SOME PHASES OF THE BIOLOGY OF THE WHEAT STEM MAGGOT (*MEROMYZA AMERICANA* FITCH (DIPTERA, CHLOROPIDAE)

by

MERLE WALTER ALLEN

B. S. Kansas State College

of Agriculture and Applied Science, 1933

A THESIS

submitted in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE

KANSAS STAGE COLLEGE

OF AGRICULTURE AND APPLIED SCIENCE

1934

TABLE OF CONTENTS

INTRODUCTION

The wheat stem maggot is a potential pest of common enough occurrence to evoke queries from farmers and wheat growers throughout the wheat growing area of North America. It is widely distributed throughout the wheat belt and has been found to injure as high as one hundred per cent of the plants of a single variety of wheat. In general the injury is much less than this, it being not uncommon, however, to find an injury of from ten to fifteen per cent of the plants in a field.

It is an insect having many food plants, and one of which comparatively little is known. For these reasons considerable attention has been devoted to the study of the biology of this pest during the past two years.

This work was carried on at the field insectary in Manhattan, Kansas, in connection with Project 8 on "The Hessian Fly and Other Wheat Insects" and with Project 164 on "The Resistance of Crop Plants to Insect Attack."

REVIEW OF LITERATURE

Biology

The literature on the wheat stem maggot consists largely of short notes in annual reports and various

periodicals. Little original work has been reported on the insect, but the literature is found to consist largely of articles quoting the work done by previous writers and brief notes giving locality records and records of injury by the maggot.

Lugger (1895) reported that the wheat stem maggot had been found as early as 1821 in Pennsylvania, but the first record available in the literature was that of Fitch (1856) when he described the fly from material collected in New York and gave it the name Meromyza americana. Walsh and Riley (1869) reported it as occurring in Missouri, and Riley again in 1880 reported its presence in that state. Lintner (1882 and 1884) noted its occurrence again in New York and included some notes as to the nature of injury, the larval and pupal forms, and the time of appearance of the fly. Webster (1884), in Ohio, reported finding a full grown larva in the stem of wheat, slightly below where the upper leaves began to diverge, on June 14; on June 16 a larva was found in the upper joint of a growing straw; June 24 puparia were collected; and on July 18 he observed the copulation of emerged adults. He also reported the frequent occurrence of the mite Heteropus ventricosus Newport as a parasite on the maggot. Forbes (1884) reported the presence of the maggot in Illinois and from material

collected near Cuba, Illinois, described the immature stages of the insect. He also collected and described the parasite Coelinidea meromyzae. Forbes (1886) contributed notes on the life history and stated the probability of a mid-summer brood in self-sown grain, making a total of three broods rather than two, as had been previously accepted. Fletcher (1888) reported injury in both spring and fall in Canada, and reported the collection of a specimen of Hymenopterous parasite thought to be a new species or a variety of Coelinidea meromyzae Forbes. He suggested hand picking of "blasted heads" and the use of a trap crop as possible means of control.

Webster (1889) found that four straws of Velvet Chaff to one of Michigan Wonder were infested. Garman (1889) reported its occurrence in Kentucky, and stated that it is found especially common in blue-grass pastures even when closely grazed. He suggested the burning of volunteer wheat and late planting as means of control when used in combination. Fletcher (1890) stated that Agropurum divergens Nees. (Awned Blue Stem) was badly injured by the maggot.

Osborn and Gossard (1891) recorded its occurrence in Iowa and reported it as being preyed upon by the parasite Coelinius meromyzae Forbes, and by two recently reared

undetermined species of parasites. Webster (1892) spoke of this maggot as being possibly the most widely distributed of all wheat stem worms. He suggested the stacking or burning of straw immediately after harvest and the use of a trap crop as possible measures of control.

Lugger (1895) reported the insect in Minnesota and recorded evidence to substantiate the idea of there being three generations of flies. Lugger (1896) again reported it in that state especially damaging late sown rye, which was damaged as much as ten per cent of the crop. He recommended as the only remedy a systematic rotation of crops. Williams (1896) reported its presence in South Dakota.

Fletcher (1898) stated that there were three broods of flies at Ottawa, Canada, one at the beginning of June, a second at the end of July, and a third at the last of September. He recommended the use of a trap crop as a control and stated that late planting would not be effective for it would be unprofitable to delay planting long enough to escape the egg-laying period of the last brood. He suggested the "application of special fertilizers as a top dressing when young wheat is known to be attacked, to help injured plants to throw out new stools to overcome the effects of the attack."

Bruner and Swenk (1907) reported the wheat stem maggot as being distributed throughout Nebraska. Three broods were recorded, the fall brood usually attacking the grain most severely. They suggested that rotation of crops, burning of straw and destruction of volunteer grain would be effective only if waste grasslands were burned over. Wheat planted in October seemed to be less liable to attack than that sown earlier.

Criddle (1911) reported the collecting of flies on Agropyron repens and Agropyron occidentales. Cooley (1916) reported the maggot as injuring wheat in Montana.

Kelly (1917) reported the laying of eggs by the parasite Coelinidae meromyzae Forbes within the eggs of Meromyza americana Fitch. His report states that the parasite eggs hatch within the eggs of Meromyza and the young larvae feed within the fatty tissue of the wheat stem maggots without disturbing their vital processes and emerge as adults from the puparia of the Meromyza.

Sanderson and Peairs (1921) suggested the burning of wheat stubble as aid to control. Webster (1925) found the insect in North Dakota and stated that "blighted heads" in wheat may also be due to a disease known as "foot rot." He stated that in such cases all the heads on a single plant are likely to be affected, while in case of insect attack

rarely more than one stem from a single plant is affected. He found the maggot attacking slender wheat grass (Agropyron tenerum), wild barley (Hordeum jirbatum), and pigeon grass (Chaetochloa glauca).

By far the best publication in the literature is that by Gilbertson (1925). He described the injury produced by the wheat stem maggot, recorded its life history, and described its immature stages. He reported a list of host plants herein recorded and added information on the control of this pest by a Hymenopterous parasite Microbracon meromyzae Gahan. He recognized an undetermined species of mite attacking the adult flies and an unidentified fungus often found on dead maggots. He reported some experiments on poison baits, but suggested that the labor and expense of their use made them unprofitable.

Classification

The wheat stem maggot belongs to the family Chloropidae and to the order Diptera. "The genus Meromyza was first described by Meigen in 1830, when he gave a European form of the insect the name Meromyza pratorum," Gilbertson (1925). Fitch, (1856) in his second report of the insects of New York, described the American form and gave it the name Meromyza americana. Becker, (1912) in his monograph on the

Chloropidae, listed the American form, Meromyza americana, as a variety of the European form, M. pratorum, and called it Meromyza pratorum var. americana. This classification has been generally rejected by the writers on the insect. Gilbertson (1925) quotes Aldrich on this point, "I now think Becker was wrong in making it a variety and it should be regarded as a distinct species."

Malloch (1914) proposed the name Meromyza flavipalpis for specimens from the vicinity of Champaign, Illinois, which he described. This name has been set as a synonym of Meromyza americana Fitch by Aldrich. Referring to Gilbertson's paper again (1925) he quotes Aldrich, "This species of Malloch's looks quite distinct in the shape of the head when you see the extreme form, but I have found all possible intermediate forms to be very common in northern material, especially from Manitoba."

Common Name

Different authors have proposed and used various common names to designate this insect. Fitch (1856) selected the name "American Meromyza" undoubtedly to differentiate between this and a closely related European form. Lintner (1882) rejected this name as being too

technical and proposed "wheat-stem maggot" as the name of the insect. He selected this name after having observed the maggots in the upper parts of wheat stems in summer. Forbes (1884), knowing the insect only from its feeding habits in fall and early spring, at which time it feeds inside and at the base of the stem just above the root, adopted for it the name "wheat-bulb worm."

Webster (1903), desiring to differentiate between this and smaller maggots of closely related genera and at the same time to designate the place of attack and nature of injury, proposed the name "larger wheat-stem maggot."

Because the name "American Meromyza" is too technical, and the name "wheat-bulb worm" does not designate the dipterus type of larva, these names have been largely rejected by the majority of writers. Of the two names "wheat stem maggot" and "larger wheat stem maggot" the former has been used to a greater extent in the literature and is the name approved for general use by the American Association of Economic Entomologists in the list of names approved by that association in the Journal of Economic Entomology for June, 1925. For these reasons the name "wheat stem maggot" will be used to designate the insect in this thesis.

MATERIALS AND METHODS

Life history studies on the wheat stem maggot (Meromyza americana Fitch) were started during the fall of 1932. On October 1 numerous adults were collected on volunteer wheat at the College Agronomy Farn. These flies were caged on young Turkey wheat plants, in the Hessian fly plots, and were observed daily for mating and egg deposition. After eggs had been deposited the plants were cut into sections, each bearing one or more eggs; these were placed in small shell vials and were examined daily for the first hatching. The stems were later examined for young maggots, some of which were preserved for study and others were used in rearing experiments.

The major part of the life history studies were carried on during the spring, summer, and fall of 1933. During the last week in March maggots were secured from bunches of volunteer wheat collected from the Agronomy Farm. These maggots were removed from the plant in which they were found and placed inside of sections of fresh wheat stems. This transfer was accomplished by removing the center of the section of stem with a flattened, curved, disecting needle, and placing the maggot in the resulting cavity. It was soon discovered, however, that it was unnecessary

to place the maggots in the stems for if given a chance they would enter the fresh section unaided. The sections used were cut from the bottom of wheat culms, were about one inch long, and included the bottom node of the culm. These stems and maggots were placed in small shell vials and numbered serially, the numbers corresponding to those on the written records kept for the individual maggots.

The maggots were examined daily or every other day and fresh food was provided every two days. The experiments had not been in progress long before it was discovered that a thin layer of moist, sifted soil packed tightly into the bottoms of the vials decreased the rate of desiccation and materially reduced the mortality of the maggots. It was likewise discovered that tight fitting cork stoppers were preferable to cotton plugs, because of the lower rate of desiccation. Moisture was added to the soil at frequent intervals to keep the humidity within the vials high, which condition seemed most favorable to the maggots.

During the spring, summer, and fall of 1933, maggots were collected from various sources and treated in a manner similar to that just described. These maggots were collected from such sources as winter wheat, spring wheat, barley, rye, volunteer wheat, and grasses from various

localities. In addition to these, several maggots were reared from eggs laid in the oviposition tests which were being carried on in the insectary at the same time as these rearing experiments. In all, 500 maggots were carried through the above described process.

Complete records were kept on each of the maggots. These records included the place and date of collection, a brief description of the maggot, record of moltings with dates, date of pupation, date of emergence, and the sex of the adult. If the maggot showed any signs of being parasitized, its condition was described and the date of emergence of the parasite was recorded with a note and number to designate the parasite.

