature, degrees F.
	Laid.	Hatched.		
15	4-20-'13	4-24-'13	4	68
158	6- 1-'13	6- 6-'13	5	74
344	6- 3-'13	6- 7-'13	4	72
364	6- 6-'13	6-10-'13	4	62
294	6-19-'13	6-24-'13	5	76
8	10-21-'15	10-29-'15	8	60
3	10-21-'15	10-30-'15	9	60
72	10-22-'15	10-28-'15	6	61
2	10-22-'15	10-29-'15	7	61
58	10-22-'15	11- 3-'15	12	60

TABLE VIII.—Length of egg stage under constant temperature conditions.

Number of eggs.	Date.		Length of stage, days.	Constant temperature, degrees F.
	Laid.	Hatched.		
10	3-31-'15	4- 3-'15	4	85
25	4- 1-'15	4- 4-'15	3	85
32	1-21-'16	1-24-'16	3	85
8	1-21-'16	1-24-'16	3	70
3	1-21-'16	1-25-'16	4	64
50	1-22-'16	1-25-'16	3	70
15	1-28-'16	2- 1-'16	4	70
45	1-28-'16	1-31-'16	3	85

TABLE IX.—Length of egg stage, life history studies. (Plant series, 1916.)

Kind of plant.	Number of eggs.	Length of stage, in days.			Constant temperature, degrees F.
		Maximum.	Minimum.	Average.	
Turkey wheat	115	6	3	3.3	70
Illini Chief wheat	17	4	3	3.1	70
Rye	1	3	3	3.0	70
Barley	2	3	3	3.0	70

MORTALITY OF EGGS.

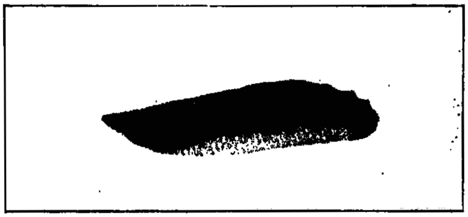
The mortality of eggs under field conditions was determined during April, 1913. Of 10,745 eggs under observation, 1,819, or 16.9 per cent, failed to hatch. In all probability many of these were infertile. Of the second spring brood in 1913, 1,772 eggs were under observation, and 218, or 12.3 per cent, failed to hatch. In a lot of 175 eggs under constant conditions of 70° temperature and 70 per cent humidity, 24 failed to hatch.

LARVA.

DESCRIPTION.

Marchal (1897) recognizes three larval stages, namely, the migrating larva, the feeding larva, and the enclosed larva. In the work at this station these were the only forms recognized, although the second stage may be divided by at least one molt. One larva hatching June 7, 1913, was removed from the plant June 16, and on being examined under the microscope was observed to be molting.

The migrating larva is about the same size and color as the egg. Seven larvæ that had just reached the base of a plant were removed and measured. The average length was found to be 0.88 mm., and the average width 0.18 mm. The body is composed of 13 segments, including the head, and on the ventral part of the anterior end there are two rudimentary appendages or tentacles. The mouth parts consist of a notched, crescent-shaped plate with short palpi on each side. The anal segment is somewhat emarginate, the two lobes bearing what appear to be suckers or prehensile feet.



(After Headlee and Parker.)

FIG. 11. Second larval stage of Hessian fly. (Magnified about eight times.)

The second larval stage, or feeding stage (fig. 11), is attached to the stalk with the head downward. The red color disappears and the body becomes white with a greenish tinge in the body cavity, due to the juices derived from the host plant. The body is rather densely covered with minute glossy spines. There are 13 segments in the body, the first segment or head being small and retracted ventrally. The body is bluntly rounded at the anterior end and tapers toward the posterior end. There is a slight emargination at the posterior end of the anal segment. When full grown the larvæ are from 3.5 to 5.5 mm. in length and about 1 mm. in width.

The enclosed larva, or third larval form, occurs when the larva reaches its full growth and ceases feeding. The body of the larva contracts from the old larval skin, which hardens and becomes the puparium or flaxseed. The maggot now undergoes a number of interesting changes, chief of which is the development of the "breastbone" or "anchor process" on the ventral side between the first and second segments. This organ is used by the larva to assist in reversing its position before pupation. There is little change in this stage from the preceding one, except that the body is a little shorter and has a more bluntly rounded form. The integument is minutely spinose, and there are two protuberances caudal to the opening.

GROWTH.

Owing to the fact that the larva lives between the leaf sheath and the stalk, it is difficult to follow its development. In 1913 an attempt was made to determine the rate of growth under field conditions. Several cages of wheat were isolated and a number of females were allowed to oviposit on these plants for a period of two hours. These plants were then pulled at intervals of a few days and the larvæ measured, the average length of the larvæ being shown in Table X.

TABLE X.—Rate of growth of larvæ.
(June, 1913.)

Age of larvæ.	Average length.	Remarks.
1 hour	0.7 mm.	....
3 days	1.5 mm.	....
7 days	2.0 mm.	....
9 days	2.5 mm.	....
11 days	3.5 mm.	....
15 days	4.2 mm.	Forming puparia.

MOLTS.

The exact number of molts has not been definitely worked out, but there are at least three. The first molt occurs shortly after the larva reaches its feeding place between the leaf sheath and the stalk. A true molt was observed in a larva that was nine days old, and another molt occurs at the time of the formation of the puparium.

The process of molting was observed in one instance when a larva which had been removed from the food plant was placed under the microscope. It was noticed that the larval skin was loose and the inclosed larva had contracted slightly. Shortly afterward the skin was seen to be split on the anterior dorsal part and partly rolled back. Then by repeated contractions and expansions, the larva slowly worked the old skin backward, finally freeing the posterior end.

The freshly molted larva is flat dorsoventral, and is about three times as long as broad. The body is slightly translucent, with well-marked regions of adipose tissue on both sides of the median plane from the second to the tenth segments. Another chain of whitish spots lies ventral to the digestive tract on the median line between the third and eighth segments. The entire body is covered with short, glossy spines. After molting the larva expanded and contracted ventrally, but not dorsally, and at the same time there was a lateral expansion. The newly molted larva was twice as wide and one and one-half times as long as it was previous to molting.

MIGRATION.

The migration of the Hessian-fly larva from the place where it hatches on the leaf to its feeding place between the leaf sheath and the stem is one of the most critical periods in the life of the insect. Packard (1883, p. 213) makes the statement that "as soon as the footless larva or maggot hatches, it makes its way down the leaf to the base of the sheath." This brief statement has been accepted by most of the writers on the fly. Enock (1891, pp. 333-334) noted that the larva moved up or down the leaf, depending on the position of the female in ovipositing. Gossard and Houser (1906, p. 4) report that they had difficulty in making the larvae ascend a slope of about 45 degrees. Headlee and Parker (1913, pp. 95-96) suggest that the maggots are assisted by the dew in their migration down the leaf.

Owing to the meager information on this point and the importance of the subject, it was investigated rather thoroughly in 1915. A report of the results has been published (McColloch and Yuasa, 1917) and a brief summary is given here. The position of the Hessian-fly egg on the leaf is determined by the position of the female in ovipositing, a subject which will be discussed in a later paragraph. As has already been mentioned, the maggot on hatching describes an arc and orients itself in a position exactly opposite to that occupied in the egg. The direction of migration is therefore predetermined by the orientation of the egg, and the larva on hatching always turns toward the posterior end of the egg, and this is the direction of progress. When the eggs are laid with their anterior end toward the tip of the leaf, the larva on hatching turn toward the base of the leaf and migrate directly to their feeding place. Conversely, if the eggs are laid with their anterior end toward the base of the leaf, the larvae on hatching turn toward the tip of the leaf. They crawl up the leaf to its extremity and then turn and move downward to the base of the leaf. The degree of inclination of the leaf has nothing to do with the direction of larval migration, and the larvæ are capable of ascending or descending an incline of anywhere between zero and 90 degrees.

The rate of migration is extremely variable and seems to be influenced by individual differences rather than physical factors. The average time required by 205 larvae hatching from eggs laid with their anterior end toward the tip, to move one millimeter was about 4½ minutes, with extremes of one-half minute and 75 minutes. The average time required by 119 larvae, hatching from eggs deposited with their anterior end toward the base, to move one millimeter was about 3½ minutes, with extremes of two-fifths of a minute and 46 minutes.

The mortality of migrating larvæ is greatest when the eggs are laid with their anterior ends towards the base of the leaf. Of the larvæ hatching from such eggs, 57 per cent died during migration, while only 23 per cent of the maggots from eggs deposited with the anterior end toward the tip perished. When the eggs are laid with the anterior end toward the tip, the mortality increases with the distance of the egg from the ligule. When the anterior end is toward the base of the leaf the mortality increases with the distance of the egg from the tip.

LENGTH OF LARVAL STAGE.

Owing to the fact that the larvæ are concealed between the leaf sheath and the stalk during the greater part of their life, and also to the fact that the third larval stage is passed within the puparium, it has been difficult to work out the length of this stage. The first larval period nominally occupies a very short time, ranging from a few hours to a day or two. This period represents the time between hatching and the establishment of the larva at the base of the leaf, or the migratory period, and observations made on over 300 larvæ indicate that this stage occupies from 12 to 25 hours. The second larval stage, or the feeding stage, varies from about two weeks to several months. Under a constant temperature of 70° F. and a constant humidity of 70 per cent, the second larval stage occupied an average of 11.4 days, with extremes of 9 and 17 days. During the spring months it varied in the field from two to three weeks, with an occasional larva requiring a month. The fall brood usually has a feeding period of four to six or eight weeks, owing to the cooler weather, and it sometimes happens that cold weather overtakes these larvae before they transform to the flaxseed. This often results fatally for the larvæ, but in many cases they are able to survive the winter as naked larvæ In one case full-grown larvae were found rather numerous in plants collected at Marysville on February 24, 1916. These larvae came from eggs laid the last of September or the first of October, since there was no supplementary fall brood. They were placed in the field insectary and transformed to flaxseed about the last of March. In this case the second larval stage was at least six months. The mean temperature from October 1 to February 24 was 39° F. with extremes of 84° F. and -16° F.

The length of the third larval stage *is* subject to even greater variation. The fact that this stage is contained within the flaxseed has rendered it difficult to determine accurately the exact length, but all the data thus far secured indicates that the transformation to the pupa does not occur until shortly before emergence. On this assumption, the third larval stage varies from about two days, under a constant temperature of 70" F. and humidity of 70 per cent, to about three years under rearing box conditions.

A summary of the rearings made during the past few years indicates that the entire larval stage varies from about 11 days to 1,100 days. Table XI shows the length of the first and second larval stages when reared under constant conditions of temperature and moisture.

TABLE XI.—Period from hatching to the formation of the puparia.
(Temperature 70° F. and relative humidity 70 per cent.)

Kind of plant.	Number of larvæ.	Length of stage, in days.		
		Maximum.	Minimum.	Average.
Turkey wheat	115	17	10	11.9
Illini Chief wheat	17	19	10	13.4
Rye	1	10	10	10.0
Barley	2	10	10	10.0

MORTALITY OF LARVÆ

Of 904 larvae handled during June, 1913, in the field insectary, 37, or 4.1 per cent, died between the time of hatching and the formation of the puparia.

It has been pointed out also that under constant conditions of temperature and moisture 23.4 per cent of the larvæ coming from eggs deposited normally died while migrating. When the eggs were laid in an inverted position, 57.1 per cent perished.

PUPARIUM.

DESCRIPTION.

The puparium or flaxseed (figs. 12 and 14) is reddish brown or dark brown in color. It is spindle-shaped and varies in length from 2.5 to 6.2 mm., the average being about 4 mm. The anterior end is bluntly rounded, while the caudal end is slightly emarginate. Transverse markings indicating the segments of the larval stage

(After Headlee and Parker.)

FIG. 12. Hessian-fly puparia in natural position on a wheat plant.

are present, but very indistinct. In shape and color the puparium closely resembles a flaxseed, and hence the name. It is in this stage that most of the wheat growers are best acquainted with the fly, although many think that the flaxseed is an egg, from which will hatch a larva. They do not realize that an adult fly will issue from it, which may deposit enough eggs to produce two or three hundred larvæ.

CHANGES WITHIN THE FLAXSEED.

The flaxseed period involves two stages—the enclosed larva and the pupa. There are a number of interesting changes which take place within the puparium. The flaxseed is formed by the body of the larva contracting and drawing away from the old larval skin. This is followed by the formation of the breastbone on the ventral side of the thoracic region of the larva. The larva, which has been resting head downwards, now reverses its position, the breastbone aiding in this process. In three cases out of several thousand this reversal in position did not occur. This change in position is then followed by the formation of the pupa, which in turn transforms to the adult.

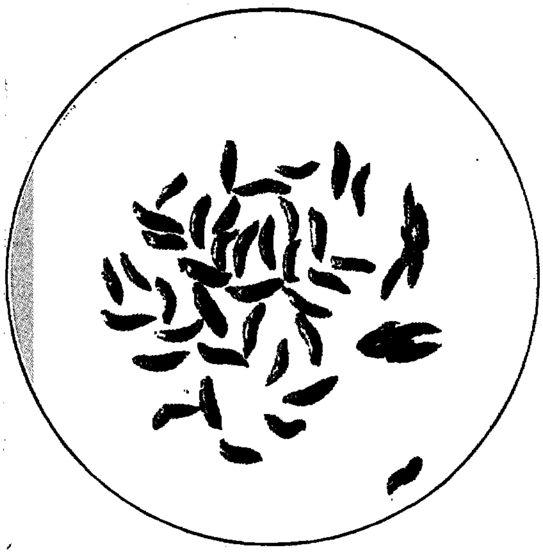


FIG. 13. Abnormal flaxseed.

ABNORMAL FLAXSEED

The puparia may often be formed before the larvæ become full grown, due to a lack of food, or adverse weather conditions, such as drought or cold. These premature puparia are capable of producing adults, as was shown during the winter of 1913-'14, when 18 such puparia gave up 4 adults. These adults were small in size, but behaved normally and reproduced. During years of heavy fly infestation there may be so many flaxseed formed at a single joint as to crowd each other and cause many of them to be greatly deformed. (Fig. 13.) In some cases the writer has found as high as

80 flaxseed at one joint in the field. In 1913, 62 deformed puparia produced 46 adults, most of which were normal in every respect except that they were small.

SIZE OF PUPARIA.

There is a great variation in the size of the puparia, ranging from 2.5 to 6.3 mm. (Fig. 14.) In order to determine whether there is any relation existing between size and vitality and sex, a number of flaxseed of various sizes were isolated for observation. Table XII gives the pertinent data secured in this experiment.

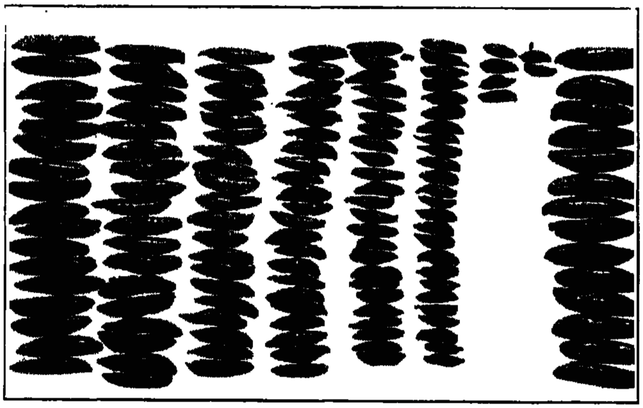


FIG. 14. Hessian-fly puparia, showing variation in size.

TABLE XII.—Relation between size of puparia and vitality and sex.

Length of puparia.	Number of puparia.	Number adults emerging.			Per cent emerging.	Relation of sexes.	
		Female.	Male.	Total.		Per cent females.	Per cent males.
6.2 mm.....	14	4	0	4	28.5	100	0
6.1 mm.....	14	4	0	4	28.5	100	0
6.0 mm.....	16	9	0	9	56.2	100	0
5.8 mm.....	16	9	1	10	62.5	90	10
5.5 mm.....	15	3	0	3	20	100	0
5.2 mm.....	30	9	2	11	36.6	81.8	18.2
4.5 mm.....	34	11	11	22	67.6	50	50
4.0 mm.....	46	12	5	17	37	70.6	29.4
3.8 mm.....	37	6	5	11	29.7	54.5	55.5
3.6 mm.....	59	8	13	21	35.5	38.1	61.9
3.2 mm.....	25	2	0	2	8	100	0
3.0 mm.....	12	1	5	6	50	16.6	83.4
2.7 mm.....	4	0	0	0	0	0	0
2.5 mm.....	2	0	0	0	0	0	0

The data indicate that flaxseed 4 millimeters and over in length produce mostly females, while the smaller ones produce males.The per cent of adults emerging indicates that size has little effect on the vitality.

LENGTH OF THE FLAXSEED STAGE.

The length of the flaxseed stage is of great importance, since it is in this stage that most of the flies withstand extreme conditions, as excessive heat and drought of summer and prolonged cold of winter. There are relatively few data on the length of this stage although several workers have found that the fly could remain dormant for a year or more. Marlatt (1900, p. 2) suggests that this is a provision of nature which is intended to prevent the accidental extermination of the species. The experiments at this station have been along two lines; namely, to determine the minimum length of the stage under the most favorable conditions, and to determine the maximum length under partial field conditions.

In the first case 115 flaxseed reared on Turkey wheat under a constant temperature of 70° F. and a humidity of 70 per cent had an average stage of 11.7 days with extremes of 26 days and 7 days. (Table XIII.)

TABLE XIII.—Length of flaxseed stage.
(Temperature 70° F. and relative humidity 70 per cent.)