Maggots of the various stages, eggs, and puparia were preserved in four per cent formalin, seventy per cent alcohol, or in Bouin's solution. These were used for study, measurements, and for the drawings of the various stages. The exuvae from the different instars were mounted in Canada Balsam on microscopic slides as were the cephalo-pharyngeal skeletons from maggots which died or were killed in handling. These slides were studied to determine the difference in the various instars and to provide the specimens from which the sketches of cephalo-pharyngeal skeletons were made.

Early in April sweepings were begun to determine the date of first appearance of the flies. These collections were made twice each week with a net one foot square; several hundred sweeps were made for each collection and the average number of flies per hundred sweeps was recorded. These sweepings were made in two locations, i.e., on volunteer wheat near the College Dairy Barn and on the wheat plots at the College Agronomy Farm. The collections were continued from April 6 to May 31, at which time the volunteer wheat was destroyed by cattle. The flies collected in these sweepings were used in oviposition tests hereafter to be described.

Shortly before harvest time sometimes "blasted heads" appear among the ripening wheat. These are usually caused by the wheat stem maggot. These "blasted heads" are heads of wheat which appear white and prematurely ripened with stiff spreading awns, presenting a striking contrast between the white of the head and the green of the leaves and normal heads of the plant (Plate III, Fig. 2). During the first two weeks of June all of these "blasted heads" were collected from the wheat variety plots and the date of planting-variety plots at the Agronomy Farm. These heads were collected by cutting the culms off near the crown of the plant so that the entire culm was preserved.

The culms from each plot were tied in bundles and placed in large cardboard rearing boxes in order to collect the Meromyza flies that emerged from the culms. These boxes were closed to the light except for two round holes near the top of one end of each. Into these holes common lamp chimneys were inserted. The outer end of the chimneys were plugged with cotton stoppers to prevent the escape of the flies upon their emerging and coming to the light. A little water was sprayed over the wheat every few days to insure sufficient moisture for the emerging flies. These boxes were examined daily and the flies and other insects were removed. The M. americana were etherized and the sex of each was determined and recorded to secure the sex ratio of the fly. All the Hymenoptera collected from the boxes which were likely to be parasitic on M. americana were pinned and labeled for future determination.

This same procedure was followed for the culms of spring wheat, rye, and barley having "blasted heads."

After the emergence of all the flies from the culms in the boxes the bundles were removed and photographed. The bundles of culms from the date of planting-variety plots were arranged under each variety according to the date of planting (Plate V). Likewise some of the representative bundles from the variety plots were grouped

together and photographed (Plate VI). Each of the culms was then thoroughly examined by splitting the straw lengthwise with a knife, the purpose of this examination being to determine exactly how many of the culms having "blasted heads" had been actually infested by the maggot. The total number of "blasted heads" in each bundle and the number found to be actually infested were recorded (Tables IV and V).

The adult flies from the various sweepings and those reared from the culms of wheat having "blasted heads" were used in oviposition tests in the field insectary and some in outdoor cages. Some of the flies were caged in pairs, and others several together on small wheat plants in pots. Common lamp chimneys with cloth tops were used for cages in these indoor experiments. Other flies were caged on wheat growing at the edge of the Hessian fly nursery. A cage three feet square and one foot high, constructed of twelve inch boards with a screen top was used in these outdoor experiments. In the outdoor experiments numerous adults were used in order to produce large numbers of eggs. Records were kept as to the number of eggs deposited and of the position in which they were deposited on the plant.

In the indoor experiments the eggs were examined daily to determine the first date of hatching and the length of

the incubation period. As soon as the eggs had hatched some of the maggots were removed from the plants and treated as previously described. Others of the maggots were preserved and still others were permitted to remain on the plant until it was dead, at which time they were removed and handled in the same way as the other maggots in the rearing experiments.

Previous to 1932, when these experiments were started, various members of the Entomology Department of Kansas State College had recorded the infestation of different wheat varieties by the wheat stem maggot. In all such cases the infestation counts were made at the same time and incidental to the Hessian fly infestation counts. All these counts were made on winter wheats and the counts were made in the fall with but one exception. The counts were made in the spring of 1921 and in the falls of 1924, 1927, and 1931.

In 1932 and 1933 infestation counts were made on the varieties grown in the Hessian fly nursery. These counts were made in the fall at the same time as those of the Hessian fly and were considered of equal importance with the fly counts. The 1932 counts were not influenced by any special artificial source of infestation, but the infestation came from natural sources and perhaps some from the

volunteer wheat used to infest the nursery with Hessian fly. The 1933 infestation came from these same sources plus the few flies liberated from the rearing experiments.

September 24, 1932, a nursery consisting of sixty varieties of wheat was planted in duplicate and on September 27 was artificially infested with the adults of the wheat stem maggot by distributing volunteer wheat, known to be infested, in the alleyways. In this nursery varieties having high and low infestation in previous tests were planted, and in addition, some varieties recommended for testing by Dr. R. H. Painter and Dr. J. H. Parker. The infestation counts were made on this nursery during the latter part of January, 1933.

In each of these various tests an equal number of plants were examined for all varieties tested. This number, however, varied from test to test and this variation is to be taken into consideration in the interpretation of the data.

The counts from each of the foregoing tests were summarized into tables giving the number and percentage of infested plants. All those varieties which were found to occur in two or more of the tests were tabulated into a single table (Table VI). This table gives the per cent of plants, of each variety, infested in each test and the per

cent of plants of the variety infested in all tests. In the table the results are checked against those of Turkey, a common variety, grown in all the tests. The purpose of these tests and tabulations was to determine the possibility of resistance of wheat to the wheat stem maggot.

Throughout the summer of 1933 an attempt was made to collect the wheat stem maggot feeding in the stems of various grasses and to rear them to maturity in a manner similar to that used for those collected in wheat.

In the early fall of 1933 volunteer wheat was collected from the Agronomy Farm and placed in rearing boxes similar to those used for the "blasted heads" collected in the spring, the main purposes being to collect Hymenoptera which might be parasitic on the maggots. These boxes were kept out of doors until cold weather, at which time they were moved into the greenhouse. Moisture was added every few days to aid the insects in emerging.

Late in the fall and through the winter sweepings were made at irregular intervals on volunteer wheat, and young winter wheat to determine the last date of appearance of the flies.

In addition to the foregoing specific tests and experiments field observations have been made and used extensively in the interpretation of the data included herein.

DISCUSSION AND RESULTS

Description

Imago. The following is a copy of the original description of Meromyza americana by Fitch (1856):

"The American Meromyza, M. americana. It is 0.17 [of an inch] in length to the tip of its abdomen, and 0.20 [of an inch] to the end of its wings. It is yellowish white with a black spot on the top of its head, which is continued backward to the pedicel of its neck. Thorax with three broad black stripes, approaching each other anteriorly but not coming in contact, the middle stripe prolonged anteriorly to the pedicel of the neck and posteriorly to the apex of the scutel. Abdomen with three broad blackish stripes, which are confluent posteriorly and interrupted by each of the sutures. Tips of the feet and veins of the hyaline wings blackish. Eyes bright green. Antennae dusky on their upper sides."

Following is a technical description of the flies by Forbes (1884):

"About .18 inch long by .08 inch wide, pale yellowish green; head produced in front of the eyes, broadly rounded anteriorly, marked above with delicate longitudional striae; a triangular black spot on the occiput, including the three ocelli and surrounded by a triangular area which is irregularly corrugated, and bordered by a row of sparse black bristles. Just outside the posterior angles of this area are two stout, erect bristles; similar but smaller bristles border the eyes internally; otherwise the head is destitute of hairs. The eyes are of a beautiful bronze-purple color.

"The thorax is marked by three very broad longitudional black bands, which occupy the greater part of the surface. The central of these extends from the tip of the scutellum to the neck, gradually widening anteriorly, and is continued to the ocelli as an obscure median stripe, outside of which is an angular brownish line bounding the corrugated area already mentioned, upon the head. The

lateral thoracic stripes are usually distinct from the median one throughout, but occasionally touch it in front. They terminate at the margin of the thorax, and extend posteriorly along the sides of the scutellum. Upon the surface of the thorax are a few scattered, short, black hairs, with a small number of long bristles intermixed, especially prominent near the posterior margin of the thorax and at the tip of the scutellum. The abdomen is also marked above by three longitudional black bands interrupted at the sutures and confluent posteriorly.

"The color beneath is a uniform pale yellowish-green, with the exception of a triangular black spot upon each side, just above the posterior coxae, and another smaller one above the middle coxae. The thighs are a slightly darker tint of the general color, the tibiae and tarsi dusky, darkening distally. The posterior pair of thighs are much thickened, being only about twice as long as wide, and are provided on the under surface with a double row of short thick black spinules. The posterior tibiae are strongly curved to conform to the inferior margin of the thighs. The femora and tibiae, and the tarsi above, are sparsely covered with short black hairs, but the pubescence of the under part of the body generally is pale.

"The two basal joints of the antennae are yellowish-brown, darker above; the basal joint very short, obconical, the second large, compressed, its vertical depth being equal to its length. Its upper margin is nearly straight, and the lower broadly and regularly rounded, continuously with the terminal. The third joint is cylindrical, about twice as long as wide, and dusky, as is likewise the flagellum. The mouth parts are green, with the exception of the palpi which are white, sometimes tipped with dusky. The face is smooth and destitute of bristles except for a scanty row of soft white hairs about the mouth."

Flies that have recently emerged are pale green in color, but as they grow older the color turns to a pale yellow or straw color. The eyes of the flies vary from bright green to a deep bronze color, which variation is likely due to the age of the flies.

The difference in appearance of the sexes of the flies is largely in the size, the male being much the smaller. The abdomen of the female fly is rounded and swollen, while that of the male is more or less cylindrical, gradually tapering to a dull point.

Egg. The eggs of the fly are snow-white and are fusiform-cylindrical in shape with the ends gently rounded; on the anterior extremity is a minute flattened, rounded area. The surface is covered with longitudional ridges, the spaces between the ridges being concave and marked off into rectangular areas by smaller transverse ridges (Plate I, Fig. 1, and Plate IV, Fig. 1). From measurements made of fifty eggs it was found that the length varied from 0.96 mm. to 1.09 mm., and the breadth from 0.165 mm. to 0.231 mm. The average length was 1.02 mm. and the average breadth was 0.194 mm. (Table I).

Larva. The following is a technical description from Forbes (1884):

"A very pale-green, slender, footless grub tapering anteriorly, somewhat narrowed, but subtruncate posteriorly; one-fourth of an inch in length by about one-eighth of an inch in width. The segments are thirteen in number, counting the head; those in the center of the body a little wider than long. The four anterior segments narrow rapidly forwards, the one next the head being at its apex less than half the diameter of the fourth. The three posterior segments are also somewhat narrowed, the penultimate being

about three-fourths the diameter of the second preceding.

"The head is provided beneath with the pair of black toothed hooks common to many dipterus maggots. The antennae are very short, scarcely longer than broad, two-jointed, the second joint extensil. There are two circular, apparently sensory areas below the antennae upon the front of the head, doubtless representing maxillary palpi. The mouth is beneath the head, sucker like in form. The last or anal segment is divided into two lobes, and bears upon its posterior surface two breathing-pores or spiracles, each guarded by a circlet of about twelve depressed spines. The surface of the larva is entirely smooth and shining, except for some very fine transverse ridges on the under-side of the segments, evidently useful in locomotion. On each side of the base of the second segment is a small, gill-like appendage, divided into two lobes, each lobe with six divisions."

It was found in these experiments that the maggots pass through three instars during the larval stage. The maggots when first hatched are very small, slender white larva, having neither a head capsule nor feet. Twenty-five of these newly hatched maggots were measured and the average length was found to be 1.75 mm., and the average width was 0.45 mm. (Table I).

The maggots of the second instar are somewhat larger than those of the first instar, and are of a very light whitish-green color. Of twenty-five such maggots measured the average length was 3.20 mm., and the average width was 0.50 mm. (Table I).

Fifty maggots in the third or last instar were measured and the average length was determined to be

Table I. Measurements of the Various Immature Stages of the Wheat Stem Maggot in mm.

	Egg		1st. Instar		2nd. Instar		3rd. Instar		Puparia	
	Length	Breadth	Length	Breadth	Length	Breadth	Length	Breadth	Length	Breadth
Maximum	1.09	0.231	1.86	0.57	3.31	0.66	6.47	1.21	5.86	1.10
Minimum	0.96	0.165	1.61	0.31	3.05	0.34	6.21	0.96	5.54	0.82
Average	1.02	0.194	1.75	0.45	3.20	0.50	6.40	1.10	5.70	0.91
No. of Insects Averaged	50		25		25		50		44	

6.40 mm., and the average width was 1.10 mm. (Table I). The description quoted from Forbes was without a doubt made from specimens of this instar (Plate I, Fig. 3).

From the sucker-like mouth, located on the under surface of the first segments, usually protrudes a pair of black toothed hooks, the mandibles. These mandibles are supported by and connected to a "V-shaped" structure which extends back into the body as far as the third segment. This structure is the cephalo-pharyngeal skeleton. It is a brownish or blackish scleritized structure usually visible through the integument of the larva. The shape of the cephalo-pharyngeal skeleton shows some variation in the various instars. In the third instar this structure is completely developed and the parts are easily distinguished. The skeleton of this instar is represented in Plate I, Fig. 6, which shows the mandibular, the hypostomal, and pharyngeal sclerites and the small arched dentate sclerite completely developed with the small accessory sclerites attached to the hypostomal sclerite. The dentes on the mandibular sclerite are fully developed and completely scleritized.

The cephalo-pharyngeal skeleton of the second instar maggot is represented in Plate I, Fig. 5. This skeleton is very similar to that of the third instar with the exception

that it is smaller and the dentes are not fully developed or scleritized.

Plate I, Fig. 4 represents the cephalo-pharyngeal skeleton of the first instar maggot. This skeleton differs greatly from that of either of the other instars. Not only is the skeleton materially smaller than either of the others, but it is far less completely developed. The dentate sclerite and the two small accessory sclerites are completely absent and the dentes of the mandibular sclerite are poorly developed. The mandibular sclerite is not heavily scleritized as it is in the skeletons of the other two instars.

Puparium. Forbes (1884) in his thirteenth report as state entomologist of Illinois gives a very adequate description of the pupa which is here quoted.

"The pupa of this species is what is technically known as a coarctate pupa; contained within the last skin of the larva, which is not shed previous to transformation, but remains as a protective envelope for the forming pupa. As the latter shows through its case, the color is green, except at the ends, where, with the growth of the pupa within, the case is left empty and transparent. It is about one-sixth of an inch long by one-fifth that in width, and divided into ten clearly recognizable segments. The anterior of these corresponding to the head and first segment of the larva, is yellowish, shrunken, and corrugated, about half the width of the third segment. The second and third are obscurely divided, the first being short, and narrowing rapidly forward. Within it are observed the retracted maxillae of the old larva.

"The remaining segments to the eighth are about equal in length, separated by deeply impressed sutures at first, the anterior sutures becoming gradually obliterated as the enlargement of the head and the thorax of the pupa within distends the envelope. The ninth is the longest of all, the tenth being nearly equally long, but narrower, and shrunken and wrinkled on its posterior border. The eleventh, representing the twelfth of the larva, is only a brown and corrugated rudiment. As the development of the pupa approaches completion, the eyes, wing-pads and legs are visible through the transparent covering, but they form no elevations of the surface."

A series of forty-four of the puparia were measured and the average length was found to be 5.70 mm. and the average width 0.91 mm. (Table I). Plate I, Fig. 2 is a representation of a typical puparium.

Life History Studies

Number of Generations. Heretofore the number of generations of the wheat stem maggot in Kansas had not been determined. In other localties from two to three generations a year have been recorded. During the period from March 28, 1933, to December 19, 1933, the writer carried on rearing experiments in which 500 maggots were reared. These experiments were carried on within the Entomology Field Insectary and under artificial conditions. Of the 500 maggots handled in the experiments 156 were reared from eggs; the remaining 344 were collected from various sources and in various of the larval stages and in the pupal stage.

Evidence from these experiments and from field observations indicated that during the year 1933 there were three and a partial fourth generation in the vicinity of Manhattan.

In these rearing experiments the eggs for the first generation of flies were deposited during the first few days of May; the larval and pupal stages required the remainder of May and the first few days of June. The adults of the first generation began to emerge June 5, and emergence continued until June 28. The flies of the second brood began to emerge July 25 and continued to emerge until August 10. These flies deposited eggs which produced maggots that emerged as mature flies from September 5 to September 16. These flies were allowed to deposit eggs, but the life history study was interrupted at this point. If these eggs had been allowed to hatch and the maggots kept under natural conditions they would probably have overwintered and produced adults in the spring, thus completing four full generations.

From field observations and from notes kept on maggots collected late in the fall it was definitely determined that this fourth generation was actually just a partial generation. It was found that only part of the maggots from the eggs deposited by those flies emerging in July and the first of August emerged as adults in the fall, most

of them overwintering as maggots. Of sixty-eight maggots collected from volunteer wheat at the Agronomy Farm September 29, sixteen pupated and emerged, twenty-two died in the larval stage, and thirty remained as mature maggots until December 19, at which time they were preserved.

Another source of evidence that there was a partial fourth generation is the fact that adult flies were collected as late as December 16, and at the same time mature and partially grown maggots were collected.

The overwintering maggots were found to pupate in late March and early April and to emerge as adults from April 15 through the remainder of that month and during the first few days in May.

Seasonal Cycle. From the rearing experiments and field observations, the following cycle was worked out for the year of 1933 in the vicinity of Manhattan.

The insects overwintered as mature maggots which pupated during the latter part of March and the first half of April. The adult flies began to emerge from these puparia April 15 and continued to emerge throughout that month and the first half of May. These adults mated within a few days and deposited their eggs during the latter part of April and through the greater part of May. The maggots began to hatch about the last of April, and they were found

in the stems of wheat, rye, and barley throughout May. They pupated about the last of May and in early June. The adult flies emerged from these puparia from June 5 until June 28.

The flies of this generation deposited their eggs during the latter part of June; the maggots emerged from the eggs from June 25 to the last of July. The maggots produced by this generation fed within the stems of wild and cultivated grasses. They pupated from the middle of July to August 8, and the adults emerged until about the middle of August.

Eggs were deposited by this brood of flies during the latter part of July and the first half of August. The maggots from these eggs emerged during the last few days of July and throughout the greater part of August. These maggots lived in the stems of grasses and volunteer wheat, and the majority of them became mature, passed the winter in this stage, and pupated the following spring. Some of the maggots from these eggs, however, pupated during August and emerged as adults during the latter part of that month and through the next three months until December 16. These adults which emerged during August, September, and the first part of October deposited eggs which hatched before October 15, the maggots overwintering and pupating the following

spring. Plate II illustrates the seasonal cycle in the vicinity of Manhattan for 1933.

Egg Stage. The eggs of the wheat stem maggot are usually deposited singly either on the leaves or sheaves of the plant. In some few cases the eggs have been found inserted between the leaf sheath and the stem. In the fall a great many of the eggs were glued to the stem just above the ground. In the oviposition experiments carried on in the insectary the majority of the eggs were glued to the upper surface of the leaves a short distance from the stem. In most cases the eggs were found to be glued parallel to the long axis of the leaves and stem.

Due to the fact that the eggs are laid singly and because the oviposition period extends over several days, it is difficult to estimate the number of eggs laid by any individual female. In cage experiments an average of ten to fifteen eggs were deposited by each female. The largest number of eggs deposited by a single fly was thirty. The eggs were deposited at an average rate of one to four eggs daily. One female, under cage conditions, deposited thirteen eggs in a single day. The oviposition period was found to range from four to ten days with an average period of 6.9 days, (Table II).

The incubation period was found to vary from four to eleven days, with an average length of 6.8 days. The length of the incubation period and the number of cases recorded are shown in Table II.

Larval Stage. The maggot stage was found to be divided into three instars, the first of which required a period of from two to eleven days, the average period being 6.19 days. The second instar was completed in from two to twenty-eight days, the average period being 11.35 days. The third and last instar required from nine to twenty-three days, with an average of 14.56 days. From these results it was calculated that the entire maggot stage would require from thirteen to sixty-two days, the average time being 32.1 days (Table II).

These calculated results, from partial life histories, when compared with results obtained from eight cases in which the maggots were actually reared through all three instars, were found to run both higher and lower, but the average time was quite close. The time required for the maggots to pass through the three instars in the eight actual tests varied from sixteen to forty days, the average time being 27.38 days.

Pupal Stage. The period from the formation of the puparia to the emergence of the adults was found to vary

from five to twenty days; the average time was 11.72 days (Table II). The length of time from the hatching of the egg to the emergence of the adults was calculated from the above results and was found to vary from eighteen to eighty-two days, the average time being 43.82 days (Table II). These results were checked against records kept on four maggots reared from egg to adult. The results from the four actual records showed a variation of time from forty-two days to fifty-seven days, with an average of 46.25 days. These results both calculated and from actual records are for the spring and summer generations and do not take the overwintering brood into consideration.