Kind of plant.	Number of flaxseed.	Length of stage, in days.		
		Maximum.	Minimum.	Average.
Turkey wheat	115	26	7	11.7
Illini Chief wheat	17	23	7	12.8
Rye	1	9	9	9.0
Barley	2	17	13	15

In order to determine the length of this stage under field conditions, clumps of infested wheat or straw were collected at all seasons of the year from many localities and placed in pasteboard boxes fitted with glass tubes into which the flies emerged. These boxes were kept in the field insectary throughout the year, and thus were subject to the same temperature conditions as in the field. The moisture, however, varied from that in the field. The material was throughly moistened when placed in the boxes, and several times during the year. A special effort was made to supply moisture when the spring rains began, in midsummer, and again when the fall rains came. In addition to this, the boxes were exposed to beating rains, and, being of paper, absorbed moisture.

While the data obtained in such an experiment can be only approximate, they have yielded some very interesting results. The fact that this material was collected in the field makes it impossible to know the age of the flaxseed at the time they were included in the experiment. The data are therefore summarized in Table XIV to show the number of days between collection and emergence. From this collected material 7,430 flies were reared, and the average time between collection and emergence was 113.2 days, with extremes of 2 days and 1,083 days. It will be noticed that 5,114 flies, or 67.4 per cent, emerged during the first month.

TABLE XIV.—Period between collection of flaxseed and emergence of flies.

Days after collection.	Number of flies emerging.	Days after collection.	Number of flies emerging.
1 to 29	5,114	360 to 389	14
30 to 59	390	390 to 419	1
60 to 89	78	420 to 449	2
90 to 119	525	450 to 479	3
120 to 149	268	480 to 509	14
150 to 179	571	510 to 539	15
180 to 209	105	540 to 569	0
210 to 239	19	570 to 599	1
240 to 269	2	600 to 669	0
270 to 299	32	670 to 700	8
300 to 329	190	1,083	1
330 to 359	77	Total	7,430

NOTE.—On May 7, 1919, the writer reared a female Hessian fly from a clump of wheat collected May 8, 1915. In this case the period between collection and emergence was 1,460 days.

PUPA.

DESCRIPTION.

The pupa is white in color after the transformation takes place and is somewhat shorter than the flaxseed. The white color rapidly gives way to a reddish tinge, which persists until after the adult emerges. The pupa is surrounded by a thin, delicate membrane or pupal case. A brownish, chitinous beak occurs on the head, which Osborn (1898, p. 17) considers is used by the pupa in cutting its way out of the flaxseed. That pupation may occur outside the puparium was shown in March, 1914, when 217 enclosed larvæ were removed from the flaxseed and placed on moist earth. Forty-two of these larvæ, or 20 per cent, pupated.

LENGTH OF THE PUPAL STAGE.

The fact that pupation occurs within the puparium makes it difficult to determine the exact length of the pupal stage. During the winter of 1913-'14 an effort was made to work out the length of this stage by bringing infested material into the greenhouse. The fly was in the larval stage within the flaxseed when brought in, but soon transformed to the pupa. In many cases this transformation occurred within two or three days. In this experiment 3,336 flies were reared and the average time between collection and emergence was 18.9 days, with extremes of 8 and 36 days. (Fig. 15.)

ADULT.

DESCRIPTION.

The adult Hessian fly (fig. 16) is a small, longlegged, dark-colored, two-winged insect, resembling in many ways a small mosquito. The female is about 4 mm. in length and has a distinct reddish tinge, especially after emergence. Its body is slender, the abdomen being ovate in shape and tapering to a point towards the distal end. The male is slightly smaller than the female, being from 2.5 to 3.5 mm. in length. The body is long and slender and is a dirty brown or black color. The abdomen is enlarged at the tip by the presence of two pairs of claspers, which are used in copulation.

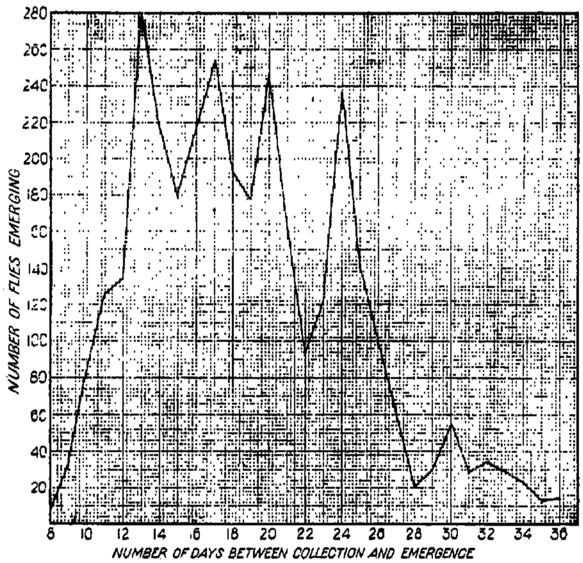


FIG. 15. Variation in length of pupal stage as determined from 3,336 pupæ.

EMERGENCE.

In emerging the pupa cuts a slit in the first or second segment of the puparium. It then works itself wholly or partly out of the flaxseed. The pupal skin then becomes separated from the adult body, which seems to be bathed in a fluid. The body contracts and expands, breaking the pupal skin on the cephalo-dorso-mesal line, and the adult emerges. The fly then crawls up on the stem of a wheat plant or other near-by object, where the body dries and the wings expand. On emerging, the body and wings are pinkish in color, the antennæ pale white and the legs gray. Within a few minutes (three in one instance) the wings are spread. As a rule the adults emerge from the puparia leaving the pupal skin partially exposed. It may often happen, however, that the pupa works its way out of the puparium and plant before the adult emerges. The adults usually emerge from the posterior end of the flaxseed, but in three instances under obeservation emergence occurred at the anterior end. Emergence generally occurs early in the morning and requires from 5 to 10 minutes.

(After Headlee and Parker.)
FIG. 16. Adult Hessian flies. Left, male; right, female. (Magnified about six times.)

The first spring emergence in the field usually occurs during the first week in April. Table XV shows the first emergence in the field and in the rearing boxes for the years 1913 to 1917. The last emergences recorded were November 25, 1914, in the field, and December 8, 1915, in the rearing boxes.

TABLE XV.—Earliest adult emergence.
(Manhattan.)

Year.	Field.	Rearing boxes.
1913	April 2	April 7
1914	April 8	April 10
1915	April 11	April 10
1916	April 1	Mar. 18
1917	April 5	April 11

LENGTH OF LIFE.

The life of the adult is of short duration, occupying an average of 2 or 3 days. Four hundred seventy-five adults under close observation lived an average of 52.6 hours, with extremes of 4 and 147 hours. There is a tendency for the females to live longer than the males. The data on the length of life are summed up in Table XVI.

TABLE XVI.—Length of adult life.

Date.	Place.	Sex.	Number of flies.	Length of life.			Remarks.
				Max. hrs.	Min. hrs.	Average hrs.	
1913.							
April	Insectary	F	153	147	7	62.6	....
April	Insectary	M	88	144	9	59.0	....
June	Insectary	F	97	106	4	42.0	....
June	Insectary	M	33	58	4	36.0	....
November	Greenhouse	F	97	120	23	48.8	Unmated.
November	Greenhouse	F	7	120	24	67.0	Mated.

PROPORTION OF SEXES.

Throughout the life-history work and the rearings from infested material, females have predominated. There has been little variation due to the seasons of the year or to climatic conditions. It has been observed, however, that the males will emerge at a slightly lower temperature than the females. Of the 16,318 flies reared from 1913 to 1917, 9,926, or 60.8 per cent, have been females. Tables XVII and XVIII summarize the data on the proportion of sexes.

TABLE XVII.—Proportion of sexes in adults reared from collected material, 1913 to 1917.

Month.	Female.	Male.	Total.
March	50	73	123
April	1,386	1,458	2,844
May	1,503	608	2,111
June	1,426	629	2,055
July	1	0	1
August	0	0	0
September	8	24	32
October	809	505	1,314
November	28	17	45
December	0	3	3
Total	5,211	3,317	8,528

TABLE XVIII.—Proportion of sexes in adults reared from various sources, 1913 to 1917.

Source.	Female.	Male.	Total.
First spring brood, 1913	164	100	264
Second spring brood, 1913	107	33	140
Insectary, fall, 1913	614	342	956
Insectary, winter, 1913-'14	117	29	146
First spring brood, 1914	55	53	108
Second spring brood, 1914	99	65	164
Fall brood, 1914	386	412	798
Supplementary fall brood, 1914	122	129	251
Collected material:			
Greenhouse, 1913-'14	2,534	1,704	4,238
Greenhouse, 1914	64	60	124
Greenhouse, 1916	67	54	121
Life-history work, 1916	248	83	331
Wind migration	138	11	149
Totals	4,715	3,075	7,790

REPRODUCTION.

Mating. The adult flies usually mate soon after emergence, often before the wings and body have assumed the usual dark color. In one instance a male emerging at 10:35 was observed trying to mate at 10:59 with a female that had emerged at 10:48. This attempt was unsuccessful, but at 11:19 this pair mated again, and egg-laying began in a few minutes. The time between emergence and mating for the male was 44 minutes and for the female 30 minutes. In the life-history work, mating and oviposition generally began in the morning from one to three hours after emergence. There seems to be a period in the life of the female when the oviposition impulse is intense, preceded by a period exactly opposite, when the female has no inclination towards oviposition. During the latter period the female remains quiet with her head up, while the males fly about her trying to mate. As many as six males have been seen endeavoring to mate with a single female. As a rule, females with unfertilized eggs do not oviposit during the first day.

Parthenogenesis. While virgin females often deposit eggs freely, in no case have any such eggs hatched. Ninety-eight unmated females kept in confinement during November, 1913, laid 8,110 eggs, none of which hatched. During 1914, 16 virgin females were placed in cages with wheat, in order to more fully determine this point. Eight of the females deposited eggs on the plants, but in every case the eggs failed to develop.

OVIPOSITION.

Age at Beginning. Egg-laying usually begins within a few hours after emergence. In 1913, 27 females of the first spring brood averaged 9 hours and 49 minutes between emergence and oviposition, with extremes of 1 hour and 40 minutes and 29 hours. The period between mating and oviposition is generally of even shorter duration, and flies have often been observed to oviposit within 15 minutes after copulation.

Location of the Eggs. Generally the eggs are deposited on the upper surface of the younger leaves, being glued into the longitudinal grooves of the blade. Frequently the eggs are laid on the lower surface, and rarely on the stalk. There seems to be no particular place on the leaf where the eggs are laid, since they may occur anywhere from the base to the tip. Egg counts made at all times of the year show that approximately 97 per cent of the eggs are laid on the central leaf or the first leaf from the center. Of the 23,202 eggs counted in the field, 7,697, or 33.1 per cent, were found on the central leaf; and 14,631, or 63.5 per cent, on the first leaf below the central one. The data summarizing the egg counts are shown in Table XIX.

TABLE XIX.—Location of eggs under field conditions.

Date.	Place.	Central leaf.		First leaf.		Second leaf.		Third leaf.		Total.
		Upper surface.	Lower surface.	Upper surface.	Lower surface.	Upper surface.	Lower surface.	Upper surface.	Lower surface.	
April, 1913	Cages	4,831	228	5,213	160	73	0	0	0	10,505
April, 1913	Manhattan	180	(a)	190	(a)	15	(a)	1	0	386
June, 1913	Cages	970	71	571	80	52	0	0	0	1,744
October 6, 1913	McFarland	227	(a)	251	(a)	21	(a)	1	0	500
April 13, 1914	McFarland	94	(a)	69	(a)	0	(a)	0	0	163
April 22, 1914	McFarland	224	(a)	188	(a)	20	(a)	0	0	432
April 16, 1916	Manhattan	101	1	249	7	34	3	0	0	395
April 23, 1916	Manhattan	16	2	40	8	15	7	3	0	91
June 7, 1916	Manhattan	64	0	27	4	1	0	0	0	96
September 27, 1916	Manhattan	393	14	1,064	279	23	0	0	0	6,773
October 2, 1916	Manhattan	57	1	590	18	387	17	1	1	1,072
October 7, 1916	Manhattan	135	0	153	0	47	0	0	0	335
October 14, 1916	Manhattan	88	0	460	10	150	2	0	0	710
Total		7,380	317	14,065	566	838	29	6	1	23,202

(a) No count.

Of 1,400 eggs laid during March, 1916, in experimental cages, 1,270 were deposited on the upper surface of the leaves, 119 on the lower surface, and 4 on the stalk. A single female ovipositing on barley placed 73 eggs on the upper surface of the leaves and 10 eggs on the lower surface.

Miscellaneous Places of Oviposition. Under natural conditions the Hessian fly probably deposits all the eggs on the leaves of wheat or other closely allied plants. In the rearing cages, however, eggs have been found on the sides of the glass cages and on the bare moist soil.

Act of Oviposition. Barring the minor modifications, there are three distinct ways in which eggs may be laid: (1) The eggs may be laid with their anterior end toward the tip of the leaf. This is what happens under normal conditions, when the female stands on the leaf with her head towards the tip. Since this mode of oviposition is the most general in nature, and since this is the most natural way of ovipositing, it is designated as normal oviposition. (2) The egg may be laid with its anterior end towards the base of the leaf. This is a situation exactly opposite to the first, and may be called inverted oviposition. Undoubtedly this is of rare occurrence in nature and occurs only when the leaf is long and bends over. In this case the female alights beyond the bend of the leaf with her head towards its base, since the base will be higher than the tip. (3) The eggs may be laid transversely or at varying angles to the long axis of the leaf. It is only necessary to mention that the three conditions described above are capable of modifications, and also that they can be realized on the lower as well as on the upper surface of the leaf.

The process of oviposition under normal conditions is about as follows: The female alights on the upper surface of the leaf with her head towards the tip. The abdomen is curved downward slightly until the ovipositor touches the leaf surface. She then feels with the tip of her ovipositor until a suitable place is found for the egg. The body then becomes rigid and the ovipositor is pressed downward on the leaf and has a much-extended position. The peristalic motion in the ovipositor can then be seen as the egg passes downward. When the first part of the egg touches the leaf the female slides it out by withdrawing the ovipositor with a quick, jerky motion.

Ordinarily the female lays from one to three eggs and then changes her position. One female under observation in laying 22 eggs changed her position 10 times. From one to three eggs were deposited at each change. After laying a few eggs the female usually rested for a few minutes before proceeding. The time required to deposit an egg by the female under observation averaged 4 to 5 seconds.

Flies were observed ovipositing on rye and barley in the life-history work. In the case of rye the females appeared restless and nervous, and considerable time was spent in examining the leaf surface before an egg was laid. The same was true in the case of barley, except that the leaves are much wider and the females had difficulty in remaining on the leaf.

Period of Oviposition. The period of egg-laying is usually of short duration, being only 1 or 2 days in length. The average period of oviposition under field conditions for 27 females of the first spring brood, 1913, was 38 hours, with extremes of 8 and 79 hours. Twenty-three females of the second spring brood had an average period of 34 hours, with extremes of 10 to 53 hours.

Egg-laying generally begins early in April, and under favorable conditions, such as cool, wet weather, eggs may be found at any time wheat is present, until late in November. This was the case in 1915, when there were five distinct broods of the fly.

Number of Eggs per Female. The number of eggs laid by a single female varies greatly. In the life-history work 226 females laid a total of 21,846 eggs, or an average of 97 eggs, with extremes of 0 and 320. Table II gives the detail data on these females.

TABLE XX.—Number of eggs laid per female.

Date.	Place.	Number of females.	Number of eggs laid.				Remarks.
			Max.	Min.	Av.	Total.	
1913.							
April	Field insectary	96	320	0	112	10,745	First spring brood.
June	Field insectary	23	137	0	77	1,772	Second spring brood.
November	Greenhouse	98	288	0	82	8,110	Unfertilized.
November	Greenhouse	9	259	14	135	1,219	Fertilized.

LENGTH OF THE LIFE CYCLE.

As has been pointed out already, the length of the various stages in the life cycle of the Hessian fly is extremely variable, and consequently there is a great variation in the length of the life cycle. The exact length of the entire life cycle has been determined for more than 900 individuals, and the approximate length has been found for 8,600. Summarizing these data the life cycle is seen to vary from 20 days, under a constant temperature of 70° F. and a humidity of 70 per cent, to at least 42 months, under conditions encountered in the rearing boxes.[1] The extremes of each stage and of the life cycle are shown in Table XXI. Tables XXII and XXIII show the length of the life cycle under varying conditions. Little difference has been found in the length of the life cycle when the flies are reared on different food plants.

TABLE XXI.—Variation in length of the life cycle.

Stage.	Length of stage.	
	Maximum.	Minimum.
Egg	12 days	3 days
Larva	182 days	9 days
Flaxseed	1,083 days	7 days
Adult	6 days	4 hours
Life cycle	1,283 days	20 days

TABLE XXII.—Variation in length of the life cycle under different conditions.

Date eggs laid.	Date adults emerged.			Length of life cycle.			Number reared.	Place.
	First.	Max.	Last.	Min.	Max.	Av.		
				Days.	Days.	Days.		
10- 6-'13	4-21-'14	4-21-'14	6-17-'14	172	183	230	108	Field insectary.
4-21-'14	5-29-'14	5-29-'14	6-11-'14	37	51	42	164	Field insectary.
5-30-'14	10- 6-'14	10- 7-'14	10- 7-'14	131	132	132	3	Field insectary.
10-21-'15	4-12-'16	4-12-'16	4-14-'16	173	175	174	3	Field insectary.
12- 6-'13	1- 1-'14	1- 7-'14	2- 1-'14	29	57	33	64	Greenhouse.
12- 6-'13	1- 4-'14	1-10-'14	1-29-'14	29	54	39	29	Greenhouse.
1- 7-'14	2- 6-'14	2- 8-'14	2-13-'14	30	37	33	36	Greenhouse.
12- 7-'13	1- 5-'14	1- 8-'14	1-29-'14	29	53	34	53	Greenhouse.
2- 7-'14	3- 7-'14	3- 9-'14	3-12-'14	28	33	30	12	Greenhouse.
3-11-'14	4-10-'14	4-12-'14	4-17-'14	30	37	33	56	Greenhouse.
3-31-'15	4-27-'15	4-27-'15	4-29-'15	27	29	28	10	Greenhouse.
4- 1-'15	4-24-'15	4-25-'15	4-29-'15	23	28	24	8	Greenhouse.
1-21-'16	3- 5-'16	3- 5-'16	3- 5-'16	43	43	43	1	Greenhouse.
1-28-'16	2-23-'16	2-23-'16	2-25-'16	26	28	27	2	Greenhouse.
1-28-'16	2-21-'16	2-22-'16	2-26-'16	24	28	26	2	Greenhouse.
2- 3-'16	2-27-'16	....	3- 7-'16	24	32	26	(a)	Greenhouse.
2- 8-'16	3- 4-'16	....	3-28-'16	24	48	29	(a)	Greenhouse.
2-27-'16	3-23-'16	....	4-16-'16	25	49	32	(a)	Greenhouse.