Adult Stage. Soon after the flies emerge from the puparia they begin mating. The mating may take place any time during the first few days after emergence, and a single female has been observed mating more than once either with the same or different male.

From records kept on ten females, the preoviposition period was found to vary from two to six days, with an average of 3.6 days.

The ratio between the sexes of this species was determined by examination of 2149 flies over the period from June 10 to June 18. Of these 2149 slightly over half of them were females--1180 were females--and 969 were

Table II. Length of Life Stages of the Wheat Stem Maggot in Days

	Oviposition Period of Adult	Incubation Period	1st. Instar	2nd. Instar	3rd. Instar	Entire Maggot Stage	Puparium	Egg to Adult	Adult
Maximum	10	11	11	28	23	62	20	82 *	19
Minimum	4	4	2	2	9	13	5	18	2
Average	6.91	6.80	6.19	11.35	14.56	32.10	11.72	43.82	9.38
No. of Insects Averaged	32	31	42	26	16		46		13

* Does not include overwintering larvae.

males; or fifty-four per cent were females and forty-six per cent were males.

Nature of Injury

Two types of injury are produced by the wheat stem maggot. The most conspicuous of these is the appearance of prematurely ripened heads in a field of green wheat, rye or barley. The white or "blasted heads" appear in sharp contrast to the green of the unripened heads and leaves. Upon examination of the stems having "blasted heads" only that part of the stem above the upper node is found to be dead. If the head is gently pulled it easily slips from the green investing sheath and upon examination, the lower end of the stem is found to be discolored, withered, and lacerated, as if it had been chewed (Plate IV, Fig. 3). This destruction of the lower part of the stem prevents the normal flow of the sap to the head, thus causing the seemingly premature ripening.

The "blasted" or white heads when examined yield in most cases no kernels whatever, and those kernels which are found are not mature, but are very small and shriveled and are unfit for either food or planting purposes. A culm of wheat injured in this way is absolutely ruined as far as the grain is concerned.

If the main stem and its investing sheath are carefully split lengthwise at or above the upper node, a glossy, watery green maggot will usually be disclosed, surrounded by excreta of the maggot and bits of abraded and torn plant tissue (Plate IV, Fig. 2). In the absence of the maggot the excreta and the abraded plant tissue are usually there to indicate that the pest had been present.

In this type of injury the head and central shoot are light straw color rather than green like those of uninfested stems. The awns are found to be stiff, brittle, and spreading, rather than compact about the head as in the normal plants (Plate III, Fig. 2).

The second type of injury produced by the maggot is less conspicuous than that just described. This type of injury is done to young plants in fall and early spring. Upon examination of injured plants the central leaf is found to be yellow and withered and in some cases completely dead (Plate III, Fig. 1). The central leaf when gently pulled readily slips from its investing sheath, and its base is found to be lacerated and torn. If the stem is split open, the maggot may be found feeding within and at the base of the central shoot, cutting the vascular bundles and preventing the flow of the sap into the upper part of the leaf. This injury caused in fall and early spring may

be of considerable consequence and at times may equal or even exceed the injury done by the Hessian fly.

In some cases the entire tiller turns yellow and dies from this type of injury. After injuring or killing one tiller in this way, the maggot may migrate to a fresh tiller and attack it in a similar manner. In laboratory experiments the maggots have been found in some cases to migrate from an injured tiller to a fresh tiller on an entirely different plant. These plants have always been in close proximity to each other, and no records are available as to the distance the maggots may migrate. Maggots placed on the soil near plants have, with but few exceptions, been able to reach the plants and feed within them.

This type of injury, even though more than one tiller may be destroyed, is frequently considered less severe than that caused in the late spring and summer, in which only one head is destroyed, because the young plants, especially those attacked in the fall, are able to produce new tillers to take the place of and to produce grain for those suffering from attack. There is, however, a serious aspect of this type of injury which is often overlooked in that the maggots producing the injury to the heading wheat in later spring are produced by adult flies emerging from puparia

formed by this generation of maggots.

It may be readily understood that these two types of injury may cause a rather severe loss to the wheat crop. The extent of damage is often under estimated because the type of injury occurring in fall and early spring is not usually considered of great importance by farmers and wheat growers, due to its being confused with injury caused by Hessian fly, chinch bugs, and other insects, and that caused by "foot rot", drouth, and drowning.

Feeding Habits

The young maggot upon emerging from an egg makes its way to that point where the central leaf or head bearing shoot emerges from its investing sheath. Upon reaching this point the maggot works its way down between the sheath and the central shoot, girdling the latter as it progresses downward to its final feeding position, which is at the base of the culm in fall and early spring, and just above the upper node of the culm in late spring and summer. Upon reaching the feeding position the maggot feeds by tearing the plant tissues with the mandibles and sucking the juices from the lacerated tissue. The maggot while feeding enters the central shoot within which most of the feeding takes place. Before entering the central shoot, the feeding takes

place between this shoot and its investing sheath.

The maggot when first entering the plant and during the migration down to the feeding position, feeds with its head down, but when the feeding position is reached, and while the maggot is still quite young, this position is reversed, and the greater part of the feeding is done with the anterior end up (Plate IV, Fig. 2).

Food Plants

During these experiments wheat stem maggots were observed feeding within the stems of the following species of plants:

Common wheat (Triticum vulgare, Vill.)

Durum wheat (Triticum durum, Desf.)

Triticum vulgare X T durum (from Sapahin and others)

Triticum macha Vav.

Triticum persicum strameneum Vav.

Triticum timopheevi Zhuk.

Barley 6 row (Hordeum vulgare L.)

Rye (Secale cereale L.)

Timothy (Phleum pratense L.)

Yellow Foxtail (Setaria lutescens (Weig) Hubb.)

Green Foxtail (Setaria viridis (L.) Beauv.)

In addition to these food plants the maggot has been reported in the literature as feeding within the stems of:

Emmer (Triticum dicoccum Schr.)

Quack Grass (Agropyron repens (L.) Beauv.)

Slender Wheat Grass (Agropyron tenerum Vasey)

Western Wheat Grass (Agropyron smithii Rybd.)

Awned Blue Stem (Agropurum divergens Nees.)

Wild Barley (Hordeum jubatum L.)

Wild Rye Grass (Elymus canadensis L.)

Brome Grass (Bromus inermis Leyss)

(Bromus japonicus Thun.)

Natural Checks

Parasites. During these experiments eighteen species of Hymenoptera were reared, nine of which are known to be parasitic upon Meromyza. Of the eighteen reared species, four were reared from puparia of Meromyza americana; three others were reared from culms having "blasted heads", and eleven other species were reared from volunteer wheat known to be infested by the wheat stem maggot. In Table III the names of the parasites are listed under family designation, with the sources from which reared, the number reared, and literature citations of previous records of their having been parasitic on Meromyza.

Of the four species of parasites reared from the puparia of M. americana, three belong to the Ichneumonoidea and one to the Cynipoidea. Of the three Ichneumonoids, two belong to the family Alysiidae and to the sub-family Dacnusinae, Coelinidea ferruginea Forbes, and Coelinidea meromyzae Gahan. The third Ichneumonoid belongs to the family Braconidae and sub-family Braconinae, Microbracon meromyzae Gahan. The Cynipoid is an undetermined species belonging to the family Figitidae, sub-family Eucoilinae and to the genus Hypodiranchis.

Coelinidea ferruginea Gahan was described by Gahan (1913) from three specimens, two females and one male reared by C. N. Ainslie at Elkpoint, South Dakota, the type locality. The host was Meromyza americana Fitch. All the parasites of this species reared during these experiments were reared from puparia formed by the overwintering maggots in May and June, and from which the first brood of flies normally emerge.

Coelinidea meromyzae Forbes was described by Forbes (1884) from specimens reared from M. americana and from specimens collected in the vicinity of Cuba, Illinois. Kelly (1917) gives detailed biological observations on this species. Four specimens of this species were reared from puparia produced by maggots of the second generation

occurring in July. The fifth specimen was reared from volunteer wheat in the greenhouse, January 10, probably from a puparium formed by an overwintering maggot.

Microbracon meromyzae Gahan was described by Gahan (1913) from six specimens, three females and three males, reared by C. N. Ainslie at Elkpoint, South Dakota. A male specimen was also reared by J. A. Hyslop at Hagerstown, Maryland. The host in both cases was Meromyza americana Fitch. All of the specimens of this species reared during these experiments were reared from puparia formed in late May and early June, and from puparia formed in July.

Hypodiranchis sp. is a new species of parasite attacking the wheat stem maggot. No species of this genus have been described from North America; the genus, the genotype Hypodiranchis hawaiiensis, and most of the known species of the genus have been described by William Ashmead from the Hawaiian Islands. A closely related European species Cothonaspis rapae (Westd.) has been reported by James (1928) as being parasitic on the cabbage root maggot (Hylemyia brassicae Bouché.). One specimen of Hypodiranchis sp. has been reared from a single puparium collected June 9 and others from volunteer wheat during October, November, December, and January. Those reared from volunteer wheat

probably came from puparia formed by overwintering maggots which were caused to mature early due to rearing under greenhouse conditions.

Information relative to the other species of parasites reared from volunteer wheat and culms having "blasted heads" is included in Table III.

In addition to the species of Hymenopterous parasites reared during these experiments, one other has been recorded in the literature. Gahan (1913) described this species, Euphoriana uniformis from the male type reared from Meromyza americana by J. A. Hyslop, Hagerstown, Maryland, and from the female type collected by W. H. Menke at Garden City, Kansas.

Numerous times in the literature reference was made to a small mite Pediculoides ventricosus Newport. It is reported as killing the maggots by sucking their blood. This mite has not been reported as occurring in Kansas.

Bacteria. In many cases both in the rearing experiments and in stems of wheat collected in the field brown or partially brown maggots were found. These maggots seemed to die slowly and when the integument was ruptured the internal organs were found to be decayed and in a liquid state. This brown color and death was attributed to undetermined bacteria.

Table III. Hymenopterous Parasites of the Wheat Stem Maggot (*Meromyza americana* Fitch)

Parasite	Number Reared From: Puparia	*"Blasted Heads Inf. by Maggot	Volunteer Wheat Inf. by Maggot	Recorded in Literature as Parasite of *Meromyza*
Ichneumonoidea				
Alysiidae				
Coelinidea ferruginea Gahan	10		13	Gahan (1913)
Coelinidea meromyzae Forbes	4		1	Forbes (1884)
Braconidae				
** *Euphoriana uniformis* Gahan				Gahan (1913)
Microbracon mellitor (Say)		1		
Microbracon meromyzae (Gahan)	3	10		Gahan (1913)
Microplitis melianae Vier.		3		
Meteorus vulgaris (Cress.)			1	
Ichnumonidae				
Casinaria scabriformis Vier.			1	
Proctotrupoidea				
Platygasteridae				
Leptacis sp.			1	
Chalcidoidea				
Eulophidae				
Horismenus texanus (Girault)			3	Gahan (1933)
Notanisomorpha meromyzae Gahan			9	Gahan (1917)
Eupelmidae				
Eupelmus allynii French			2	Gahan (1933)
Eurytomidae				
Eurytoma tylodermatis Ashm.		1		
Mymaridae				
Polynema striaticorne Girault			2	
Pteromalidae				
Bubekia fallax Gahan			15	Gahan (1933)
Callitula bicolor Spinola			1	Gahan (1933)
Eupteromalus fulvipes (Forbes)			7	
Halticoptera aenea (Walk.)			1	
Cynipoidea				
Figitidae				
Hypodiranchis sp.	1		14	

* Culms of wheat having "blasted heads".

** Not reared in these experiments.

Fungus. Often associated with the dead maggots was found a fungus determined by Dr. C. L. Lefebvre as Cladosporum sp. Most of the species of this genus are saprophytic and some few are parasitic. This one is probably a saprophyte, but until the species is definitely determined, no definite statement can be made concerning it.

Proposed Methods of Control[1]

Rotation of Crops. Rotation of crops has been mentioned several times in the literature as a method of controlling the wheat stem maggot. This method would tend to decrease the number of maggots, but since the insect breeds readily in many of our cereal crops and native grasses, rotation of crops is at best only a partial control.

Destruction of Volunteer Grain. Another method of control that is often recommended in the literature is the destruction of volunteer grain. It has been recommended that grazing of volunteer grain might reduce the number of maggots. It is quite evident that grazing would do little if any good, as the maggots feed within the base of the

---

1 Control methods proposed by previous authors and the present writer.

volunteer plants. If volunteer grain is plowed under and completely covered about the last of June or the first of July when the maggots, from eggs deposited by the first brood of flies, are about half grown, a majority of them will probably be killed.

Destruction of Grasses. Destruction of grasses which might harbor the maggots has likewise been recommended as a control measure. Here again grazing has been mentioned as a possible means, but the same objections are evident as were stated for destruction of volunteer grain. Plowing under or burning the grass would probably destroy most of the maggots infesting the stems. Such a method would only be advisable for along fence rows, field borders, and roadways. Unless the infestation was extremely heavy, the grasses which would be destroyed would probably be of more value than the grain destroyed by the pest.

Hand Picking. Hand picking of the infested culms has been suggested in the literature, but the impractibility of such a method makes it of little value.

Date of Planting. It has often been reported in the literature that late sown wheat is less severely injured by the wheat stem maggot than that sown earlier. From counts made of the "blasted" or white heads collected from the date of planting-variety plots at the Agronomy Farm, this was

found not to be entirely true. In the case of the type of injury caused in late spring, after the wheat heads, it was found that in general the later sown plots were more heavily injured than those sown earlier. It was also found in these same studies that the date of planting which produces the greatest injury may vary according to the variety of wheat planted. Four varieties of wheat planted upon seven dates at approximately one week intervals were studied. In Table IV are listed the varieties studied, the dates planted, and the number of "blasted heads" collected together with other information later to be discussed. Plate V also shows the difference in the number of "blasted heads" formed in each variety on the various dates of planting. According to this table and plate it is shown that Oro planted October 5, Kanred planted October 11, Quivira planted October 18, and Early Blackhull planted October 25 produced the most "blasted heads".

An attempt was made to correlate this difference with some influencing factor. Several factors such as date of emergence of plants, date of first heading, date fully ripe, stand in plants per acre, stand in culms per acre, yield, length of fruiting period, plant height, test weight per bushel, rainfall, and temperature were considered. The closest correlation was found to exist between the

amount of injury and the date of "first heading" of the plants. It was found that plants of these four varieties which were marked by agronomists as "first heading"[1] between May 22 and May 26 were more heavily infested than those heading earlier or later, regardless of the variety or the date planted. This fact is probably due to the condition of the plants at the time of oviposition by the female flies. Apparently in late spring some specific stage in the maturity of the plants is more acceptable to the female flies than are other stages of maturity. The dates of "first heading" and the number of "blasted heads" found to have actually been infested by maggots are included in Table IV. The latter shows how definite and dependable a criterion the number of "blasted heads" is in the determination of an infestation by this generation of the maggot.

In data collected in 1934, studies made on these same plots tend to verify the results discussed in the foregoing discussion.

No actual check was made to determine the relationship between the date of planting and the amount of the fall and

---

1 That date when about ten per cent of the plants have headed.

Table IV. Effect of Date of Planting on Spring Injury by Wheat Stem Maggot

No.	Date	No. of Blasted Heads *	Blasted Heads Infested	Date of First Heading
Oro - C.I. 8220 - Ks. 495				
1.	Sept. 14	10	10	May 20
2.	Sept. 23	20	19	May 21
3.	Sept. 28	28	28	May 22
4.	Oct. 5	110	110	May 24
5.	Oct. 11	93	93	May 26
6.	Oct. 18	83	83	May 28
7.	Oct. 25	35	35	May 31
	Total	379	378	
Kanred - C.I. 5146 - Ks. 2401				
1.	Sept. 14	16	16	May 18
2.	Sept. 23	23	23	May 20
3.	Sept. 28	25	25	May 21
4.	Oct. 5	98	98	May 23
5.	Oct. 11	146	146	May 26
6.	Oct. 18	123	123	May 28
7.	Oct. 25	82	82	May 30
	Total	513	513	
Quivira - C.I. 8886 - Ks. 2628				
1.	Sept. 14	15	15	May 14
2.	Sept. 23	24	24	May 15
3.	Sept. 28	31	31	May 16
4.	Oct. 5	171	171	May 19
5.	Oct. 11	221	221	May 21
6.	Oct. 18	366	366	May 23
7.	Oct. 25	305	305	May 25
	Total	1133	1133	
Early Blackhull - C.I. 8856 - Ks. 483				
1.	Sept. 14	13	13	May 11
2.	Sept. 23	17	17	May 12
3.	Sept. 28	13	13	May 13
4.	Oct. 5	80	79	May 16
5.	Oct. 11	200	198	May 19
6.	Oct. 18	393	389	May 21
7.	Oct. 25	516	510	May 22
	Total	1232	1219	

* Per 40th acre plot

early spring type of injury, but from our knowledge of the life history of the maggot, it is evident that early planted wheat would be more severely injured than that planted later. There is a generation of flies which emerge during the latter part of August and the first of September and deposit their eggs during most of September and the first part of October. Wheat planted early in September would probably be large enough to attract the females for egg deposition.

In consideration of the two types of injury and the occurrence of the flies that deposit eggs producing the maggots which cause the injury, it is necessary to plant wheat during a fairly limited period.

The best date to plant wheat, in the vicinity of Manhattan, to escape the most injury by the wheat stem maggot, appears to be about the same as the safe seeding date for the Hessian fly. From September 28 to October 4 is probably the safest date, as this is late enough to escape most of the egg laying period of the third brood of flies in the fall, and is early enough so that the plants may pass, in the spring, the most acceptable stage of growth for egg deposition before the flies are ready to lay their eggs.

Recommendation. Of the five methods of control just discussed, the destruction of volunteer grain and the date of planting of grain seem to be the most promising. A combination of these two methods would afford more control than the use of either one alone. Neither of these methods should cause any additional expense or labor, as good cultural practices and clean cultivation will destroy the volunteer grain, and the recommended date of planting is the same as for the Hessian fly.

Resistance of Wheat to Attack

Some varieties of wheat may be more resistant than others to that type of injury occurring in the spring after the plants have headed. As is shown in Tables IV and V and in Plates V and VI there is evidence that there may be varietal differences as to resistance, but these studies have not been extensive enough to make any definite statements in regard to resistance. The writer believes that varietal differences as to resistance may be obscured by the date of planting and the date of "first heading".

From a summary of those counts of maggot infestation made during the several years previous to 1934 it was found that some varieties of wheat appear to be more resistant to that type of injury caused by the maggot in fall and early

Table V. Relative Injury to Wheat Varieties in the Variety Plots of the Agronomy Farm, Spring 1933

Kans. No.	C. I. No.	Variety	Number of Blasted Heads per 1/30 Acre Plot								Aver. No. Inf.	Date of First Heading
			1st. Series		2nd. Series		3rd. Series		Total	Infested		
			Total	Infested	Total	Infested	Total	Infested				
483	8856	Early Blackhull	27	27	10	10	9	9	46	46	15.3	13-V-33
2690		Kan. X Marq. *	24	24	9	9	15	15	48	48	16.0	19-V-33
2464	6156	Minturki	23	23	23	21	8	8	54	52	17.3	23-V-33
2671	11373	Kan. X H. Fed. **	9	9	21	21	64	64	94	94	31.3	16-V-33
2628	8886	Quivira	49	49	10	10	36	36	95	95	31.7	17-V-33
2672	10091	Kan. X H. Fed. **	40	40	15	13	51	50	106	103	34.3	15-V-33
19	6199	Harvest Queen	44	43	40	39	23	22	107	104	34.7	20-V-33
499	8861	Cooperatorka	32	32	65	63	17	16	114	111	37.0	21-V-33
570	1558	Turkey	40	39	31	29	47	47	118	115	38.3	21-V-33
2593	8180	Kawvale	45	45	38	38	36	35	119	118	39.3	19-V-33
2644	10090	Kan. X. Marq. *	44	44	32	32	57	57	133	133	44.3	19-V-33
2401	5146	Kanred	52	50	47	46	51	51	150	147	48.0	21-V-33
322	6250	Nebr. #60	50	50	69	69	35	34	154	153	51.0	23-V-33
505		E. G. Clark #40	68	67	57	57	30	30	155	154	51.3	20-V-33
317	6471	Fulcaster	54	53	51	51	56	55	161	159	53.0	20-V-33
2673	10092	Kan. X H. Fed. **	73	73	21	21	65	65	159	159	53.0	16-V-33
2670	10089	Tenmarq Sel.	53	51	44	44	69	69	166	164	54.7	19-V-33
495	8220	Oro	44	43	68	68	--	--	112	111	55.5	22-V-33
514	6936	Tenmarq	67	67	73	73	35	34	175	174	58.0	20-V-33
343	6251	Blackhull	39	39	91	89	87	87	217	215	71.7	19-V-33
2667	8885	Cheyenne	33	32	59	58	135	135	227	225	75.0	21-V-33
2591	1442	Kharkov	66	65	139	139	80	80	285	284	94.7	22-V-33
2659	6686	Kharkov Hays #2	89	88	186	185	--	--	275	273	136.5	22-V-33

* - Kanred X Marquis
** - Kanred X Hard Federation

Varieties planted September 28, 1932

spring than are other varieties. Of the eighty varieties and strains of wheat studied in two or more tests (Table VI), several varieties were found to have an infestation of zero in one or more tests. These zero counts were not considered by the writer as being significant, because these varieties were studied in only two or three tests, which is not a sufficient number to warrant any definite statement as to their resistance to the maggot. There are, however, three varieties in the studies--Honor, Dawson Golden Chaff, and Kanred--which seem to be more resistant than the other varieties. Each of these varieties has been studied in five tests, and even though these three varieties do not have a consistently low infestation, it is low enough to indicate a possibility of resistance. The results of the five tests in which the above mentioned varieties were studied are compared in Table VII with the results secured from Beechwood and Turkey in these same tests. Beechwood has a comparatively high infestation record, and Turkey is a common variety used more or less as a check in all the studies.