(a) Number of flies not counted.

TABLE XXIII.— Variation in length of the life cycle at 70° F. and 70 per cent humidity.

Kind of host plant.	Number reared.	Length of life cycle, in days.			Remarks.
		Max.	Min.	Av.	
Turkey wheat	115	46	20	26.3	Reared on individual plants.
Illini Chief wheat	17	40	26	29.4	Reared on individual plants.
Rye	1	22	22	22.0	Reared on individual plants.
Barley	2	30	26	28.0	Reared on individual plants.
Turkey wheat	131	50	22	30.0	Reared in cages.
Rye	69	35	26	29.1	Reared in cages.

1. On May 7, 1919, the writer reared a female Hessian fly from a clump of wheat collected May 8, 1915. Allowing approximately a month for the fly to reach the flaxseed stage, this gives a life cycle of at least 49 months.

NUMBER OF BROODS.

There has been a great divergence of opinion as to the number of broods of Hessian fly, different authorities giving from one to six. Most of the early entomologists placed the number of generations at two per year, and this same view has been maintained by certain writers until recent years.

Chapman (1826), writing in 1797, states that there are two broods during the year, one generation lasting from the last of April to the 15th or 20th of September, and the other from the middle of September to the beginning of the following May. Worth (1820) was one of the first to suggest that there were more than two broods. He writes: "It may be said that during the past year there have been three complete broods and a partial fourth."

Fitch (1847) states that the fly has two annual broods and that individuals may have their life cycle retarded as much as to require a year for complete development.

Lindemann (1887) concludes from his work in Russia that in the vicinity of Moscow there are three different broods having well-marked periods of emergence.

Marchal (1897), working in France, demonstrated that under the most favorable conditions six generations may occur during the year. Several of these broods are only partial, however, the most incomplete being the third, fourth and sixth. Osborn (1898), in commenting on Marchal's work, states that the conditions necessary to such a continuous series of broods do not exist in nature.

Webster (1899), speaking of the territory between the Allegheny mountains and the Mississippi river and between the Great Lakes and the Ohio river, says there are only two broods, and that apparent supplementary broods are composed of either advance guards or stragglers resulting from acceleration or retardation as a result of weather conditions. He also suggests that farther north the fall brood may be eliminated, making the species single-brooded.

Luggar (1899) says that the fly is single-brooded in the Red river valley of Minnesota, while Washburn (1903) holds that it is double-brooded.

Headlee and Parker (1913) in summarizing their work in Kansas state that, "The number of broods is variable. In 1908, main spring, supplementary spring, midsummer, main fall and supplementary fall broods were determined. In dry summers it is likely that midsummer and supplementary fall broods would not appear, and it is likely that in very dry years, particularly when the drought begins early, the supplementary spring brood might be eliminated."

Webster and Kelley (1915) state that, "There are two generations of the Hessian fly each year, one in the fall and one in the following spring, the latter being the children of the former. Therefore, if there were no flies to lay eggs in the fall, it stands to reason that there could be none to lay eggs in the spring.''

FIELD OBSERVATIONS ON THE NUMBER OF BROODS.

A thorough knowledge of the number of generations of flies occurring under field conditions is essential to the development of measures of control. The wide divergence of results recorded in the literature, however, indicates that the subject is still open to investigation. Careful observations have been made each year since 1913, in the fields at Manhattan and elsewhere, to determine this point. Regular counts of the number of eggs, larvæ and flaxseed have been made, and these results have been supplemented by life-history studies in the insectaries and by the emergence from the boxes of collected material.

A summary of these studies shows that there has been a varying number of generations each year, and they confirm the finding of Headlee and Parker that there may be as many as five broods in a year. The data indicate that normally there are three main broods and two partial or supplementary broods, which necessitates some change in the nomenclature of the spring broods given by Headlee and Parker. The main spring brood becomes the first spring brood, and the supplementary spring brood becomes the second spring brood. No change of the other broods is required. The field observations are summarized briefly by years to show the number of broods present and their importance.

Field Observations, 1913. The first spring brood began to emerge at Manhattan April 2, and emergence continued throughout the month. Cold weather during the latter part of April retarded the development of the brood, and as a result the second spring brood was only moderate. Adults of this generation did not emerge until late in May. The months of June, July, August, and the first part of September were extremely hot and dry, and no flies emerged. The main fall brood began to emerge September 20 and reached its maximum about the first of October. No supplementary fall brood developed. Observations made at McFarland coincided with those at Manhattan. Practically the same climatic conditions prevailed and the same number of broods were recorded. The main fall brood began emerging September 27, and the maximum emergence occurred October 2.

Field Observations, 1914. Four distinct broods of fly were present during 1914. The first and second spring broods and the main fall brood were large and did much injury. Emergence of the first spring brood began April 7 and reached its maximum April 16. The second spring brood was out May 20, reaching its maximum May 28. This summer was also dry and hot and no midsummer brood appeared. Flies of the main fall brood began emerging September 8, the maximum occurring September 20. A small supplementary fall brood appeared during November. At McFarland the first and second spring broods were especially large. Emergence began early in April and was at its maximum by April 13. The second spring brood emerged about May 30 and reached its maximum by June 9. A large emergence of the main fall brood occurred, which reached its maximum about October 1, but owing to the delay in planting and the thorough destruction of the volunteer wheat little damage was done. An examination made November 27 showed that there had been a slight supplementary fall brood.

Field Observations, 1915. This was an exceptionally bad Hessian-fly year, five distinct broods being detected in the field. The year was characterized by a high rainfall and moderate temperatures during the spring, summer and fall. A large first spring brood began to emerge about April 15, and by April 20 most of the flies were out. The second spring brood was especially large and did a great amount of injury. Emergence began about May 20 and reached its maximum June 2. Harvest was late and most of the maggots reached their full growth and transformed to flaxseed. The continued rainfall during July and August started the volunteer wheat, and also brought out a moderate midsummer brood. The main fall brood was large, and continued warm weather in the fall brought out a small supplementary fall brood. Numerous field observations made at many places in the state were in accord with those at Manhattan, indicating that the fly was five-brooded over most of the infested area.

Field Observations, 1916. This year was characterized by a heavy first spring brood and a heavy main fall brood. A light second spring brood and a small supplementary fall brood also developed. Spring emergence began April 1 and reached its maximum about April 16. The second spring brood appeared about May 20. The main fall brood began to appear September 18, the maximum occurring September 25. A few eggs were found in the field early in November, indicating a supplementary fall brood.

Field Observations, 1917. The outbreak which began in 1912 was about over this year. A moderate first spring brood began to emerge April 5, but owing to the backward weather the emergence was slow and continued into May. Many of the first eggs deposited failed to mature. A very light second spring brood appeared about June 9, but most of the resulting larvae failed to mature before harvest. The summer was dry and there was no midsummer brood. The main fall brood began emerging September 25, but cold weather throughout October delayed emergence and the development of the various stages, with the result that in November very few maggots and flaxseed were to be found in the wheat. Table XXIV shows the number of broods each year and the relative importance of each brood.

TABLE XXIV.—Field observations showing the relative importance of the various broods of Hessian fly, 1913 to 1917.

Year.	First spring brood.	Second spring brood.	Midsummer brood.	Main fall brood.	Supplementary fall brood.
1913	Heavy	Moderate	None	Heavy	None.
1914	Heavy	Heavy	None	Heavy	Light.
1915	Heavy	Very heavy	Light	Heavy	Very light.
1916	Heavy	Light	None	Heavy	Very light.
1917	Moderate	Very light	None	Very light	None.

NUMBER OF GENERATIONS IN LIFE HISTORY STUDIES.

Life-history studies have been conducted from time to time under various conditions, and these furnish considerable data on the possible number of broods.

In 1914 three broods were reared in the field insectary, where the conditions approximated those in the field. Adult flies began emerging April 21 from wheat collected November 6, 1913. These adults were supplied with wheat plants, and oviposition occurred at once. The second brood emerged May 29 and oviposition occurred on May 30. The flaxseed stage was reached the last of June, and the summer was passed in this stage. The fall brood emerged October 6 and the flaxseed stage was reached by the middle of November. The winter was passed in this stage, but no attempt was made to continue the work during the following spring.

Five successive generations were reared in the greenhouse during the winter of 1913-'14, each brood requiring about 30 days. Adults emerging December 6 from wheat collected November 17, 1913, were placed in cages containing wheat. Egg-laying began at once and the second brood emerged January 7, 1914. The third brood of adults was out February 7; the fourth, March 10; and the fifth, April 10. It was impossible to secure eggs from the fifth brood of adults.

Three generations were reared during January, February and March, 1916 in the constant-temperature chamber, where the temperature was maintained at 70° F. and the moisture at 70 per cent. Each brood required an average of 31 days to complete development, with extremes of 22 and 50 days.

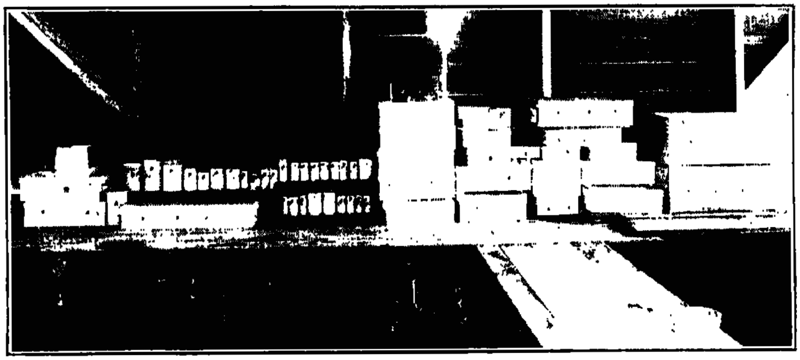


FIG. 17. Emergence boxes in the field insectary for rearing adult flies from collected material.

NUMBER OF GENERATIONS AS SHOWN BY THE REARINGS FROM COLLECTED MATERIAL.

In order to gather more data on the number of broods and also to establish the source of the flies composing each brood, infested wheat was collected at all seasons of the year from various localities in the state and placed in pasteboard rearing boxes. (Fig. 17.) Each box had at least one glass tube, into which the flies were attracted by the light on emerging. These boxes were kept in the field insectary under practically natural temperature conditions. The wheat was moistened when placed in the boxes, and also three times each year—in the spring when the first rains occurred, in midsummer, and when the fall rains began. Being of pasteboard, the boxes absorbed some of the atmospheric moisture, and they were also subject to wetting by beating rains. The material placed in the boxes consisted of regular-crop wheat, volunteer wheat, and stubble, and each box of material was held for at least three years before discarding. More than 250 collections of infested material have been under observation. The emergence in these boxes, especially in those containing material collected in the vicinity of Manhattan, has been checked with the field emergence; and with the exception of the midsummer brood, it has coincided very closely with field conditions. The data secured in this experiment are graphically summarized in figures 18 to 21.

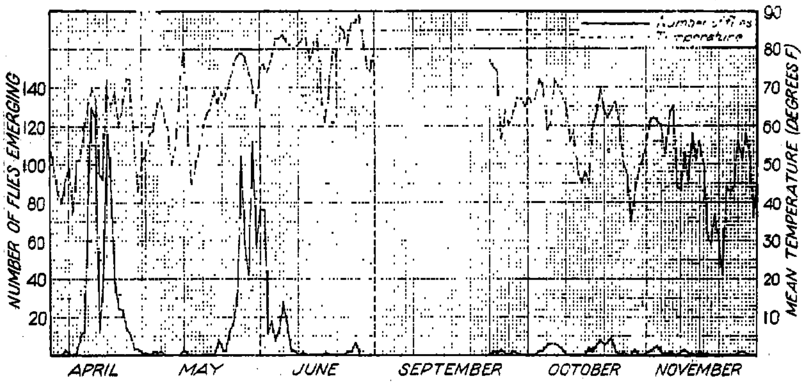


FIG. 18. Mean daily temperatures and daily emergence of flies, 1914.

A little discrepancy will be noted in comparing the appearance of the broods in these figures with the appearance of the broods in the field study. This is due to the fact that these figures are a composite of the emergence from all material. In many cases the infested material was collected in southern Kansas, where development is earlier and where the fall emergence is later.

In 1914 the two spring broods appeared with a definite period of a little over 20 days between them. Both of these broods were large. There were two periods of emergence for the first spring brood, caused by a few days of low temperatures. This had its effect on the emergence of the second spring bood, as is shown by the two periods of large emergence, although the temperature remained high all of the time. The fall emergence in the boxes was rather light and was interrupted twice by decided drops in temperature. A light supplementary fall brood is also shown.

Emergence started in 1915 on April 10 and reached its maximum April 19. The first spring brood was rather heavy, and the second spring brood was exceptionally heavy and characterized by two

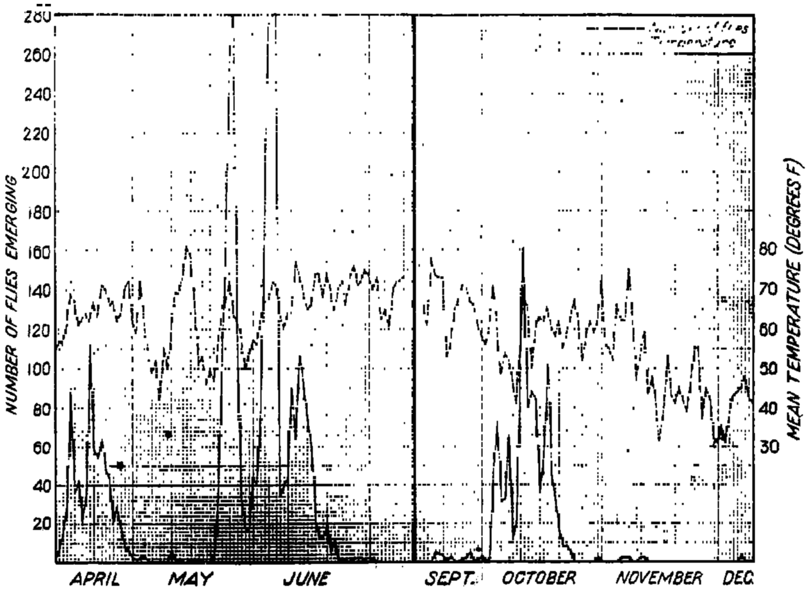


FIG. 19. Mean daily temperatures and daily emergence of flies, 1915.

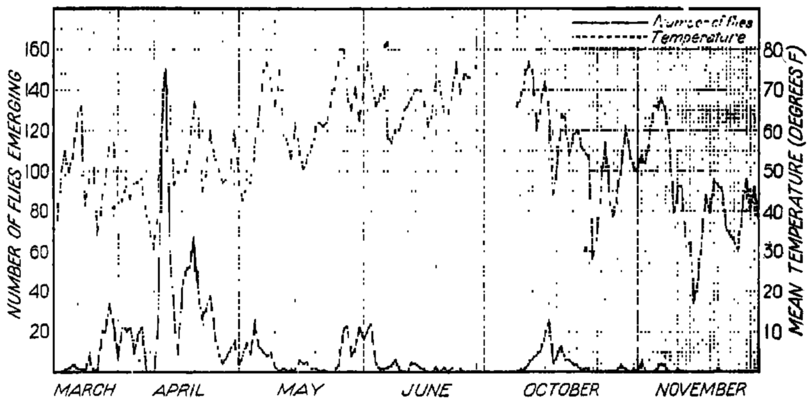


FIG. 20. Mean daily temperatures and daily emergence of flies, 1916.

periods of emergence. The fall emergence started September 18 and reached its maximum October 10. A very light supplementary fall brood was in evidence, as indicated by the emergence in November and on December 8.

In 1916 emergence began March 18, due to rather high temperatures that prevailed at that time. The maximum, however, did not occur until April 11. Apparently an overlapping of the first and second spring broods occurred, although the maximum emergence of the second brood did not occur until the last of May. The main fall brood began to emerge October 1 and reached its maximum October 8. A light emergence of the supplementary fall brood occurred on November 20.

The first spring brood commenced emerging in 1917 on April 10 and reached its maximum April 18. The low temperatures which

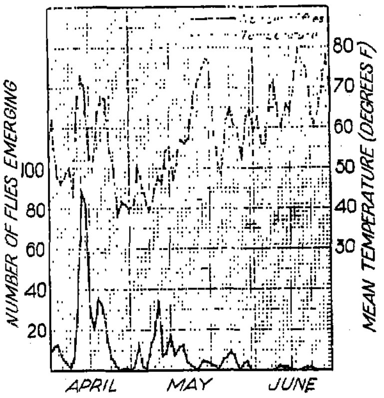


FIG. 21. Mean daily temperatures and daily emergence of flies, 1917.

prevailed during the last of April and much of May delayed emergence and development. A very light second spring brood was discerned in June. No midsummer or supplementary fall brood appeared, and the main fall brood was very light.

SOURCE OF BROODS.

Apparently very little has been done on the source of broods by the various workers on the Hessian fly. In so far as the writer has been able to ascertain, Headlee and Parker (1913) are the only ones who have attempted to show the source of each brood. Their findings may be summarized as follows:

The main spring brood comes from:

1. Puparia in the preceding crop.
2. Puparia in the present year's crop.
3. Puparia in volunteer wheat.

The supplementary spring brood comes from:

1. Puparia of the main spring brood.
2. Puparia in the volunteer wheat of the previous year.
3. Puparia in the stubble of the preceding crop.

The midsummer brood comes from:

1. Puparia of the main spring brood.

The main fall brood comes from:

1. Puparia of the main spring brood.

The supplementary fall brood comes from:

1. Puparia in the volunteer wheat of the past summer.

This point has been rather fully investigated during the past four years, and the data indicate that the adults of any one generation may be the progeny of any brood of the previous two years, that no brood is complete in itself, and that some flies always hold over to another generation. Table XXV shows the number of flies reared from flaxseed of known generations and the broods they go to form. It has been found that in nearly every case adults emerging from a known brood of flaxseed go to make up from two to six distinct broods, and that the periods of emergence may be separated by several months, and even years.

Using the data shown in the table as a basis, the source of the broods may be summarized as follows:

The first spring brood may come from:

1. The previous fall brood. (This is the main source.)
2. The previous first and second spring broods.
3. The previous midsummer brood.
4. The previous supplementary fall brood.
5. The first and second spring broods of two years previous.

The second spring brood may come from:

1. The preceding first spring brood. (This is the main source.)
2. The previous main fall brood.
3. The previous midsummer brood.
4. The first and second spring broods of the previous year.
5. The previous supplementary fall brood.
6. The first and second spring broods of two years previous.
7. The first and second spring broods of three years previous.

The source of the midsummer brood is not revealed in the table. Field examinations made during the summer of 1915, when a fair midsummer brood was present, indicated that this brood came principally from the second spring brood. Most of the first spring

TABLE XXV.—Number of flies reared from flaxseed of known generations and the broods they go to form.

Place collected.	Date of collection.	Broods represented by the flaxseed (a)	1S	2S	MS	MF	SF	1S	2S	MS	MF	SF
Manhattan	10-12-'16	M F	0	0	0	0	9	29	2	0	0	0
Anthony	5-17-'15	1 S	0	404	0	13	0	0	0	0	0	0
Arkansas City	3-13-'16	M F	0	0	0	0	0	54	0	0	0	0
Basehor	5-25-'16	1 S	0	19	0	3	0	0	0	0	0	0
Bern	5-20-'14	1 S	0	51	0	1	0	13	5	0	0	0
Caldwell	5- 8-'15	1 S	0	273	0	127	0	0	5	0	1	0
Clay Center	11- 1-'14	M F	0	0	0	0	2	5	0	0	0	0
Clearwater	9-24-'15	M S	0	0	0	18	0	0	0	0	0	0
College farm	7- 4-'13	1 S, 2 S	0	0	0	6	0	0	1	0	0	1
College farm	11- 6-'14	M F	0	0	0	0	7	84	39	0	0	0
College farm	3-23-'15	M F, S F	0	0	0	0	0	221	5	0	0	0
College farm	10-30-'15	M S, M F	0	0	0	0	1	46	0	0	0	0
College farm	7-13-'16	1 S, 2 S	0	0	0	23	0	9	1	0	2	0
Cuba	10-21-'14	M S	0	0	0	0	11	0	2	0	0	0
Manhattan	5- 7-'15	1 S	0	36	0	8	0	0	0	0	0	0
Manhattan	9-29-'15	M S	0	0	0	16	0	1	0	0	0	0
Glasco	11- 1-'14	M F	0	0	0	0	1	6	0	0	0	0
Hollenberg	5-31-'15	1 S	0	11	0	7	0	1	0	0	0	0
Kellogg	6-24-'15	1 S, 2 S	0	0	0	14	0	3	0	0	2	0
Leavenworth	6-20-'14	1 S, 2 S	0	0	0	0	0	2	(b)	0	0	0
Leavenworth	7-26-'14	1 S, 2 S	0	0	0	9	1	17	2	0	1	0
Lorraine	9-25-'16	M S	0	0	0	16	2	23	0	0	0	0
Manhattan	10-30-'15	M F	0	0	0	0	1	17	1	0	0	0
Marysville	5-20-'14	1 S	0	17	0	2	7	2	0	0	23	0
McFarland	11- 6-'13	M S	0	0	0	0	0	1	0	0	2	0
McFarland	5-10-'14	1 S	0	338	0	1	0	4	0	0	0	0
McFarland	6- 9-'14	1 S	0	0	0	5	5	0	3	0	0	0
McFarland	10-18-'14	M S	0	0	0	0	10	0	0	0	0	0
Minneapolis	7-11-'14	1 S, 2 S	0	0	0	18	10	5	1	0	0	0
Newton	6-22-'16	1 S, 2 S	0	0	0	49	8	111	40	0	0	0
Ogden	10-18-'15	M S	0	0	0	0	10	4	0	0	0	0
Paola	9-20-'15	M S	0	0	0	24	0	0	0	0	0	0
Preston	5- 8-'16	1 S	0	16	0	0	0	0	3	0	0	0
Salina	7-12-'14	1 S, 2 S	0	0	0	4	5	0	0	0	0	0
Stafford	5-25-'15	1 S	0	52	0	7	0	0	0	0	0	0
Waterville	5-27-'15	1 S	0	3	0	2	1	0	0	0	0	0
Wellington	5-18-'15	1 S	0	779	0	166	0	0	2	0	2	1
Wellington	6-29-'15	1 S, 2 S	0	0	0	99	0	(c) 8	(c) 1	0	1	0
Wichita	5-20-'16	1 S	0	39	0	4	0	10	1	0	0	0
Winfield	5- 8-'15	1 S	1	163	0	220	3	0	0	0	0	0
Winfield	6-22-'15	1 S, 2 S	0	0	0	321	0	(d) 47	(e) 4	0	0	0

(a) In this table the names of the broods are abbreviated as follows: First spring brood, 1 S; second spring brood, 2 S; midsummer brood, M S; main fall brood, M F; supplementary fall brood, S F.
(b) One fly emerged in this brood of two years later.
(c) One fly emerged in this brood of the following year.
(d) Five flies emerged in this brood of the following year.
(e) Two flies emerged in this brood of the following year.

brood had emerged to form the second spring brood. Probably some of the midsummer brood came from various preceding broods, since this has been the case with all the other generations.

The main fall brood may come from:

1. The previous second spring brood. (This is one of the main sources.)
2. The previous first spring brood. (This is one of the main sources.)
3. The previous midsummer brood.
4. The first and second spring broods of the preceding year.
5. The midsummer brood of the previous year.

The supplementary fall brood may come from:

1. The previous midsummer brood. (This is probably the main source.)
2. The previous main fall brood.
3. The previous second spring brood.
4. The previous first spring brood.
5. The first and second spring broods of the preceding year.

The results of this study support the statement of Marlatt (1900) that, "Under exceptional conditions the insect may remain dormant in the flaxseed state for a year or more and still bring forth the adult—a provision of nature which is doubtless intended to prevent the accidental extermination of the species." Marchal (1897) in his work in France was able to rear six broods a year. He found that most of these broods were partial, and that the third, fourth, and sixth were especially so. He advanced the idea that the species is perpetuated, in spite of the obstacles placed in its way by exterior conditions, by the great variability of its biologic cycle.

NATURAL CONTROL.

MECHANICAL.

PLANT STRUCTURE.

Various plant structures undoubtedly have an important bearing on the successful development of the fly on various varieties. In the variety test of small grains already referred to it was shown that some varieties having a large number of eggs deposited on them developed a very low per cent of infestation. On the other hand, some varieties bearing but few eggs had a heavy infestation. In this case the conditions prevailing at the time of hatching were practically the same for all varieties and the explanation of the scarcity of flaxseed in some varieties and the abundance in others seems to be due to factors within the plant. What these factors are remains to be determined, but from observations already made it might be suggested that the character of the leaf surface, the ligule, the degree of tenacity with which the leaf clasps the straw, the composition of the straw, etc., are to be considered.

CLIMATOLOGICAL CONDITIONS.

The increase and diminution of Hessian fly are dependent to a large extent on the influence of meteorological conditions. The climatic factors more directly concerned are temperature and moisture, and these are operative not only on the fly, but also on the host plants and on the parasites and enemies. It has become an axiom that the fly reaches its greatest abundance in cool, wet years, while the chinch bug flourishes in hot, dry years. In general this is true, but studies at this station and elsewhere show that at only certain stages in the fly's life history are these climatic extremes operative against the fly. In the adult, egg, and first larval stages the fly is readily influenced by weather conditions, while the second larval stage is resistant to considerable variation in temperature and moisture, and the flaxseed stage is able to withstand the greatest extremes thus far recorded for Kansas.

While it is known that the fly is greatly influenced by meteorological conditions, the exact part these conditions play and the interrelations between temperature and moisture are still open to investigation. A large amount of data are at hand bearing on these points, and they will be discussed under separate headings. The results give a good working basis for interpreting many facts in the life economy and in developing measures of control. They emphasize the fact, however, that there is much yet to be learned with respect to the influence of climatic conditions on the life economy of the fly. With the data at hand, the axiom quoted above might be changed to read: "Those conditions most favorable to the growing of wheat are also most favorable to the development of the fly, and, conversely, conditions adverse to the growth of wheat are adverse to the development of the fly."

EFFECT OF TEMPERATURE ON EMERGENCE.

It has been noticed that emergence in the spring usually begins during the first warm days early in April, especially if there has been some rainfall. In order to find the effect of temperature on emergence of adults in the rearing boxes, the average mean temperature was compared with the number of flies emerging. (Figs. 18 to 21.) A comparison of these records shows that there is a direct relation between temperature and emergence.

Emergence rarely occurs when the mean temperature is below 50° F., and reaches its maximum at a mean temperature of 60° to 70° F. It will be noticed that the peaks of emergence occur on days of high mean temperature, and that a drop in this temperature is followed by a corresponding drop in the emergence.

The effect of temperature on emergence is best illustrated by the data for 1917 (fig. 21) when abnormally low temperatures prevailed through much of April and May. In this case the period of emergence was prolonged and the first spring brood continued to emerge until the last of May. A decided increase in the emergence is shown with each rise in temperature.

EFFECT OF HIGH TEMPERATURES.

The Hessian fly normally passes the hottest part of the year in the flaxseed stage. During the past few years it has been observed that those conditions prohibitive to the growth of volunteer wheat are also prohibitive to the emergence of the fly. Various studies in recent years have shown that the immature stages are able to withstand high temperatures provided the relative humidity is high. On the other hand, eggs failed to hatch at a temperature of 90° F. and a relative humidity of 45 per cent, or if they hatched the larvæ were unable to make any progress on the leaf and soon died.

That the flaxseed stage is able to withstand unusually high temperatures is shown by its survival of the extremely hot summers of 1913 and 1914. Riley (1881,p. 916), writing of conditions in Ohio, says: "The intense heat had not only desiccated the *Cecidomyia,* but what is still more remarkable, in most cases the parasites also." Considerable data were obtained in 1913 on the maximum temperatures the fly would have to withstand under field conditions in Kansas. Temperature studies were made at various depths of plowed wheat ground and in unplowed stubble when the maximum air temperature in the shade was over 100° F. Figures 22 and 23 graphically summarize the results. It will be noticed in the plowed soil that the temperatures at the surface and one inch below are extremely high and the daily range is great. At three inches below the surface the temperature does not vary greatly from the air temperature and the range of temperature is less than that of the air. In unplowed stubble the temperature at the crown varied from 115° to 119° F. when the temperature of the air was above 100° F.

EFFECT OF LOW TEMPERATURES,

The fly is able to withstand extremely cold weather in the flaxseed stage. During the last outbreak temperatures as low as -21° F. were recorded with no appreciable mortality to the flaxseed. Full-grown larvæ have also been known to survive a temperature of —16° F. In general, the length of the life cycle increases with the decrease in the temperature, and the main fall brood requires from the last of September to the first of April to complete its development. It has been pointed out that prolonged cool weather in the spring retards emergence and development of the first spring brood.

Temperatures of about 32° F. are fatal to the adults, and in many

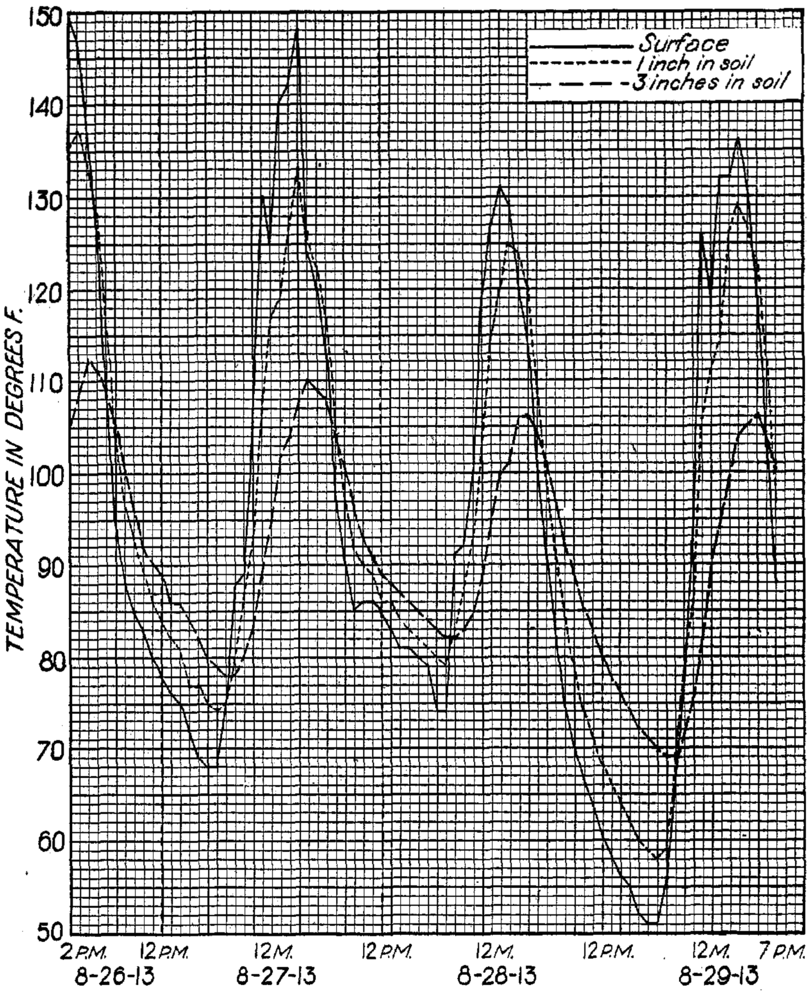


FIG. 22. Chart showing the hourly temperatures of plowed wheat land on the surface and at depths of one inch and three inches, August 26 to 29, 1913.

cases to the eggs and migrating larvæ. The last outbreak was largely brought to a close by such conditions. Abnormally low temperatures in the fall of 1916, together with the same conditions in the spring and fall of 1917, caused a large mortality in the field.

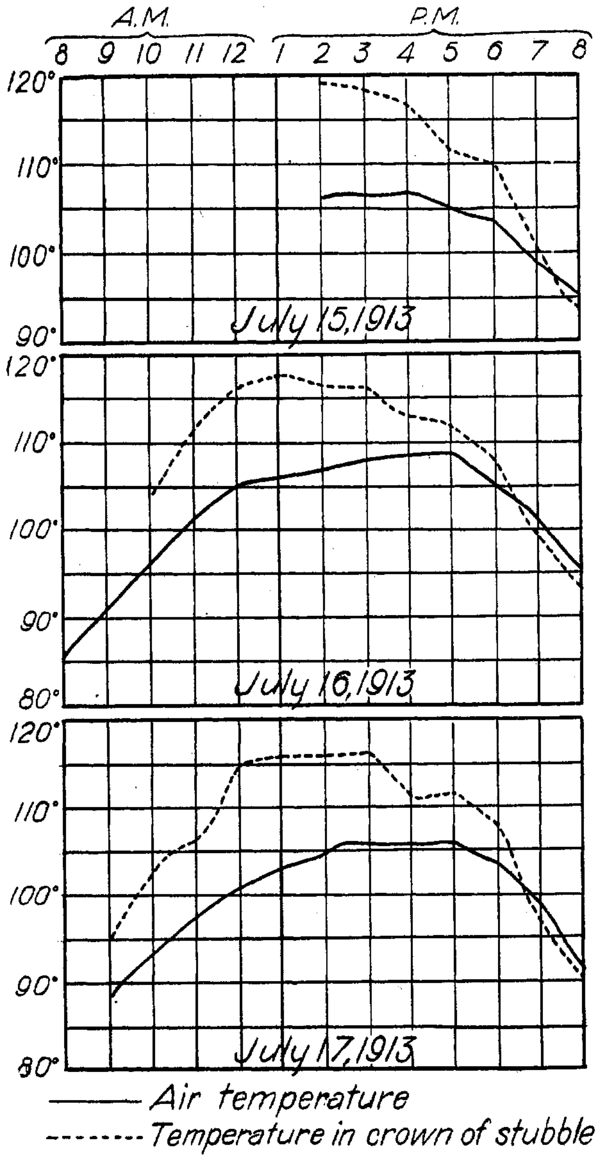


FIG. 23. Chart showing the hourly temperature in the crown of wheat stubble when the air temperature was above 100° F., July 15 to 17, 1913.

The number of broods is also reduced by low temperature as well as by low rainfall.

EFFECT OF MOISTURE.