Table VI. Relative Infestation of Wheat Varieties by the Wheat Stem Maggot * in Per Cent of Plants Infested

Kansas or Sel. No.	C.I. No.	Variety or Strain	When Counts Were Made							Av. Per Cent	Turkey Same Test
			Spring 1921	Fall 1924	Fall 1927	Fall 1931	Fall 1932	Spring 1933	Fall 1933		
40	1923	Fultz		0.0	0.0					0.0	27.5
525		Marion				0.0		0.0		0.0	4.0
2450	5149	Minhardi		0.0				0.0		0.0	22.0
502		Prohibition				0.0		0.0		0.0	4.0
392		Regal			0.0			0.0		0.0	9.5
505		E. G. Clark #40				4.0		0.0		2.0	4.0
427		Mediterranean #30		0.0	5.0					2.5	27.5
496		Menno			0.0			5.0		2.5	9.5
SEK503		Nittany			5.0			0.0		2.5	9.5
2546	7002	Ohio #9920		0.0	5.0					2.5	27.5
2544		Portage		0.0	5.0					2.5	27.5
2580	5332	Treadwell		0.0	5.0					2.5	27.5
2548	6999	Fulhio		6.8	0.0					3.4	27.5
2583	4873	Rudy		6.8	0.0					3.4	27.5
2522	6161	Honor		0.0	0.0	10.0	8.0	0.0		3.6	13.8
385		Alton		0.0		8.0				4.0	22.0
SEK506	5679	Gypsy					0.0	8.0		4.0	5.0
511		Sibley New Golden		6.8		2.0		4.0		4.3	16.0
2564	3342	Dawson Golden Chaff		0.0	10.0	3.5	10.0	0.0		4.7	13.8
2401	5146	Kanred		7.2	8.9	2.5	2.0	4.0		4.9	13.8
Nebr.1058		Kruse					10.0	0.0		5.0	5.0
2587	5737	Russian		0.0	10.0					5.0	27.5
36	2008	Mammoth Red		6.8	5.0					5.9	27.5
	3604	Fultz		13.3	0.0					6.6	27.5
2693		Zemka				4.0	12.0	4.0		6.7	7.0
2624		Denton				13.6		0.0		6.8	4.0
19	6199	Harvest Queen	24.0	6.8	0.0	4.0		0.0		6.9	20.6
2545		Gladden		0.0	15.0					7.5	27.5
480	5829	Turkish Amber			10.0	8.0	8.0	4.0		7.5	14.5
527		Smithsonian				11.5		4.0		7.7	4.0
2679		Kanred X Marquis				12.0		4.0		8.0	4.0
2547		Trumbull		0.0	25.0			0.0		8.3	19.7
	5772	Gypsy #62		6.8	10.0					8.4	27.5
	5303	Mediterranean #30		6.8	10.0					8.4	27.5
2533		Michigan Wonder		6.8	10.0					8.4	27.5
439	6936	Tenmarq		6.8	5.0	4.0	4.0	0.0	28.0	9.1	17.8
440	6937	Kanmarq		13.3	5.0					9.2	27.5
	5658	Valley	7.7	0.0	20.0					9.2	31.7
34	5147	Nebr. #28		0.0	25.0			4.0		9.7	19.7
2270	4430	Sherman		20.0	0.0					10.0	27.5
2448	6155	Minturki		0.0	15.0		12.0		14.0	10.3	24.8
2672	10091	Kanred X Hard Federation				13.0	6.0	5.9	28.0	10.7	13.0
2584	4856	Glutten		6.8	15.0					10.9	27.5
431	6934	Iobred		6.8	20.0	12.0		4.0		10.9	18.3
383	1442	Kharkov	36.0	0.0				0.0		12.0	28.0
435	6163	Shepherd		6.8	10.0	25.0	18.0	0.0		12.0	13.8
2557	6203	Jones' Climax		0.0	25.0					12.5	27.5
223415		I. C. Sel.		9.2	8.8	1.3	6.0	8.0	44.0	12.9	17.8
2667	8885	Cheyenne				14.1	8.0	0.0	30.0	13.0	13.0
2559	6301	Early Oakley		16.6	10.0					13.3	27.5
459	5366	Nigger		0.0	40.0			0.0		13.3	19.7
500		Michigan Wonder				2.7	10.0	4.0	38.0	13.7	13.0
483	8856	Early Blackhull				25.8	10.0	0.0	20.0	13.9	13.0
	4475	Odessa	28.0	0.0						14.0	40.0
2585	2496	Silver Chief		3.3	25.0					14.2	27.5
	3326	Currell	20.0	3.3	30.0			4.3		14.5	24.8
2132		Red Winter	28.0	0.0	30.0	14.0	12.0	4.0		14.7	18.2
193287		I. C. Sel.				2.0	10.0	8.0	40.0	15.0	13.0
2593	8180	Kawvale			15.0	1.9	22.0	8.0	28.0	15.0	16.8
2628		Quivira				25.4	8.0	0.0	26.7	15.0	13.0
2574	4846	Wheedling		30.0	0.0					15.0	27.5
2588	5338	Imperial Amber		33.3	10.0	14.0	6.0	12.5		15.2	13.8
495	8220	Oro					12.0	0.0	34.0	15.3	16.0
2525	6990	Michikof		6.8	25.0			0.0		15.9	19.7
317		Fulcaster	32.0					0.0		16.0	22.0
	4898	Malakof			10.0	28.0	12.0			16.7	12.5
2594	8257	Fulhard			30.0	9.3	10.0	8.0	28.0	17.1	16.8
	5566	Beechwood	32.0	13.3	25.0	20.0	14.0	0.0		17.4	18.2
343	6251	Blackhull			12.3	13.8	12.0	10.5	44.0	18.5	16.8
359	5597	Red Rock		0.0	25.0	40.0	12.0	4.5	32.0	18.9	17.8
5933-31		Texas Mediterranean Sel.					6.0		32.0	19.0	22.0
2534		Michigan Wonder		0.0	40.0					20.0	27.5
2215	1561	Theiss		0.0	40.0					20.0	27.5
2576	3488	Poole		13.3	5.0				44.0	20.8	31.0
570	1558	Turkey	40.0	40.0	15.0	4.0	6.0	4.0	38.0	21.0	21.0
2084	6211	Zimmerman	48.0	0.0	20.0					22.7	31.7
326	6156	Basca	48.0	0.0						24.0	40.0
8184		Texas Sel.				36.0	14.0			25.0	5.0
2519	4843	Hussar		66.6	10.0			4.0		26.9	19.7
332	6250	Nebr. #60	48.0				10.0			29.0	23.0
Average Infestation all var.			32.6	7.1	13.1	11.5	7.8	2.8	32.3	10.8	
Number of plants examined			25	15	20	60	50	25	50		

*-Varieties tested two or more times

Table VII. High and Low Infestation of Wheat Varieties by the Wheat Stem Maggot in Per Cent of Plants Infested

Kans. No.	C. I. No.	Variety	When Counts Were Made					Av. Per Cent
			Fall 1924	Fall 1927	Fall 1931	Fall 1932	Spring 1933	
2522	6161	Honor	0.0	0.0	10.0	8.0	0.0	3.6
2564	3342	Dawson Golden Chaff	0.0	10.0	3.5	10.0	0.0	4.7
2401	5146	Kanred	7.2	8.9	2.5	2.0	4.0	4.9
570	1558	Turkey	40.0	15.0	4.0	6.0	4.0	13.8
	5566	Beechwood	13.3	25.0	20.0	14.0	0.0	14.5
Average per cent all varieties in tests			7.1	13.1	11.5	7.8	2.8	
Plants examined			15	20	60	50	25	

Average per cent of all varieties in all tests 8.4

SUMMARY AND CONCLUSIONS

The wheat stem maggot (Meromyza americana Fitch) is a native insect occurring commonly throughout the wheat growing area of North America. It is an insect having diverse host plants and of which comparatively little has been known in regard to its biology.

Results of these experiments indicate that:

1. The wheat stem maggot produced three full and a partial fourth generation during 1933 in the vicinity of Manhattan, Kansas. The adults of the first generation appeared in June; those of the second appeared the first of August; part of the adults of the third generation appeared the first part of September and deposited eggs which gave rise to the overwintering maggots of the fourth generation, which became adults in late April and early May. Others of the third generation did not emerge in September, but remained as mature maggots throughout the winter and emerged as adults during April and May.

2. The maggot passes through three larval instars before pupating. The mandibles of the maggot are attached to a "V-shaped", blackish, chitinized structure usually visible through the integument. This is the cephalopharyngeal skeleton, the shape of which differs in the

various larval instars.

a. The cephalo-pharyngeal skeleton of the third instar, or mature maggot, is completely developed, and the parts can easily be distinguished. The mandibular, hypostomal, pharyngeal, and dentate sclerites are completely developed, with two small accessory sclerites attached to the hypostomal sclerite. The dentes of the mandibular sclerite are fully developed and completely scleritized.

b. The cephalo-pharyngeal skeleton of the second instar maggot is very similar to that of the third instar, with the exception of being somewhat smaller and the dentes are not so fully developed or scleritized.

c. The cephalo-pharyngeal skeleton of the first instar maggot differs greatly from that of the second and third instar. Not only is the skeleton materially smaller than either of the others, but it is far less completely developed. The dentate sclerite and the two small accessory sclerites are completely absent, and the dentes of the mandibular sclerite are poorly developed. The mandibular sclerite is not heavily scleritized, as in the skeletons of the other two instars.

3. The wheat stem maggot produces two entirely different types of injury:

a. In the type which occurs in the fall and early

spring the central leaf of the young culm is cut off near the base, causing the death of that leaf.

b. In the type which occurs later in the spring after heading of the plants and just before their maturity, the head bearing shoot is cut off just above the top node of the culm and the head appears prematurely ripened, with stiff, brittle spreading awns. These heads are known as "blasted heads" and when examined, yield few or no kernels. The few kernels which are formed are unfit for either food or planting purposes.