Moisture is an important factor in the life economy of the Hessian fly. Undoubtedly it has a much greater influence than temperature. In the life-history studies under constant conditions it was found that the fly developed rapidly at temperatures of from 70° to 90° F. provided the relative humidity was 70 per cent or above. At a relative humidity of 60 per cent and below the eggs rarely hatched, and if they did the larvæ were unable to make any progress on the leaf. Observations in the field and in the rearing

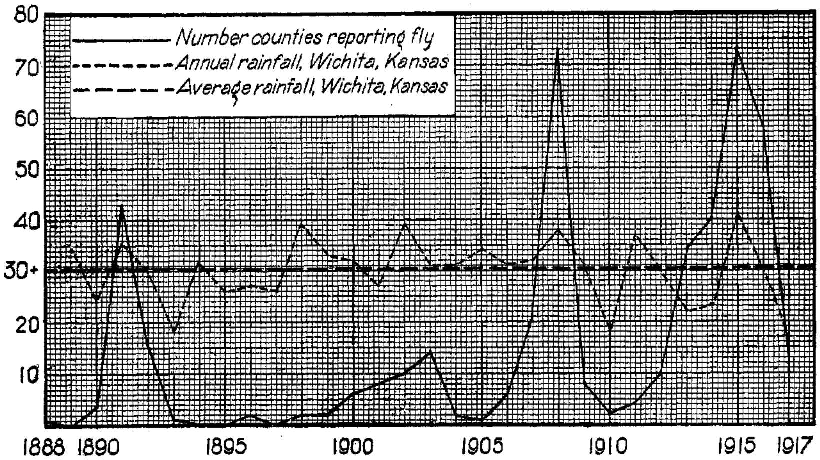


FIG. 24. Chart showing the relation of rainfall to the last four outbreaks of the Hessian fly. Rainfall records are for Wichita.

boxes have shown that the first spring brood comes out shortly after the spring rains begin and the main fall brood follows the fall rains. During the years 1912 to 1917 only one midsummer brood appeared, and that was in 1915, a year of abnormally high summer rainfall.

Hard rains and prolonged submergence are not detrimental to the fly. Examinations made in the field after hard, beating rains have shown that few, if any, of the eggs have been dislodged or injured. Wheat leaves bearing eggs have been submerged from the time the eggs were laid, and in nearly every case the eggs have hatched. Newly hatched larvæ have lived for at least 123 hours on wheat leaves submerged in water. Full-grown larvæ were found on wheat plants at Marysville that had been under water for a period of two weeks. Fifty flaxseed were submerged for one week, and on removal adults emerged from 24 per cent of them. Another lot of 50 flaxseed were left in water for a period of two weeks and 14 per cent yielded adults. In the latter case the puparia were punctured in several places to insure the penetration of the water. The adult flies were not able to withstand submergence of any length of time, but they were able to live for several days floating on the surface, and oviposition was noted under such conditions. In six cases where the flaxseed were placed under water the pupæ emerged from the submerged puparia, and in one case an adult fly emerged.

RELATION OF RAINFALL TO THE FLY.

A definite relation between rainfall and outbreaks of the fly occurs. Studies of rainfall records at Wichita, in relation to the last four outbreaks (fig. 24), show a number of interesting facts in this regard. The records of the Wichita Weather Bureau station are used, since Wichita is located in the heart of these outbreaks and the records are typical of much of the infested area. It has been stated that these outbreaks reached their maximum in 1892, 1903, 1908 and 1915. In three cases these were years of excessive rainfall. In the case of the outbreak of 1903 there was a superabundance of rain during the spring months and during the time that most of the injury occurred. The decline of each outbreak was accompanied by a decrease in the precipitation, which was generally much below the normal. It is also interesting to note that each outbreak started in a year of high rainfall.

A direct relation occurs also between rainfall and the number of broods, as is shown by a comparison of the monthly precipitation at Wichita and the number of generations present in the field. (Fig. 25.)

In 1913 the April rainfall was about normal and there was a heavy first spring brood. During May and June the rainfall was considerably below normal and the second spring brood was only moderate. A large amount of rainfall in September and October is associated with a large main fall brood.

The rainfall of April, May and June, 1914, was approximately normal and the two spring broods were large. The fall rains were also copious and the main fall brood was heavy. A light supplementary fall brood also appeared. The year 1915 was characterized

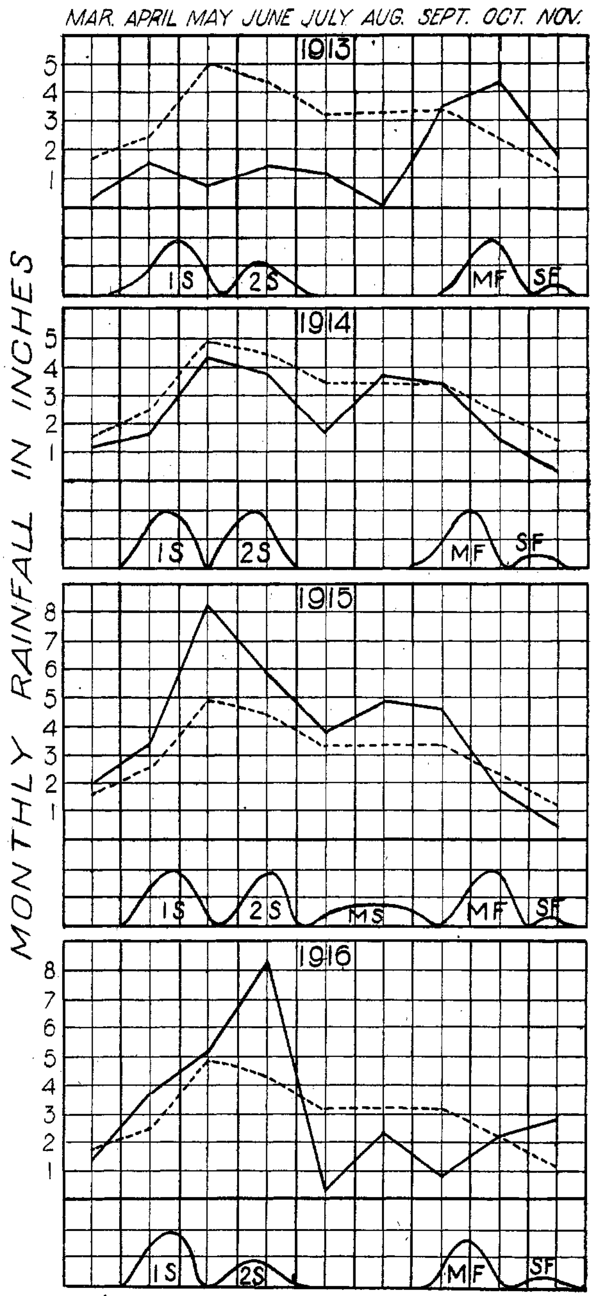


FIG. 25. Chart showing the relation of rainfall to the number of broods. Solid line shows the monthly rainfall; dotted line the average monthly rainfall at Wichita. 1S, first spring brood; 2S, second spring brood; MS, midsummer brood; MF, main fall brood; SF, supplementary fall brood.

by excessive rainfall during the spring, summer, and fall months, with the result that there were five broods of the fly. During 1916 the rainfall was above the average during the spring, and two broods appeared. Good rains in October and November were accompanied with a heavy main fall brood and a light supplementary fall brood. The summer rainfall in 1913, 1914 and 1916 was much below normal, and the midsummer brood did not appear.

PARASITES.

The Hessian fly is attacked by a number of parasites which are an important factor in aiding in the control. Five primary parasites *(Merisus destructor* Say, *Micromelus subapterus* Riley, *Eupelmus allynii* French, *Polygnotus hiemalis* Forbes, and *Platygaster herrickii* Packard) and one secondary parasite *(Tetrastichus* sp.) have been reared from Hessian-fly flaxseed collected in this state. Other parasites are known to attack the fly, but they have not been reared in connection with the work at this station. *Eupelmus allynii* may also be classed as a secondary parasite, since it has been reared on the larvæ of *Micromelus subapterus* and *Merisus destructor* as well as on the larvæ of the Hessian fly (Packard, 1916, p. 372).

EFFICIENCY OF PARASITES.

During the winter of 1913-'14 counts were made of the number of flaxseed parasited in the stubble of the previous crop. This material came from McFarland, where the fly had been especially bad. Table XXVI gives the per cent of parasitism in the material examined.

TABLE XXVI.—Parasitism among flaxseed in old wheat stubble.
(McFarland.)

Date collected.	Number of flaxseed.	Number parasitized.	Per cent parasitized.	Condition of parasitized flaxseed.		
				Emerged.	Dead.	Alive.
11-13-'13	248	95	38.3	88	7	0
11-28-'13	819	312	38.0	277	35	0
12-10-'13	12	4	33.3	3	1	0
3-14-'14	157	51	32.4	45	6	0
4-13-'14	272	161	59.1	131	10	20

LOCATION OB PARASITES.

The location of parasitized flaxseed was determined in a number of instances from material collected at several localities. These data are shown in Table XXVII.

TABLE XXVII.—Location of parasitized flaxseed on the wheat plant.

Place of collection.	Date of collection.	Number of parasitized flaxseed found	Location of flaxseed on plant.				
			Crown.	1st joint.	2d joint.	3d joint.	4th joint.
McFarland........	3-14-'14	51	0	28	23	0	0
McFarland........	4-13-'14	161	0	100	59	2	0
McFarland........	6- 9-'14	?	11	54	2	0	0
McFarland........	6-17-'14	?	0	2	6	1	0
Winfield...........	6-22-'15	?	0	14	10	0	0
Wellington........	6-29-'15	?	0	11	9	2	0
Newton...........	6-22-'16	?	3	3	8	2	1

LIFE HISTORY.

In this study little attention has been given to the life history of the various species of parasites attacking the Hessian fly. Packard (1916) worked out the life history of *Merisus destructor, Eupelmus allynii* and *Micromelus subapterus* under laboratory conditions at Wellington. The data at hand add nothing new to his results.

RELATIVE NUMBER OF FLIES AND PARASITES.

A comparative study of the number of Hessian flies and parasites issuing from different lots of collected material is of especial interest. Table XXVIII shows some of the more interesting data. It will be noticed that *Micromelus subapterus* has been the predominating parasite and *Merisus destructor* is next in efficiency. *Polygnotus hiemalis* was rare except in some of the rearings from the 1917 material. For the most part all species of parasites were present in varying numbers over most of the fly-infested area. In nearly every case material that yielded a large number of flies gave up few parasites, and conversely material that produced a large number of parasites yielded few flies.

TABLE XXVIII.—Numbers of both Hessian flies and parasites reared from different lots of infested wheat.

Place of collection.	Date of collection.	Number of flies or parasites found.					
		Flies.	(a).	(b).	(c).	(d).	(e).
Manhattan	6-17-'16	3	5	8	142	0	0
McFarland	Fall 1913	0	15	1	1	0	0
McFarland	8- 4-'14	0	11	2	0	0	0
McFarland	6-17-'14	0	6	2	20	0	0
McFarland	10- 2-'13	0	29	3	0	0	0
McFarland	6- 9-'14	16	87	1	68	0	0
McFarland	5-13-'14	146	2	0	112	0	0
McFarland	4-13-'14	0	18	0	2	0	0
McFarland	11- 6-'13	3	10	0	1	0	0
McFarland	10- 6-'13	0	21	0	1	0	0
McFarland	4- 3-'16	507	1	1	7	0	1
McFarland	8-11-'14	0	1	0	0	0	0
McFarland	5-31-'16	7	1	2	3	0	0
McFarland	11- 2-'15	15	0	0	1	0	0
Leavenworth	6-20-'14	3	101	53	65	0	0
Leavenworth	7- 7-'14	0	1	95	10	0	0
Leavenworth	7-26-'14	30	11	6	0	0	0
Leavenworth	8- 4-'14	0	2	16	0	0	0
College farm	7- 4-'13	8	84	5	0	0	0
College farm	7-13-'16	35	12	54	109	0	1
College farm	10-30-'15	47	0	0	0	4	2
Salina	7-12-'14	9	28	11	31	0	0
Minneapolis	7-11-'14	34	49	33	12	0	0
Winfield	6-10-'15	17	0	1	0	1	0
Winfield	6-22-'15	380	20	4	0	0	0
Winfield	8-12-'15	27	14	16	1	0	0
Winfield	7- 7-'15	12	101	1	1	0	1
Winfield	7-12-'15	0	3	1	0	0	0
Rock	6-24-'14	2	47	13	23	0	0
Wellington	6-29-'15	111	18	5	0	0	0
Wellington	5-13-'16	283	2	0	24	0	0
Bern	5-20-'14	69	0	0	20	0	0
Newton	6-22-'16	211	11	3	1	0	0
Ent. Plots	7- 5-'16	2	15	15	10	0	0
Arkansas City	3-13-'16	3	35	4	0	0	1
Agri. Nursery	3-24-'17	122	0	0	1	59	0
Ent. Plots	4-15-'17	6	0	0	0	21	0
Ent. Plots	6- 9-'17	3	1	0	0	19	0

(a) *Merisus destructor;* (b) *Eupelmus allynii;* (c) *Micromelus subapterus;* (d) *Polygnotus hiemalis;* (e) *Platygaster herrickii.*

MERISUS DESTRUCTOR SAY.

Distribution. *Merisus destructor* is one of the most efficient parasites in Kansas. It has occurred in nearly every fly-infested locality in sufficient numbers materially to reduce the number of flies present. The distribution in Kansas by years, as shown by rearings from collected material, is summarized in Table XXIX.

TABLE XXIX.—Distribution of *Merisus destructor* in Kansas as ascertained from collected materials.

Place of collection.	Date of collection.	Where found.	Year.				Total.
			1914.	1915.	1916.	1917.	
McFarland	10- 2-'13	Stubble	29	0	0	0	29
McFarland	10- 6-'13	Volunteer	21	0	0	0	21
McFarland	Fall, 1913	Stubble	15	0	0	0	15
McFarland	11- 6-'13	Regular crop	10	0	0	0	10
McFarland	4-13-'14	Stubble	18	0	0	0	18
McFarland	5-13-'14	Regular crop	2	0	0	0	2
McFarland	6- 9-'14	Regular crop	31	1	0	0	32
McFarland	6- 9-'14	Regular crop	26	23	0	0	49
Manhattan (*a*)	7- 4-'13	Stubble	39	1	0	0	84
Leavenworth	6-20-'14	Stubble	12	60	21	0	93
Leavenworth	7- 7-'14	Stubble	1	0	0	8	9
Minneapolis	7-11-'14	Stubble	1	48	4	0	53
Salina	7-12-'14	Stubble	3	25	0	0	28
Rock	6-24-'14	Stubble	42	5	5	0	52
Leavenworth	7-26-'14	Stubble	0	11	0	0	11
McFarland	8- 4-'14	Stubble	0	4	7	1	12
Wellington	6-29-'15	Regular crop	......	18	0	0	18
Winfield	6-22-'15	Regular crop	......	20	0	0	20
Winfield	7-7, 12-'15	Stubble	......	73	6	15	94
Winfield	8-12-'15	Stubble	......	2	12	0	14
Manhattan	7- 7-'15	Stubble	......	11	1	1	13
Paola	9-20-'15	Stubble	......	......	2	0	2
McFarland	11- 2-'15	Volunteer	......	......	1	0	1
Paola	9-20-'15	Volunteer	......	......	3	0	3
Paola	8-10-'15	Stubble	......	......	2	0	2
Winfield	8-12-'15	Threshed straw	......	......	1	0	1
Arkansas City	3- 3-'16	Stubble	......	......	35	0	35
Wellington	5-13-'16	Regular crop	......	......	2	0	2
Wabaunsee	5-23-'16	Regular crop	......	......	14	0	14
Basehor	5-26-'16	Regular crop	......	......	6	0	6
Newton	6-22-'16	Regular crop	......	......	5	6	11
McFarland	5-31-'16	Regular crop	......	......	1	0	1
Hays	6-10-'16	Regular crop	......	......	1	0	1
Ent. Plots	7- 5-'16	Stubble	......	......	12	3	15
Manhattan	7-13-'16	Stubble	......	......	5	7	12

(*a*) In 1913, 44 specimens were reared from this material.

From the data given in Table XXX, *Merisus destructor* is seen to be of general distribution over the fly-infested area. The largest numbers of these parasites were reared from stubble. In the case of the stubble collected at Leavenworth, June 20, 1914, parasites continued to emerge until June 6, 1917. Only one parasite was bred from threshed straw.

Period of Emergence. *Merisus destructor* emerges for the most part during May and June, although in 1915 a large number were reared in July. The data on this point are summarized in Tables XXX and XXXI.

TABLE XXX.—Months of emergence of *Merisus destructor*.

Month.	1913.	1914.	1915.	1916.	1917.	Total.
May	0	136	147	90	15	388
June	0	92	31	37	28	188
July	14	46	131	23	0	214
August	30	0	3	0	0	33
September	0	0	1	0	0	1

TABLE XXXI.—Periods of emergence of *Merisus destructor*.

Emergence.	1914.	1915.	1916.	1917.
First	5-3	5-10	5-5	5-23
Maximum	6-1	6-2	5-27	6- 4
Last	7-22	9-1	7-26	6-18
Days in period of	80	114	82	26

Location. Some data were collected with reference to the location of the parasites on the plant. These are summarized in Table XXXII.

TABLE XXXII.—Location of parasites on the wheat plant.

Place of collection.	Date of collection.	Location of parasite on plant.				
		Crown.	1st joint.	2d joint.	d joint.	4th joint.
Manhattan	6-15-'14	0	1	4	0	0
McFarland	6- 9-'14	3	43	2	0	0
Wellington	6-29-'15	0	10	8	0	0
Winfield	6-22-'15	0	11	9	0	0
Newton	6-22-'16	1	1	6	2	1

Proportion of Sexes. The proportion of sexes was determined for 589 of the parasites reared since 1914. Of this number, 313, or 53 per cent, were males, showing that males predominated to a small extent.

MICROMELUS SUBAPTERUS RILEY.

Distribution. This species occurs generally over most of the fly-infested area and during the past outbreak has been the most efficient parasite reared. It is peculiar in that both winged and wingless forms appear. In the rearing at this station the wingless form has predominated over the winged in the ratio of about 3 to 1.

This species has been present in relatively large numbers every year since 1913. It is interesting to note, however, that Headlee and Parker do not record it in connection with the outbreak of 1908. Table XXXIII gives the distribution of *M. subapterus* in Kansas according to the rearings from collected material.

TABLE XXXIII.—Distribution of *Micromelus subapterus* in Kansas as ascertained from collected material.

Place of collection.	Date of collection.	Where found.	Year. 1914.	1915.	1916.	1917.	Total.
McFarland	4-13-'14	Stubble	2	0	0	0	2
McFarland	5-13-'14	Regular crop	112	1	0	0	113
McFarland	6- 9-'14	Regular crop	71	2	1	0	74
McFarland	6-17-'14	Regular crop	19	0	0	0	19
McFarland	11- 2-'15	Volunteer	....	....	1	0	1
McFarland	4- 3-'16	Regular crop	....	....	7	0	7
McFarland	5-31-'16	Regular crop	....	....	3	0	3
Leavenworth	6-20-'14	Stubble	65	0	0	0	65
Leavenworth	7- 7-'14	Stubble	10	0	0	0	10
Rock	6-24-'14	Stubble	23	0	0	0	23
Salina	7-12-'14	Stubble	23	8	0	0	31
Minneapolis	7-11-'14	Stubble	10	2	0	0	12
Bern	5-20-'14	Regular crop	18	2	0	0	20
Marysville	4-22-'15	Regular crop	....	1	0	0	1
Winfield	7- 7-'15	Stubble	....	1	0	0	1
Winfield	3-13-'15	Burned stubble	....	0	1	0	1
Winfield	8-12-'15	Stubble	....	0	1	0	1
Winfield	8-12-'15	Threshed straw	....	0	1	0	1
Manhattan	10-30-'15	Volunteer	....	0	1	0	1
Manhattan	5-25-'16	Regular crop	....	....	7	0	7
Manhattan	7-10-'16	Stubble	....	....	13	2	15
Manhattan	7-13-'16	Stubble	....	....	60	49	109
Manhattan	6-17-'16	Regular crop	....	....	142	0	142
Paola	9-20-'15	Stubble	....	....	1	0	1
Hays	6-10-'16	Regular crop	....	....	1	0	1
Ellsworth	6- 3-'16	Regular crop	....	....	3	0	3
Wellington	5-13-'16	Regular crop	....	....	24	0	24
Newton	6-22-'16	Regular crop	....	....	1	0	1

In the rearing work it is interesting to note that one specimen emerged May 17, 1916, from wheat collected June 9, 1914. Another individual was bred from threshed straw, and a third from stubble that had been burned over

Period of Emergence. The maximum emergence of *Micromelus subapterus* usually occurs in June or July. Emergence may begin as early as the last of April and continue into September. Tables XXXIV and XXXV summarize the data on the period of emergence.

TABLE XXXIV.—Months of emergence of *Micromelus subapterus.*

Month.	1914.	1915.	1916.	1917.	Total.
April	0	0	1	0	1
May	7	7	10	24	48
June	159	9	12	28	208
July	171	1	56	0	228
August	5	0	47	0	52
September	17	0	0	0	17

TABLE XXXV.—Periods of emergence of *Micromelus subapterus.*

Emergence.	1914.	1915.	1916.	1917.
First	5–3	5–11	4–19	5–23
Maximum	6–26	6–2	7–26	6–1
Last	9–28	7–22	8–27	6–18
Days in period of	148	72	99	26

Location. The number of this species reared from the different joints of the plant is not sufficient to draw any conclusions. The data at hand show that eleven parasites emerged from flaxseed taken at the crown, eleven from the first joint, one from the second joint, and one from the third joint.

EUPELMUS ALLYNII FRENCH.

Distribution. *Eupelmus allynii* has been taken rather generally as far west as Hays. (Table XXXVI.) It has never occurred in abundance in the material kept in the rearing boxes. This parasite not only attacks the Hessian fly, but also two of its parasites, *Merisus destructor* and *Micromelus subapterus,* and therefore its importance as a beneficial parasite of the Hessian fly is rather obscure. In addition, it has been reared on larvae of *Isosoma* sp. (Packard, 1916.)

TABLE XXXVI.—Distribution of *Eupelmus allynii* in Kansas as ascertained from collected materials.

Place of collection.	Date of collection.	Where found.	Year.			Total.
			1914.	1915.	1916.	
McFarland	Fall, 1913	Stubble	1	0	0	1
McFarland	10- 2-'13	Volunteer	3	0	0	3
McFarland	6- 9-'14	Regular crop	1	0	0	1
McFarland	6-17-'14	Regular crop	1	0	0	1
McFarland	8- 4-'14	Stubble	1	0	0	1
Leavenworth	6-20-'14	Stubble	53	0	0	53
Leavenworth	7- 7-'14	Stubble	95	0	0	95
Leavenworth	7-26-'14	Stubble	6	0	0	6
Leavenworth	8-10-'14	Stubble	15	1	0	16
College farm	7- 4-'13	Stubble	5	0	0	5
Minneapolis	7-11-'14	Stubble	30	3	0	33
Salina	7-12-'14	Stubble	9	2	0	11
Rock	6-24-'14	Stubble	13	0	0	13
Winfield	6-10-'15	Regular crop	....	1	0	1
Entomological plots	7- 7-'15	Regular crop	....	5	0	5
Wellington	6-29-'15	Regular crop	....	5	0	5
Winfield	6-22-'15	Regular crop	....	4	0	4
Winfield	8-12-'15	Stubble	....	16	0	16
Paola	8-12-'15	Stubble	....	4	0	4
Manhattan	9- 1-'15	Volunteer	....	2	0	2
Entomological plots	6-17-'15	Regular crop	....	11	0	11
Paola	9-20-'15	Stubble	....	0	4	4
Arkansas City	3-13-'16	Stubble	....	....	4	4
Entomological plots	5-25-'16	Regular crop	....	....	1	1
McFarland	5-31-'16	Regular crop	....	....	2	2
Hays	6-19-'16	Regular crop	....	....	3	3
Entomological plots	7- 5-'16	Regular crop	....	....	14	14
Newton	6-22-'16	Regular crop	....	....	5	5
College farm	7-13-'16	Stubble	....	....	54	54

Period of Emergence. The maximum emergence of this species occurs during July. Emergence usually began in May and continued until the first of October. Apparently only one generation develops each year. Tables XXXVII and XXXVIII show the data on emergence.

TABLE XXXVII.—Months of emergence of *Eupelmus allynii.*

Month.	1914.	1915.	1916.	Total.
May	1	1	6	8
June	11	6	5	22
July	156	8	68	232
August	39	21	8	68
September	12	9	1	22
October	1	0	1	2

TABLE XXXVIII.—Periods of emergence of *Eupelmus allynii.*

Emergence.	1914.	1915.	1916.
First	5–29	5–31	5–21
Maximum	7–26	8–14	7–19
Last	10–16	9–27	10–2
Days in period of	140	120	134

Proportion of Sexes. The proportion of sexes was determined for 229 parasites reared in 1914. Of these 111, or 50 per cent, were males.

POLYONOTUS HIEMALTS FORBES.

Distribution. This species has been prevalent in the northeastern part of Kansas. Previous to 1917 it occurred in very limited numbers, but in 1917 it was especially numerous in the vicinity of Manhattan, and there is some indication that it aided in arresting the present outbreak.

Polygnotus is of especial interest, since it deposits its eggs in the egg of the Hessian fly, but the eggs do not hatch until after the fly egg does. The parasite larvae feed within the fly larva, but do not kill it until after the puparium is formed. As many as 40 adult *Polygnotus* have been reared from a single flaxseed. Table XXXIX shows the localities from which *Polygnotus* was bred and the numbers emerging.

TABLE XXXIX.—Distribution of *Polygnotus hiemalis* in Kansas as ascertained from collected materials.

Place of collection.	Date of collection.	Where found.	Year.		
			1915.	1916.	1917.
Severance	2-15-'15	Regular crop	1	0	0
Marysville	4-22-'15	Regular crop	3	0	0
Waterville	....	....	1	0	0
Winfield	6-10-'15	Regular crop	1	0	0
Paola	8-12-'15	Stubble	1	0	0
Manhattan	10-30-'15	Volunteer	0	4	0
Ellsworth	6- 3-'16	Regular crop	....	1	0
Hays	6-10-'16	Regular crop	....	7	0
Manhattan	7-10-'16	Stubble	....	7	0
Manhattan	10-13-'16	Volunteer	....	....	1
Manhattan	3-24-'17	Winterkilled	....	....	59
Manhattan	3-31-'17	Winterkilled	....	....	6
Manhattan	3-24-'17	Regular crop	....	....	5
Manhattan	3-31-'17	Regular crop	....	....	27
Manhattan	4-15-'17	Regular crop	....	....	21
Manhattan	6- 9-'17	Regular crop	....	....	19

Period of Emergence. Practically all the emergence from the rearing boxes occurred during May and June, although a few were reared as late as October. Tables XL and XLI show the emergence by months and the period of emergence.

TABLE XL.—Months of emergence of *Polygnotus hiemalis.*

Month.	1915.	1916.	1917.	Total.
May	0	0	48	48
June	3	9	90	102
July	1	0	0	1
August	2	0	0	2
September	0	3	0	3
October	0	7	0	7

TABLE XLI.—Periods of emergence of *Polygnotus hiemalis.*

Emergence.	1915.	1916.	1917.
First	6–14	6–12	5–23
Maximum	6–15	6–26	6–2
Last	8–15	10–27	6–24
Days in period of	62	137	31

PLATYGASTER HERRICKII PACKARD.

Distribution. Very few specimens of this species were reared during the past four years. Apparently it has played a small part in reducing the number of flies present. Table XLII summaizes the data on distribution.

TABLE XLII.—Distribution of *Platygaster herrickii* in Kansas as ascertained from collected materials.

Place of collection.	Date of collection.	Specimens reared in 1916.
Arkansas City	3-13-'16	1
Winfield	7- 7-'15	1
Manhattan	5-12-'16	1
Kensington	4- 2-'16	1
College farm	10-30-'15	2
College farm	7-13-'16	1
McFarland	4- 3-'16	1

PREDACEOUS ENEMIES.

Few predatory enemies are known to attack the Hessian fly. Marchal (1897) found nematodes in the puparia and in the infested straw, but at no time within the body of the larvæ, although they had the appearance of having been destroyed by them. The writer has often found nematodes associated with full-grown larvae and flaxseed, but has never been able to demonstrate that they are injurious to them. It has been possible, however, to rear many generations of the nematodes on the crushed larvae and flaxseed.

Adult flies have often been found in spider webs in wheat fields. A small, reddish mite has been observed many times at Manhattan and McFarland feeding on the eggs of the fly. An ant *(Solenopsis molest* Say) was observed attacking Hessian-fly larvae at Winfield in 1915. Headlee and Parker (1913, p. 112) record the larvæ of a fungus gnat *(Sciara* sp.) feeding on the flaxseed. They also mention finding what was thought to be a wireworm destroying flaxseed in western Kansas. These worms were feeding on the wheat plants, and incidentally destroyed the flaxseed. The writer found the false wireworm *(Eleodes opaca* Say) similarly destroying flaxseed at Turon. In 1914 grasshoppers invaded a plot of wheat used in the experimental work on the fly and destroyed most of the leaves. As the leaves bore a large number of fly eggs, doubtless many were destroyed. The plants recovered from the grasshopper injury and were practically free from the fly.

ARTIFICIAL CONTROL.

The control of the Hessian fly, like the control of most of the cereal-crop insects, is of necessity largely a matter of prevention and is dependent primarily on good farm management and cooperation. The control of any injurious insect is based principally on a thorough knowledge of the important factors in the life economy. In the case of the Hessian fly these factors are: (1) the life history of each brood, (2) the number of broods, (3) the source of each brood, (4) the period of emergence, and (5) the effect of climatic conditions.

During the 140 years that the fly has been recognized in the United States numerous measures have been advocated for its control. Many of these methods have no foundation, some may prove effective under certain conditions, while others have proved especially efficient under the most trying conditions. The development of the control measures has now reached a point where it may be said that over most of the fly-infested area of Kansas wheat may be raised in spite of the fly.

In discussing the various measures of control, brief mention will be made of the impractical methods, since many of them are revived during each outbreak and considerable reliance is placed in them by a small number of wheat growers to the detriment of the practical measures.

IMPRACTICAL MEASURES OF CONTROL.

ROLLING.

Many farmers urge the rolling of the field either in the fall or in the spring to destroy the fly. They argue that rolling will crush the eggs on the leaves and also the maggots and flaxseed at the crown of the plant. They do not realize that pressure sufficient to crush the various stages will also be injurious to the plant. The destruction of the eggs by this method is out of the question, since the period of oviposition may occupy a month or more, and this would necessitate rolling every few days.

PASTURING.

One of the earliest methods advocated for the destruction of the fly, and one that is still held by many farmers, is the pasturing of wheat with live stock. The claim for this method is that the eggs will be destroyed by feeding and the larvæ and flaxseed will be killed by trampling. If the life history of the fly is associated with the common practice of grazing the futility of this method becomes apparent. As has been pointed out, egg-laying occurs early in the fall and during April and May. On the other hand, the pasturing season is from the first of November to about the first of April. To pasture wheat at other times is detrimental to the crop. In order to prevent egg-laying it would be necesary for the plants to be kept eaten to the ground for several weeks. As for the crushing of the other stages by the hoofs of the stock, it must be remembered that during the winter the fly is at the crown of the plant an inch or more below the surface, and that trampling sufficient to destroy the fly would also injure the wheat plant.

SPRAYING.

The use of various sprays for the control of the Hessian fly has attracted the attention of a number of workers. The experiments thus far conducted, however, have given negative results; and there is no indication that spraying ever will be practical. In the first place, the location of the larvæ on the plant is inaccessible to spraying. In the second place, the cost of materials and apparatus necessary to spray a wheat field the size of those in Kansas precludes this method.

MOWING.

Among the earlier methods advocated for the control of the fly was that of mowing the wheat in the spring after the first brood had emerged and infested the plants. The object of this treatment was to destroy the larvæ developing at the various joints, and also to remove leaves bearing eggs. The fallacy of this method is readily seen when we consider that a large per cent of the first spring brood develops at the crown of the plant. Mowing would also tend to delay harvest—a factor which would be favorable to the second spring brood.

TRAP PLANTING.

Many writers urge the planting of small plots or strips of wheat some time in advance of the regular planting. The adult fly on emerging would be attracted to this wheat and deposit its eggs here before the regular crop was up. The trap plantings should then be plowed under and the flies thus destroyed. The objection to this method is that it provides another source of infestation. Normally the infestation in the fall wheat comes from two sources—stubble of the preceding crop and volunteer and early-sown wheat. To plant these decoy plots of wheat would be adding to the chances of increasing the injury.

CONTROL MEASURES THAT MIGHT PROVE EFFICIENT UNDER SPECIAL CONDITIONS.

A number of methods of control, while not practical on a large scale, may prove beneficial under certain special or local conditions. They are not to be recommended, however, where it is possible to put into operation practical measures of control.

INTERMITTENT WHEAT CULTURE.

A serious Hessian-fly outbreak is generally followed by an effort on the part of some farmers to organize the community for the purpose of discontinuing wheat growing for a year or two. While no doubt the fly could be controlled by this method, yet it is not to be recommended. In Kansas wheat is one of the principal crops, and many fields are better adapted to the growing of wheat than any other crop. The uncertainty of weather conditions also necessitates the growing of more than one crop. It must be remembered that the fly will migrate long distances, and that it will breed in rye, barley, and certain of the wild grasses.

BURNING THE STUBBLE.

Burning the stubble in the summer is often recommended as an effective measure of control. Without doubt a large number of flaxseed will be destroyed by such procedure, but as has been pointed out, about 66 per cent of the flaxseed may be at the crown of the plant, where the fire will not reach them. It also must be remembered that a varying per cent of the flaxseed occurring above ground are parasitized. A large number of burned fields have been examined during the past four years, and in no case has a material reduction in injury been noticed. Collections of stubble from burned fields have yielded, on an average, about one-half as many flies as have collections from unburned fields. Headlee and Parker (1913, pp, 119, 120) investigated this point rather carefully, and they conclude that burning will not kill enough flaxseed to control the fly. Parks (1917), working in McPherson county, found that no protection was noticed where the stubble had been burned over the previous year, and that this method gave little encouragement. Burning should also be discouraged from another standpoint. The soils of Kansas are rapidly being depleted of humus, and it is of great importance that all of the available stubble and straw be returned to the soil. Fire is also a dangerous agent in a state like this, where the stubble acreage is so large.

RESISTANT VARIETIES.

It has long been recognized that certain varities of wheat exhibit varying degrees of resistance to Hessian-fly injury. Such varieties as Underhill, Mediterranean, Clawson, Lancaster, and Dawson's Golden Chaff have been mentioned in this connection. The work of this station on the different varieties confirms the fact that there is such a thing as resistance to Hessian-fly injury. As has been pointed out in the discussion on the "Susceptibility of different varieties of small grain to Hessian fly injury," one variety, Illini Chief, was entirely free from infestation, while other adjacent varieties were heavily infested. Other varieties, as Red Winter No. 2132, Nigger, Fulcaster, Beechwood Hybrid, Miracle, Currell P. 1092, Valley, Rudy, Dawson's Golden Chaff, and Dietz had a very low per cent of infestation.

The fact that a variety is resistant to the fly, however, does not mean that it is the variety to raise. It must also be a good yielder, be able to withstand the climatic conditions of the locality, be of good milling quality, and meet a number of other important requirements. With the successful methods now known for the control of the fly, the growing of fly-resisting wheats is to be recommended only when those wheats meet the other requirements.

The variety Illini Chief has been grown in variety tests in southeastern Kansas and has proved a good-yielding wheat in the soft-wheat section of the state. It is not a good variety for central and western Kansas, as it has not been able to survive severe winter weather and has been one of the first varieties to winterkill. For this reason it cannot be recommended generally, although it may prove a good wheat for southeastern Kansas.

FERTILIZERS.

The use of fertilizers, either commercial or barnyard manure, is often recommended where the field is infested with the fly. Fertilizers are not an insecticide and will not destroy the fly, but they may stimulate growth, and if the infestation is light they may enable the plants to overcome the injury.

ROTATION OF CROPS.