4. The young maggots upon hatching migrate to the point where the central shoot of the culm emerges from the investing sheath and from there work their way downward to the feeding position. This position is at the base of the young culms in the fall and early spring, and just above the upper node of the culm in late spring.

a. The maggots feed by tearing the plant tissues with the mandibles and sucking the juices from the lacerated tissues.

b. The feeding takes place, mostly, within the central shoot, but maggots have been observed feeding between it and its investing sheath.

c. The maggots when first entering the plant usually feed with their heads down, but this position is

generally reversed while the maggots are still quite young, and the greater part of the feeding is done with head end up.

5. The stem maggot is attacked by at least ten Hymenopterous parasites and one mite, all of which were reared in these experiments with the exception of one Hymenopteran Euphoriana uniformis Gahan, and the mite Heteropus ventricosus Newport. The parasite Euphoriana uniformis Gahan has been reported by Gahan as occurring in Kansas.

6. One presumably new species of parasite was reared during these experiments, Hypodiranchis sp., belonging to family Figitidae and sub-family Eucoilenae of the Cynipoid wasps.

7. Maggots, in several cases, were found to have been killed by bacteria and quite often associated with these dead maggots, both in the laboratory and in the field, was a fungus, Cladosporium sp.

8. The infestation of wheat, in the spring, seems to depend to a large extent upon the stage of maturity of the plants at the time of oviposition of the eggs. Apparently in late spring some specific stage in the maturity of the plants is more acceptable to the female flies for egg deposition than are other stages of maturity. It was found

that plants marked by agronomists as "first heading" between May 22 and May 26 were more heavily infested than those heading earlier or later, regardless of the variety.

9. The best date to plant wheat, in this vicinity, to escape the most injury by the wheat stem maggot, is about the same as the safe seeding date for the Hessian fly. From September 28 to October 4 is probably the safest date, as this is late enough to escape most of the egg laying period of the third brood of flies and is early enough so that the plants may pass, in the spring, the most acceptable stage of growth for egg deposition before the flies are ready to lay their eggs.

10. To that type of injury occurring in the spring after the plants have headed, some varieties of wheat may be more resistant than others, but varietal differences as to resistance may be obscured by the date of planting and the date of "first heading" of the plants.

11. To that type of injury caused by the wheat stem maggot in fall and early spring some varieties of wheat appear to be more resistant than others. Of the eighty varieties and strains studied in two or more tests, three varieties--Honor, Dawson Golden Chaff, and Kanred--seem to be more resistant than the other varieties.

ACKNOWLEDGMENTS

The writer wishes to express his gratitude to Dr. R. H. Painter, major instructor, for his valuable advice and assistance during the experiments and for his suggestions and criticisms in the preparation of the manuscript. Indebtedness is likewise expressed to Dr. J. H. Parker, Professor H. H. Laude, Professor D. A. Wilbur and Mr. C. W. Sabrosky for materials and information furnished during the work on the experiments; and to Dr. H. Morrison, Mr. C. F. W. Muesebeck, Mr. R. A. Cushman, Mr. A. B. Gahan, and Mr. L. H. Weld for determination of parasites. Many helpful aids and criticisms were also given by Dr. R. C. Smith and Professor H. R. Bryson.

BIBLIOGRAPHY

Aldrich, J. M.
Meromyza americana. In A catalog of North American Diptera. Smithsonian Miscellaneous Collections, 46:632. 1905.

Ashmead, Wm. H.
Hypodiranchis hawaiiensis. In Classification of the gall-wasps and the parasitic Cynipoids .... Psyche, 10:67. 1903.

Becker, Theodore
Meromyza. In Chloropidae eine monographische studie, I teil. Palärorktische region. Archivum Zoologicum, 1:(10)40-44. 1910.

_____
Meromyza. In Chloropidae eine monographische studie, IV teil. Nearktische region. Ann. Nat. Mus. Hungaric, 10:23-24. 1912.

Bruner, L.
The wheat stem maggot (Meromyza americana Fitch). In Insect enemies of small grains. Ann. Rpt. Nebr. St. Bd. Agr. 1892:371-373.

Bruner, L. and Swenk, M. H.
The wheat-stem maggot (Meromyza americana Fitch). In Insects affecting wheat in Nebraska. Nebr. Agr. Exp. Sta. Bul. 96:24-26. 1907.

Buckhout, W. A.
Wheat stem maggot. In Insect enemies. Penn. State Bd. Agr. Rpt. 1892:99-100.

Cooley, R. A.
The wheat stem maggot. In 13th Ann. Rpt. State Ent. of Mont. Mont. Agr. Exp. Sta. Bul. 109:158-159. 1916.

_____
Wheat stem maggots. In 14th Ann. Rpt. State Ent. of Mont. Mont. Agr. Exp. Sta. Bul. 112:59. 1916.

Criddle, Norman
The greater wheat stem maggot, Meromyza americana. In Injurious insects of 1910 at Treesbank, Manitoba. Jour. Econ. Ent. 4:236. April 1911.

_____ Some stem maggots attacking growing grain. Canad. Agr. Gaz. 3:504-507. 1918.

Dalla Torre, W. and Kieffer, J. J.
Cothonaspis (Cynipidae). In Das Tierreich 24:104-127. 1910.

Fernald, H. T.
The wheat-stem maggot. In Some insects injurious in Pennsylvania. Penn. Dept. Agr. Rpt. 4:(1)379-381. 1898.

Fitch, Asa
Meromyza americana. In Rpt. on the noxious, beneficial, and other insects of N. Y. 2nd. Rpt. Insects of N. Y. 1856:299.

Fletcher, J.
The wheat-stem maggot, "wheat bulb-worm" (Meromyza americana Fitch). In Rpt. of the entomologist and botanist. Rpt. Exp. Farms Canada. 1888:52-53.

_____ The wheat-stem maggot (Meromyza americana Fitch). In Rpt. of the entomologist and botanist. Rpt. Exp. Farms Canada. 1890:179.

_____ The wheat-stem maggot (Meromyza americana Fitch). In Rpt. of the entomologist and botanist. Rpt. Exp. Farms Canada. 1898:175-176.

_____ The wheat-stem maggot (Meromyza americana Fitch). In Injurious insects in 1898. Ontario Ent. Soc., 29 Ann. Rpt. 1898:75-78.

_____ Wheat-stem maggot (Meromyza americana Fitch). In Rpt. of the entomologist and botanist. Rpt. Exp. Farms Canada. 1900:202.

Forbes, S. A.
The wheat-bulb worm. In 13th Ann. Rpt. State Ent. Ill. 1884:13-29.

_____ The wheat-bulb worm. In 15th Ann. Rpt. State Ent. Ill. 1886:35-39.

Gahan, A. B.
New Hymenoptera from North America. U. S. Nat. Mus., Proc. 46:431-444. 1913.

_____ Notanisomorpha meromyzae. In Descriptions of some new parasitic Hymenoptera. U. S. Nat. Mus., Proc. 53:216. 1917.

_____ The Serphoid and Chalcidoid parasites of the Hessian fly. U. S. Dept. Agr. Misc. Pub. 174. 147 p. 1933.

Garman, H.
The American meromyza, wheat-bulb worm. In Observations on injurious insects and fungi. 2nd. Ann. Rpt. Ky. Exp. Sta. 1889:16-19.

Gilbertson, G. I.
The wheat-stem maggot. S. Dak. Agr. Exp. Sta. Bul. 217. 28 p. 8 fig. 1925.

Imms, A. D.
[Dipterous larvae]. In A general textbook of entomology. N. Y. E. P. Dutton. p. 609-610. fig. 570. 1924.

_____ Some methods of technique applicable to entomology. Bul. Ent. Res. 20:(2)165-171. 1929.

James, H. C.
On the life-histories and economic status of certain Cynipoid parasites of Dipterous larvae ... Ann. Appl. Biol. 15:287-315. 1918.

Kelly, E. O. G.
The biology of Coelinidea meromyzae (Forbes). Jour. Econ. Ent. 10:527-531. Dec. 1917.

Lintner, J. A.
Meromyza americana, the wheat-stem maggot. In 1st Ann. Rpt. State Ent. N. Y. 1882:221-227.

_____
The wheat-stem maggot - Meromyza americana Fitch. In Rpt. on some of the injurious insects of the year 1879. N. Y. State Agr. Soc., Trans. 33:150-154. 1884.

Lockhead, William
Insects sometimes mistaken for the Hessian fly. In The Hessian fly in Ontario. Ont. Agr. Col. Exp. Sta. Bul. 116:7-8. 1901.

Lugger, O.
The wheat-stem maggot (Meromyza americana Fitch). In Insects injurious in 1895. Minn. Agr. Exp. Sta. Bul. 43:210-213. 1895.

_____
The wheat-stem maggot (Meromyza americana Fitch). In Insects injurious in 1896. Minn. Agr. Exp. Sta. Bul. 48:38. 1896.

Malloch, J. R.
Meromyza flavipalpis. In a synopsis of the genera in Chloropidae for North America. Canad. Ent. 46:(4)117. 1914.

Marlatt, C. L.
The wheat bulb worm. In The principle insect enemies of growing wheat. U. S. Dept. Agr. Farmers' Bul. 132:29-30. fig. 17. 1901.

Osborn, H.
Silver-top in grass and the insects which may produce it. Canad. Ent. 23:(5) 93-96. 1891.

Osborn, H. and Gossard, H. A.
The wheat bulb worm (Meromyza americana Fitch). In Rpts. of entomological work. Iowa Agr. Exp. Sta. Bul. 14:178-179. 1891.

Perkins, R. C. L.
[Cothonaspis hypodiranchis sp.]. In Hymenoptera. Fauna Hawaiiensis 2:(6)667-674. 1910.

Pettit, R. H.
Wheat-head fly (Meromyza americana Fitch). In Insect and animal life ... Mich. Agr. Exp. Sta. Bul. 186:36. 1900.

_____
Wheat-stem maggot (Meromyza americana Fitch). In Insects of field crops. Mich. Agr. Exp. Sta. Bul. 258:75-76. 1910.

Riley, C. V.
Worms in joints of wheat. Amer. Ent. 3:180-181. July 1880.

_____
Worms injuring wheat. Amer. Ent. 3:202. Aug. 1880.

Sanderson, E. D. and Peairs, L. M.
Some wheat maggots. In Insect pests of farm ... 2nd ed. New York. John Wiley Sons. p. 130-133. 1921.

Stedman, J. M.
The wheat bulb-worm. In The more important insects injurious to wheat. 34th Ann. Rpt. Missouri State Bd. Agr. 1902:86-94. 6 figs.

Swenk, M. H.
The principle insects injurious to agriculture during 1908-1909. In Ann. Rpt. Nebr. State Bd. Agr. 1910:362-370.