The rotation of crops is to be recommended more because of its general value to the crop and to the soil than of its value as a means of preventing fly injury. The changing of the wheat land necessitates the migration of the fly from one field to another, and allows the element of chance to enter in. While it has been definitely established that the fly may migrate for considerable distances, the possibility of successfully reaching other wheat fields is limited. When rotation is practiced the stubble on the old wheat land should be plowed early in the fall. Otherwise the flies emerging from this source will migrate to near by fields.

PRACTICAL MEASURES OF CONTROL.

As has been stated, the control of the Hessian fly is largely a matter of prevention. Once the fly infests the crop there are no remedial measures that can be applied. A study of the source of the broods shows that the infestation in the fall wheat comes from two sources—the stubble of previous crops and volunteer and early-sown wheat. The control of the fly then becomes a matter of handling these sources of infestation in such a manner as to destroy the fly and prevent the infestation of the fall wheat. With the knowledge of the life history of the fly under varying conditions, it has been possible to devise a method of control which is not only effective against the fly, but is practical from the standpoint of good farm management.

SEEDBED PREPARATION.

The preparation of the seedbed has an important bearing on the control of the fly as well as on the yield of wheat. Call (1913) has shown that deep, early plowing is conducive to higher yields; that early listing is better than late plowing; and that early disking followed by medium early plowing is a good farm practice. The same practices that are conducive to maximum yields are also conducive to the minimum amount of Hessian-fly injury.

Since infestation in the fall wheat comes mainly from two sources—stubble of previous crops and volunteer wheat—for effective fly control it is imperative that these sources be eliminated. This can be done by plowing the land soon after harvest to a depth of about 7 inches. Care should be taken to turn the stubble under at least 3 inches of soil, since it has been found that the number of flies emerging decreases with an increase in the depth of plowing. The rolling coulter and jointer has been very efficient in the covering of stubble, weeds, volunteer wheat, and trash. By its use this material is so deeply covered that in harrowing it is not pulled out on the surface where the flies can emerge successfully.

If it is not possible to plow soon after harvest, the land should be thoroughly disked by the middle of July. Disking not only conserves the moisture and makes plowing easier, but also starts the growth of volunteer wheat, and this is conducive to the early emergence of the fly. Approximately a month after disking, the land should be plowed to a depth of 6 or 7 inches.

After plowing, the ground should be worked down into a good seedbed. The soil should be kept mellow and free from weeds and volunteer wheat until wheat-seeding time. The experiments of the Department of Agronomy of the Kansas Agricultural Experiment Station have shown conclusively that ground prepared in the above manner not only produces the maximum yields of wheat, but may be planted with safety later in the season.

In order to determine the effect of various methods of seedbed preparation on the emergence of the fly, cages were placed over a portion of each of the seedbed preparation plots on the agronomy farm. These cages were of India linen and covered areas of 4 square feet each. All cages were placed July 15, 1916, and examined daily until the last of October. The data summarized in Table XLIII show a marked reduction in the number of flies emerging in the early-prepared plots. There is little difference in the number of flies emerging from the plowed, double-disked, and listed plots of July 15. In the plots plowed 7 inches deep it will be noticed that the number of flies issuing increases with the delay in plowing. The data also show that any method of seedbed preparation is better than that of disking before sowing.

TABLE XLIII.—Emergence of flies from an area of 4 square feet under different conditions of seedbed preparation in 1916.

Cage No.	Method of seedbed preparation.	Number of flies emerging.		
		Female.	Male.	Total.
1	Plowed July 15, 3 inches deep	2	0	2
2	Plowed July 15, 7 inches deep	2	1	3
3	Plowed August 15, 7 inches deep	4	2	6
4	Plowed September 15, 7 inches deep	5	3	8
5	Double disked July 15, plowed Aug. 15, 7 inches deep.	3	0	3
6	Double disked July 15, plowed Sept. 15, 7 inches deep.	1	0	1
7	Listed July 15, ridges split August 15	2	0	2
8	Listed July 15, worked down	1	2	3
9	Disked at seeding	19	1	20

DESTRUCTION OF VOLUNTEER WHEAT.

Volunteer wheat is one of the greatest sources of fly infestation, especially to late-sown wheat. Conditions that are favorable to the germination of volunteer wheat are conducive also to the early emergence of the fly. Since this is the only food present, the flies infest it and later attack the regular crop. Parks (1917, p. 253) states that, in Kansas, destroying volunteer wheat should take first rank in the war against the Hessian fly. He bases this statement on a careful study of 306 wheat fields in McPherson county, which was made to determine the effect of time of sowing and the presence of volunteer wheat upon the degree of injury by the Hessian fly in this county in 1916. These data are shown in Table XLIV.

TABLE XLIV.—Effect of time of sowing and the presence of volunteer wheat upon the degree of Hessian-fly injury.

(McPherson county, 1916.)

Conditions.	Degree of infestation	Number of fields.	Percent of fields.
(1) SOWN BEFORE FLY-FREE DATE.			
With or without volunteer wheat	Slight	15	23.4
	Medium	12	18.8
	Heavy	37	57.8
(2) SOWN AFTER FLY-FREE DATE.			
With no volunteer wheat	Slight	78	73.6
	Medium	23	21.7
	Heavy	5	4.7
With some volunteer wheat	Slight	46	44.2
	Medium	40	38.5
	Heavy	18	17.3
With much volunteer wheat	Slight	1	3.1
	Medium	8	25.0
	Heavy	23	71.9

A comparison of the fields sown after the fly-free date shows that the subsequent infestation has a direct bearing on the amount of volunteer wheat present. Where no volunteer wheat occurred in the field, 73.6 per cent of the fields had but a slight infestation, while of the fields having much volunteer wheat 71.9 per cent had a heavy infestation.

The field investigations of this station bear out these results. Many cases of severe injury to late-sown fields can be attributed to volunteer wheat, either in the field or in an adjacent one. There is a tendency to leave stubble fields containing much volunteer wheat for spring crops. These are not plowed until the next spring, often after the spring emergence, and consequently serve as a source of infestation to the neighborhood.

LATE SOWING.

The late sowing of wheat was one of the earliest measures recommended for control of fly. Cooper (1799) was one of the first to suggest this method, and practically every writer since that time has given it as one of the most important measures. The theory of late sowing is based on a knowledge of the life history and habits of the fly with special reference to the number of broods and the time the main fall brood is present. As pointed out by Headlee (1912, p. 98), "There can be no doubt that the seasonal periodicity so characteristic of animals and plants generally is exhibited in both the Hessian fly and its host plants—that there is a period of time in the fall during which, under normal conditions of food supply, the emerging flies have the best possible opportunity to perpetuate their kind, and that there is likewise a period during which wheat placed in the soil stands the best chance to produce the maximum yield. This period may be designated as the normal time of fall-brood fly emergence and the normal time for wheat sowing, respectively. The problem of determining when wheat should be sown to escape the fall brood of the fly involves the explanation of the relationship existing between the normal period of fly emergence and the normal period of wheat sowing."

Webster (1899) attempted to explain this relationship in terms of latitude. He found that there was a difference in dates of appearance and normal periods of egg deposition due to a difference in latitude. Hopkins (1900, p. 241) found that latitude alone could not be used as a determining factor for the fly-free date, especially in hilly or mountainous country. As a result he expanded Webster's idea of latitude and included his observations on the effect of altitude on the fall emergence of the fly. The environmental factor operative on the fall emergence of the fly as expressed by latitude and altitude is apparently temperature. Headlee (1912) attempted to apply Hopkins' theory to Kansas conditions and found that it held very well for limited areas. When applied to widely separated localities (Marysville, Kan., and Columbus, Ohio, in this instance), however, there was a discrepancy of nine days or more. He attributed this difference to a difference in the normal annual precipitation, and states that if the latitude, altitude, and rainfall are known for a place where the fly-free date has been determined, it is possible to calculate the fly-free date for any other locality where these three factors are known.

Inasmuch as the best time to sow wheat to secure maximum yield varies with different sections of the state, with different seasons, and with other conditions, and since the fall appearance of the fly is correlated with a number of factors, the proper time of seeding must be determined for each locality by experimental sowings extending over a period of years.

In order to secure data bearing on the problem, a series of experimental sowings was begun in 1907 by Dr. T. J. Headlee, then entomologist, and A. M. Ten Eyck, then agronomist of the Kansas Agricultural Experiment Station. These sowings have now extended over a period of ten years, and it is planned to continue them over another similar period. The sowing in 1907 consisted of a single series of stations extending along the eastern edge of the wheat belt from the northern to the southern part of Kansas, but all subsequent sowings consisted of a double series of stations (fig. 26), one along the eastern and one along the western edge of the great

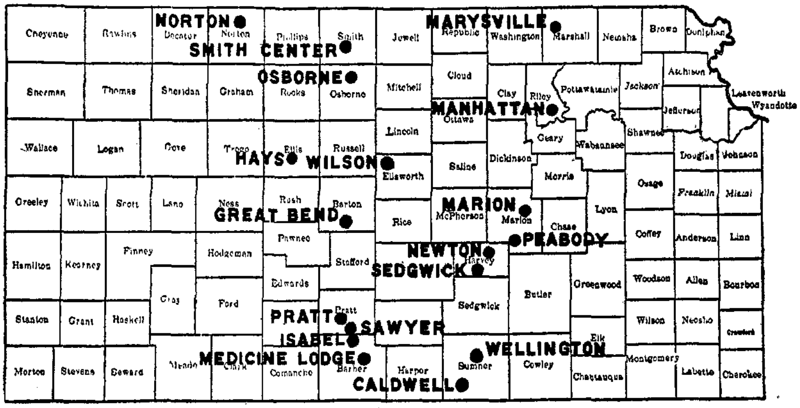


FIG. 26. Map of Kansas showing location of date-of-sowing experiments, 1907 to 1917.

central Kansas wheat belt. The individual stations of the eastern series are located at Marysville, Manhattan, Marion, Peabody, Newton, Sedgwick, Wellington, and Caldwell. The individual stations of the western series are located at Norton, Smith Center, Osborne, Hays, Wilson, Pratt, Sawyer, Isabel, and Medicine Lodge. Each sowing consisted of seeding a series of plots at weekly intervals for six or seven weeks, beginning the second week in September. The stations have been secured and managed coöperatively by the Departments of Agronomy and Entomology of the Kansas Agricultural Experiment Station. In all cases the ground was prepared, the seed selected and planted, and the crop harvested under the direction of the Department of Agronomy.

The following discussion summarizing the data on these experimental wheat sowings is taken largely from the work of Dean (1917):

1. In northeastern Kansas (Table XLV) the best yield in one year was obtained from seeding September 23, and in the five other years from seeding September 29 to October 18. The experiments show a very clear and definite decrease in the infestation of Hessian fly

with late seeding. In one season (1914) about half of the wheat sown before September 20 was infested, while none sown after the first week in October had any flies.

2. At Manhattan (Table XLV) in practically all seasons the best yields were obtained from seeding during either the fourth week in September or the first week in October. Even in several of the years when very little Hessian fly was present, early seeding was not advantageous. This is especially true if the ground is well prepared.

3. In east central Kansas (Table XLV) the best yields were obtained from seeding between September 29 and October 20. In the years of 1914-'15 and 1915-'16, wheat sown early was practically a total loss because of the fly, and in 1916-'17 the yield of the early plots was largely reduced.

4. In southeastern Kansas (Table XLV) the sowings seem to favor rather early seeding; that is, from September 15 to September 23, as shown by the results obtained in 1913 and 1914. However, the Hessian fly caused practically no damage in these two seasons. In the seasons of 1914-'15 and 1915-'16 all plots sown before October 1 were practically destroyed by the fly, and the late-sown wheat produced very small yields, because the flies that infested the early plots migrated in the spring into the late-sown plots and deposited their eggs in large numbers.

5. In north central Kansas (Table XLV) seeding should be done somewhat earlier than for points east and south. This is because the elevation and latitude shorten the season, and grain must be sown earlier to get a good start before winter. However, the seeding tests show that if Hessian fly is abundant seeding should be delayed until the first week in October.

6. In west central Kansas (Table XLV) the best yields have been secured from September seedings. Probably the best date for this section is from September 15 to September 20. However, as in other sections of the state, if the Hessian fly is present in damaging numbers, seeding should be delayed until October 1.

7. In Pratt and Barber counties (Table XLV) the seeding tests show that where no flies are present, seeding earlier than September 15 gives no better yields than somewhat later seeding. When flies are present, later seeding, up to October 1 on poor soil and October 6 or 7 on fertile soil and a well-prepared seedbed, will give better results than early seeding.

8. For the greater part of the wheat belt, with an average seed-

bed when Hessian fly is not present in damaging numbers, the maximum yield of wheat generally will be obtained by seeding a little earlier than the fly-free date. (Table XLVI.) The better the seed bed is prepared, the safer it is to wait until the fly-free date to sow. It should be understood that if the Hessian fly is present in damaging numbers and the wheat is seeded earlier than the fly-free date, there is a greater risk of the crop being injured by the fly, and, therefore, seeding should be delayed to as near the fly-free date as is practical.

9. According to Call, Salmon, and Cunningham (1916, p. 5), wheat sown late usually winterkills considerably. Since the roots do not penetrate the ground so deeply as when it is sown early, it is more subject to injury from drought and hot winds. Late-sown wheat tillers very little, and hence usually gives a thin stand. It ripens later, and in the eastern part of the state it is more likely to be injured by rust than wheat that is sown somewhat earlier. The quality of late-sown wheat is usually not as good as that of early-sown wheat. On the other hand, if Hessian fly is present in the neighborhood, wheat sown early is practically certain of fly injury, and in many instances is totally destroyed. In dry seasons very early seedings is often detrimental, because the heavy growth uses all the moisture stored in the soil and leaves the crop entirely dependent on seasonable rains. This happens frequently in the western edge of the wheat belt.

10. Early plowing of the stubble at least 5 inches deep is not only very effective in controlling the Hessian fly, but is also very conducive to a rapid growth of wheat in the fall. For this reason wheat may be sown considerably later on early deeply plowed ground. "When ground is plowed early, plant food is developed very rapidly and water is usually stored in the soil for the growth of the plant. As a result, growth is rapid, the plants tiller abundantly, and strong roots are developed before winter. Rather late seeding on a well-prepared seedbed will give much better yields than early seeding on poorly prepared ground, even when no Hessian flies are present. Also, wheat that has made a good growth is better able to resist attacks of the fly, since it tillers more and there are more stalks to take the place of those destroyed." (Call *et al.*, 1916, p. 14.)

11. Since many of the flies migrate considerable distances, early, deep plowing, to be effective, must be practiced by the entire neighborhood in such a manner as to include all infested fields, and

since it is usually impractical to plow all fields in a neighborhood early and deep, the only way to insure safety from the fall brood of fly is to sow after the fly-free date.

12. Late sowing alone will protect most of the wheat in the fall from becoming infested by the fall brood of the fly, but it should be remembered that there is also a main spring brood, and if any volunteer wheat is growing in the main field of wheat or in the old near-by stubble fields, or if there is a field of early-sown wheat, near by, the spring brood of flies emerging from infested plants about the first of April is very apt to infest the late-sown crop. Thus, wheat absolutely free from fly in the fall may become dangerously infested next spring by the spring brood. (Table XLVII.) In Kansas, in the springs of 1915 and 1916, hundreds of cases of this sort occurred, and they will probably always occur when there is a general infestation over a whole neighborhood. The Hessian fly will migrate in dangerous numbers for several miles, hence the importance of community coöperation cannot be overemphasized. One man with a field of volunteer wheat or with a field of early-sown wheat may endanger a number of wheat fields which were free from infestation in the fall.

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TABLE XLV.—Per cent of plants infested by the fall brood of Hessian fly, and yields obtained in Kansas date-of-seeding tests.

Year.	Place.	Seeding period—									
		September 6-10.	September 11-15.	September 16-20.	September 21-25.	September 26-30.	October 1-5.	October 6-10.	October 11-15.	October 16-20.	October 21-25.
NORTHEASTERN KANSAS.											
Per cent of Plants Infested by the Fall Brood of Hessian Fly.											
1907-'08	Marysville			0		0		0		0	
1908-'09	Marysville		37.2		54.3		0		0		
1909-'10	Marysville		26.0		1.3		0	0			
1910-'11	Marysville		3.0	0.8		0	0	[illegible]		0	
1911-'12	Marysville		6.1	4.6	0.3		0		0		0
1912-'13	Marysville	41.3		24.4	4.6	0.7		0	0		0
1913-'14	Marysville	48.8	53.0		42.4	18.0		[illegible]	0	0	
1914-'15	Marysville				12.0	10.0		0	0		0
1915-'16	Marysville		84.2	59.2		19.5	0		0	0	
1916-'17	Marysville			58.0	83.0		11.0	0		0	0
1917-'18	Marysville			0	0		0	0		0	
Yield in Bushels per Acre.											
1911-'12	Marysville		(*a*)	(*a*)	(*a*)		26.6		25.0		(*a*)
1912-'13	Marysville	42.2		42.2	45.2	41.5		39.3	27.8		25.6
1913-'14	Marysville	22.5	26.4		32.7	39.1		38.4	33.9	36.1	
1914-'15	Marysville				29.2	35.0		34.2	29.4		33.1
1915 '16	Marysville		0	17.9		26.9	26.2		29.0	26.9	
1916-'17	Marysville			21.6	20.6		22.4	22.6		25.4	
Per cent of Plants Infested by the Fall Brood of Hessian Fly.											
1907-'08	Manhattan	7.7		7.3		3.3		0		0	
1908-'09	Manhattan	2.2	1.0	1.8	1.7	1.4	0.6	0	0	0	
1909-'10	Manhattan	0		0		0		0		0	
1910-'11	Manhattan		0	0		0	0	0		0	
1911-'12	Manhattan		2.0	3.5		0	0	0		0	
1912-'13	Manhattan			28.7	12.2	1.8		0	0	0	
1913-'14	Manhattan	24.1	21.9		9.0	0		0	0		
1914-'15	Manhattan	87.1		19.2	15.4	7 7	2.4		1.0	0	
1915-'16	Manhattan	93.0	66.0		69.0	5.0	1.0		0	0	
1916-'17	Manhattan		97.0	77.0		72.0		0	0	0	

Yield in Bushels per Acre.

1907-'08	Manhattan	22.5	......	28.5	......	31.5	......	34.4	......	32.1	......
1910-'11	Manhattan	......	44.8	50.0	......	53.8	52.8	51.2	47.5	45.0	......
1911-'12	Manhattan	......	15.0	26.8	......	25.4	27.0	14.5	......	6.8	......
1912-'13	Manhattan	......	......	41.3	44.1	47 5	......	40.3	25.1	20.0	......
1913-'14	Manhattan	46.2	44.5	......	46.5	46.8	......	44.5	36.8	22.8	......
1914-'15	Manhattan	0	......	0	17.3	21.3	26.0	......	28.7	22.7	......
1915-'16	Manhattan	0	0	......	0	16.3	23.2	......	17.1	18.5	......

EAST CENTRAL KANSAS.

Per cent of Plants Infested by the Fall Brood of Hessian Fly.

1907-'08	Sedgwick	23.7	......	22.1	......	0	......	......	0	0	......
1908-'09	Sedgwick	......	100.0	......	95.2	......	20.3	0	......	0	0
1909-'10	Sedgwick	......	......	......	0	1.1	......	0	0	0	......
1910-'11	Marion	......	1.1	......	0	0	0	......	0	0	0
1911-'12	Marion	......	......	0.4	0	......	0	0	......	0	0
1912-'13	Peabody	4.4	......	0	2.1	1.0	......	0	0	......	
1913-'14	Peabody	......	40.5	......	19.3	12.8	......	0	0	0	......
1914-'15	Newton	......	......	54.0	66.0	31.0	16.0	......	3.0	0.3	......
1915-'16	Newton	......	......	88.9	......	85.2	30.0	......	8.7	1.0	0
1916-'17	Newton	......	......	34.1	37.2	......	6.7	0	......	0	0
1917-'18	Newton	......	......	1.0	0	......	0	0	0	......	0

Yield in Bushels per Acre.

1910-'11	Marion	......	20.3	......	20.3	18.9	20.8	......	20.2	16.6	14.5
1911-'12	Marion	......	......	(b)	(b)	......	(b)	(b)	......	(b)	(b)
1912-'13	Peabody	13.7	......	14.0	12.2	16.9	......	9.0	7.0	......	
1913-'14	Peabody	......	24.1	......	24.4	28.3	......	14.3	12.7	11.9	......
1914-'15	Newton	......	......	1.08	1.0	1.8	6.0	......	8.75	11.0	......
1915-'16	Newton	......	......	1.04	......	1.41	3.32	......	15.18	16.99	16.58
1916-'17	Newton	......	......	9.4	12.3	......	14.6	15.1	......	16.9	14.8

SOUTHEASTERN KANSAS.

Per cent of Plants Infested by the Fall Brood of Hessian Fly.

1907-'08	Caldwell	1.3	......	2.4	......	3.0	......	5.1	......	0	0
1908-'09	Caldwell	......	......	100.0	100.0	......	......	......	0	......	0
1909-'10	Caldwell	......	5.6	51.7	43.1	9.9	23.0	......	......	......	......
1911-'12	Caldwell	......	0	0	0	......	0	0	......	0	0
1912-'13	Caldwell	......	......	0	......	0	......	0	0	......	0
1913-'14	Caldwell	1.7	1.2	......	0.2	0	......	0	0	0	......
1914-'15	Caldwell	......	......	100.0	95.0	35.0	......	15.0	......	0.05	0
1915-'16	Caldwell	......	......	......	......	70.7	36.4	......	9.5	2.4	0
1916-'17	Caldwell	......	......	7.0	1.6	......	0.4	1.3	......	0	0

TABLE XLV.—CONTINUED.

Year.	Place.	Seeding period— September 6–10.	September 11–15.	September 16–20.	September 21–25.	September 26–30.	October 1–5.	October 6–10.	October 11–15.	October 16–20.	October 21–25.
		Yield in Bushels per Acre.									
1912-'13	Wellington	....	....	8.4	8.6	6.8	....	2.4	1.3	....	0.2
1913-'14	Wellington	30.4	31.3	....	30.8	30.7	....	30.3	22.5	13.1	....
1914-'15	Wellington	....	....	0.7	1.43	2.7	....	3.7	....	4.8	3.1
1915-'16	Wellington	....	....	....	....	3.5	5.7	....	8.7	9.8	11.2
1916-'17	Wellington	....	....	15.0	16.0	....	20.0	21.0	....	16.0	12.7
		NORTH CENTRAL KANSAS.									
		Per cent of Plants Infested by the Fall Brood of Hessian Fly.									
1908-'09	Norton	0	....	0	....	0	....	0	....	0	....
1909-'10	Norton	....	....	0	0	0	0	0	....	0	....
1910-'11	Smith Center	....	0	0	....	0	0	0	....	0	....
1911-'12	Smith Center	....	4.0	0.6	0	....	0	0.01	....	0	....
1912-'13	Osborne	0.5	....	0	0	0	....	0	0	0	....
1913-'14	Osborne	0.5	2.0	....	0	0	....	0	0	0	....
1914-'15	Osborne	....	....	0	0	0	0	....	0	0	....
1915-'16	Osborne	....	1.0	37.7	....	51.9	44.0	....	28.5	23.0	....
1916-'17	Osborne	....	....	41.0	42.0	....	13.0	1.0	0	0	....
1917-'18	Osborne	....	....	0	0	....	0	0	0	....	....
		Yield in Bushels per Acre.									
1911-'12	Smith Center	....	28.8	28.8	32.2	....	31.8	30.0	....	18.8	....
1912-'13	Osborne	44.2	....	35.0	33.2	32.1	....	29.8	27.5	24.9	....
1913-'14	Osborne	21.9	21.5	....	23.7	19.0	....	17.3	14.1	10.6	....
1914-'15	Osborne	....	....	30.6	36.7	39.9	36.3	....	31.8	36.3	....
1915-'16	Osborne	....	....	15.9	....	16.8	31.7	....	36.7	30.9	....
1916-'17 (*a*)	Osborne	....	....	0	0	....	0	0	0	0	....

WEST CENTRAL KANSAS.

Per cent of Plants Infested by the Fall Brood of Hessian Fly.

1908-'09	Wilson	64.0	58.0	...	71.0	66.0	3.0	...	0	...	...
1909-'10	Wilson	...	0	0	...	0	...	0	...	...	...
1910-'11	Wilson	...	0	0	...	0	0	...	0	0	0
1911-'12	Wilson	...	0	0	0	...	0	0	...	0	0
1912-'13	Wilson	0	...	0	0	0	...	0	0	0	...
1913-'14	Wilson	0	0	...	0	0	...	0	0	0	...
1914-'15	Wilson	...	0	...	0	0	0	...	0	0	...
1915-'16	Hays	...	13.4	...	...	...	3.0	...	0	...	...
1916-'17	Hays	44.0	...	7.0	...	...	0	...	...	0	...
1917-'18	Hays	0	...	0	...	0	...	...	0	...	...

Yield in Bushels per Acre.

1911-'12	Wilson	...	20.1	24.9	26.0	...	25.7	19.3	...	8.4	10.3
1912-'13	Wilson	17.8	...	13.4	11.7	10.2	...	11.3	11.6	8.7	...
1913-'14	Wilson	16.5	18.0	...	20.0	21.9	...	24.4	22.2	20.5	...
1914-'15	Wilson	...	31.9	...	28.6	29.9	26.1	...	18.5	22.2	...
1915-'16	Hays	...	...	31.5	...	...	27.7	...	...	29.7	...
1916-'17	Hays	...	...	0	...	...	0	...	...	0	...

SOUTH CENTRAL KANSAS.

Per cent of Plants Infested by the Fall Brood of Hessian Fly.

1908-'09	Sawyer	...	...	56.0	100.0	...	...	0	...	...	...
1909-'10	Pratt	...	3.2	...	0.5	...	10.4	12.3	...	...	...
1910-'11	Pratt	...	...	...	...	...	...	...	...	...	...
1911-'12	Pratt	...	0	0	0	...	0	0	...	0	...
1912-'13	Pratt	1.8	...	0	0	0	...	0	0	0	...
1913-'14	Medicine Lodge	...	...	...	0	0	...	0	0	0	...
1914-'15	Medicine Lodge	...	0.6	...	0	0	0	...	2.2	0	...
1915-'16	Medicine Lodge	...	...	...	...	...	...	...	...	...	...
1916-'17	Isabel	...	...	9.5	6.1	...	2.5	0	...	0	...
1917-'18	Isabel	...	...	2.0	8.0	...	3.5	1.0	0	...	...

Yield in Bushels per Acre.

1911-'12	Pratt	...	23.3	21.6	23.3	...	23.3	25.0	...	14.4	...
1912-'13	Pratt	18.6	...	25.6	17.8	18.1	...	20.3	14.8	12.6	...
1913-'14	Medicine Lodge	...	...	...	31.7	28.6	...	28.5	27.8	26.5	...
1914-'15	Medicine Lodge	...	...	...	19.0	21.7	18.7	...	18.9	19.0	...
1915-'16	...	...	...	...	...	...	...	...	...	...	...
1916-'17	Medicine Lodge	...	...	23.3	23.9	...	20.9	21.2	...	18.5	...

(*a*) Winterkilled. (*b*) Destroyed by drought and chinch bugs.

TABLE XLV.—Summary of Table XLVI: Dates of maximum yields and safe sowing in date-of-seeding tests.—*Concluded.*

Year.	Northeastern Kansas.		Manhattan.		East central Kansas.		Southeastern Kansas.		North central Kansas.		West central Kansas.		South central Kansas.	
	Max. yields.	Safe sowing.	Max. yields.	Safe sowing.	Max. yields.	Safe sowing.	Max. yields.	Safe sowing.	Max. yields.	Safe sowing.	Max. yields.	Safe sowing.	Max. yields.	Safe sowing.
1907-'08	....	No fly	10-9	9-29	....	9-26	....	10-16	....	....	....	....	....	....
1908-'09	....	10-5	....	9-28	....	10-10	....	10-12	....	No fly	....	10-5	....	10-7
1909-'10	....	9-22	....	No fly	....	No fly	....	(*a*)	....	No fly	....	No fly	....	10-18
1910-'11	....	9-19	9-26	No fly	10-5	No fly	....	....	....	No fly	....	No fly	....	....
1911-'12	10-4	9-25	10-3	9-26	....	No fly	....	No fly	9-25	9-18	9-25	No fly	10-9	No fly
1912-'13	9-23	9-30	9-30	9-30	9-30	9-16	9-23	No fly	9-9	No fly	9-9	No fly	9-16	No fly
1913-'14	9-29	10-6	9-29	9-29	9-29	10-6	9-15	No fly	9-22	No fly	10-6	No fly	9-22	No fly
1914-'15	9-30	10-7	10-12	9-28	10-19	10-12	10-17	10-17	9-27	No fly	9-14	No fly	9-27	No fly
1915-'16	10-11	10-4	10-4	10-4	10-20	10-20	10-25	10-18	10-11	(*a*)	9-17	10-1	....	....
1916-'17	10-16	10-9	....	10-6	10-16	10-9	10-9	9-25	(*b*)	10-9	(*b*)	10-2	9-25	10-2
1917-'18	....	....	....	....	....	....	....	....	....	....	....	....	....	10-3

(*a*) Planting not late enough to obtain date of safe sowing. (*b*) Winterkilled.

TABLE XLVII.—Percentage of infestation of Hessian fly on April 1, 1915, before the spring brood had emerged, and June 1, 1915, after the spring brood had emerged, at Wellington and Newton.

Date of inspection.	Place.	Seeding period—					
		Sept. 16-17.	Sept. 21-23.	Sept. 27-30.	Oct. 5-7.	Oct. 12-17.	Oct. 19-21.
April 1, 1915.......	Wellington.....	100.0	95.0	34.7	15.2	0.50	0.000
June 1, 1915.......	Wellington.....	100.0	100.0	100.0	100.0	100.00	100.000
April 1, 1915.......	Newton........	54.0	66.0	31.0	16.0	0.03	0.003
June 1, 1915.......	Newton........	97.0	96.0	97.0	90.0	80.00	60.000

In addition to the date-of-seeding tests, numerous observations have been made in many localities in the state during the past five years on the date of seeding. Records are available for several hundred fields, and the results are in accord with those given in the experimental data. As a result of these experiments and observations it is possible to determine the fly-free date for all localities in Kansas. (Fig. 27.) Figures 28 and 29 show the results of a deter-

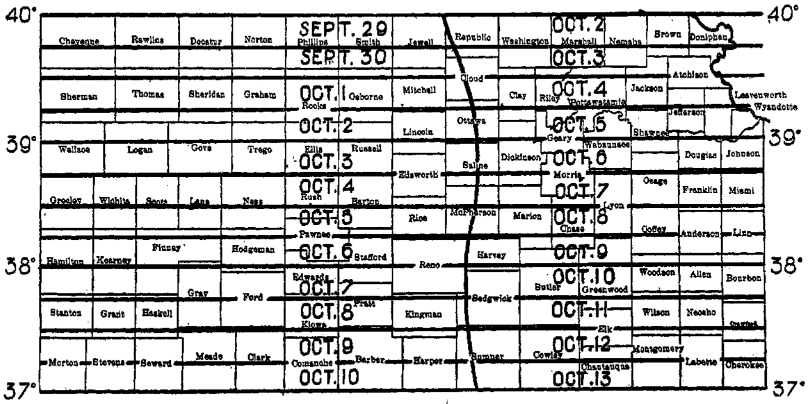

FIG. 27. Map of Kansas showing the date of safe sowing to escape the main fall brood of Hessian fly.

mined effort to reduce the injury from the fly, The two fields illustrated are adjoining and are identical with reference to soil and climatic conditions. However, in one case (the upper illustration in figures 28 and 29) no effort was made to destroy the volunteer wheat, and seeding began about 10 days before the fly-free date. In the other case (the lower illustration in figures 28 and 29) the volunteer wheat was destroyed and planting was delayed until the fly-free date.

FIG. 28.—A field of wheat in Wabaunsee county practically destroyed by Hessian fly; and an adjoining one, showing the results of a determined effort to control the fly. The field in the upper illustration was planted September 27 on land containing much volunteer wheat; the field in the lower illustration was planted October 6 on land containing no volunteer wheat.

COOPERATION.

The Hessian fly, like most of our staple-crop insects, is best controlled by the combined efforts of all the farmers in the community. It often happens that the individual farmer can successfully combat

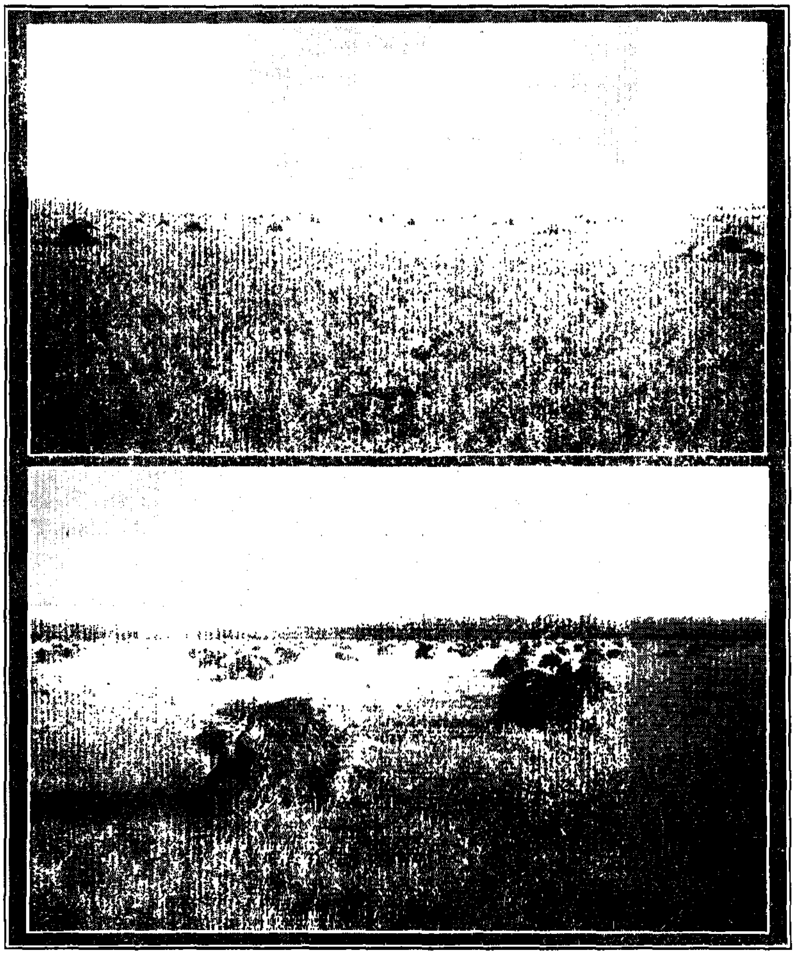

FIG. 29.—The fields of wheat shown in figure 28 after harvesting. The field in the upper illustration produced 5 to 10 bushels per acre, while the field in the lower illustration produced 30 to 40 bushels per acre.

the fly on his farm, but in years when the fly is abundant this is the exception. When it is considered that the fly may migrate long distances, that it breeds readily in volunteer wheat, that adults may continue to emerge from a stubble field for a period of at least a year, and that there may be as many as five broods a year, the necessity of community coöperation becomes apparent.

SUMMARY OF METHODS OF CONTROL.

In Kansas the important steps in the control of the Hessian fly are: (1) Early, deep plowing of the stubble; (2) proper preparation of the seedbed; (3) destruction of all volunteer wheat; (4) delay in sowing until the fly-free date; and (5) coöperation.

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