Washburn, F. L.
[The wheat stem maggot]. In Injurious insects in Minnesota in 1904. U. S. Dept. Agr. Bur. Ent. Bul. 52:56. 1905.

_____
Oscinidae. In Diptera of Minnesota. 14th Ann. Rpt. Minn. Agr. Exp. Sta. 1905:106-111.

Walsh, B. D. and Riley, C. V.
Wheat maggots. Amer. Ent. 1:248. Aug. 1869.

Webster, F. M.
The American meromyza (Meromyza americana Fitch). In Insects affecting fall wheat. U. S. Dept. Agr. Rpt. 1884:389.

_____ The American meromyza (Meromyza americana Fitch). In Insects affecting small grains and grasses. U. S. Dept. Agr. Rpt. 1886:574.

_____ Does the wheat stem maggot Meromyza americana discriminate between different varieties of wheat. Insect Life, 2:87. Sept. 1889.

_____ The wheat stem maggot, Meromyza americana Fitch. In Insects which burrow in the stems of wheat. Ohio Agr. Exp. Sta. Bul. 40:74-79. 1892.

_____ The greater wheat stem-maggot (Meromyza americana Fitch). In Some insects attacking the stems of growing wheat, rye, barley and oats. U. S. Dept. Agr. Bur. Ent. Bul. 42:43-51. 1903.

Webster, R. L.
Insects affecting stems of wheat and other small grains in North Dakota. N. Dak. Agr. Exp. Sta. Cir. 25:20 p. 1925.

Williams, T. A.
The wheat stem maggot or American meromyza (Meromyza americana Fitch). In Three injurious insects. S. Dak. Agr. Exp. Sta. Bul. 48:17-20. fig. 1. 1896.

EXPLANATION OF PLATES

Plate I

Fig. 1. Egg.

Fig. 2. Puparium.

Fig. 3. Mature larva.

Fig. 4. Cephalo-pharyngeal skeleton, First instar.

Fig. 5. Cephalo-pharyngeal skeleton, Second instar.

Fig. 6. Cephalo-pharyngeal skeleton, Third instar.

Phary. Sc. - Pharyngeal sclerite.

Hypo. Sc. - Hypostomal sclerite.

Mand. Sc. - Mandibular sclerite.

Dent. Sc. - Dentate sclerite.

Acc. Sc. - Accessory sclerite.

Plate I

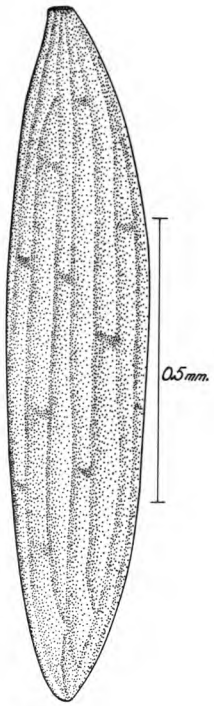

Figure 1.

Figure 4.

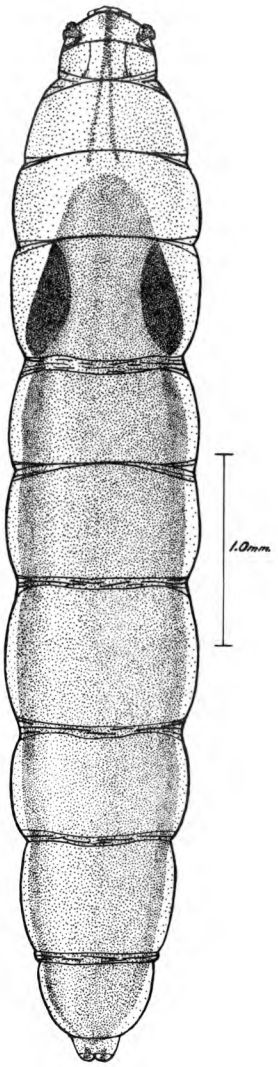

Figure 2.

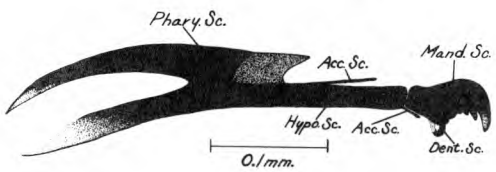

Figure 5.

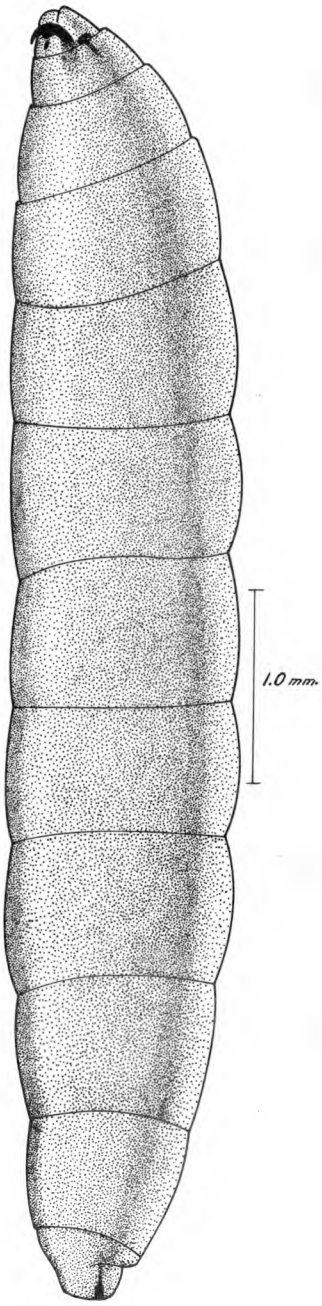

Figure 3

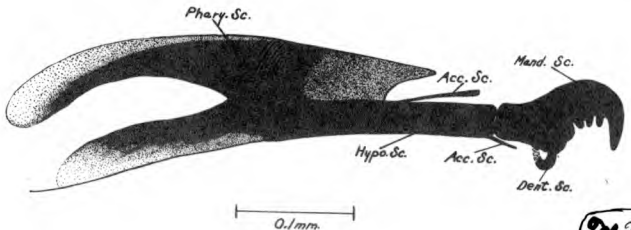

Figure 6.

M.W.A.

Plate II

Life cycle of the wheat stem maggot at Manhattan, Kansas, 1933.

Plate II

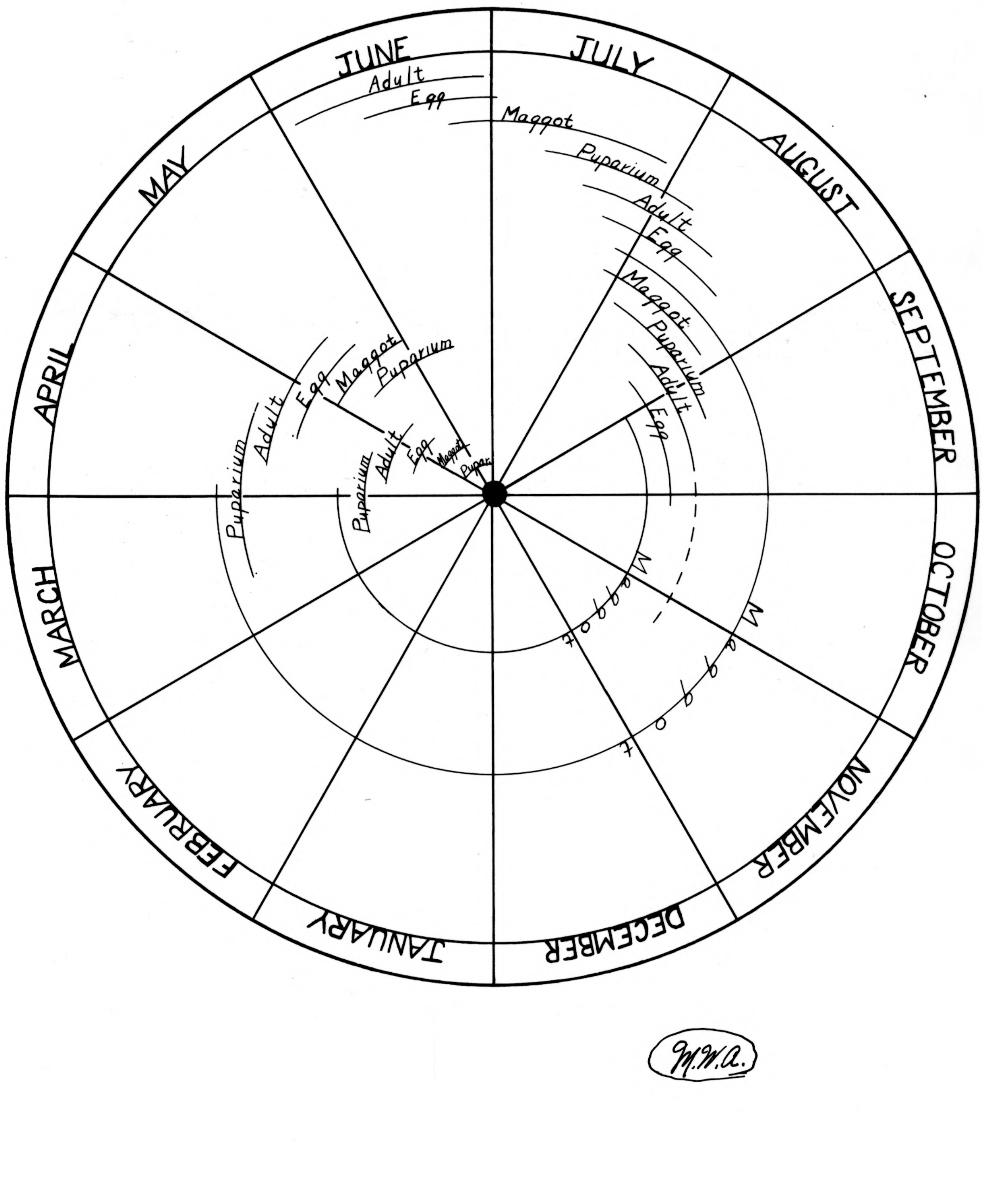
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL
MAY
Adult
Egg
Maggot
Puparium
Adult
Egg
Maggot
Puparium
Adult
Egg
Maggot
Maggot
Puparium
Adult
Egg
Maggot
Puparium
Puparium
Adult
Egg
Maggot
Pupar.
Puparium
M.W.A.

Plate III

Fig. 1. Type of injury caused by the wheat stem maggot in fall and early spring. (Injured tillers on left and normal tiller on right.)

Fig. 2. Type of injury caused by the wheat stem maggot in late spring and early summer. ("Blasted heads" on left and normal heads on right.)

Plate III

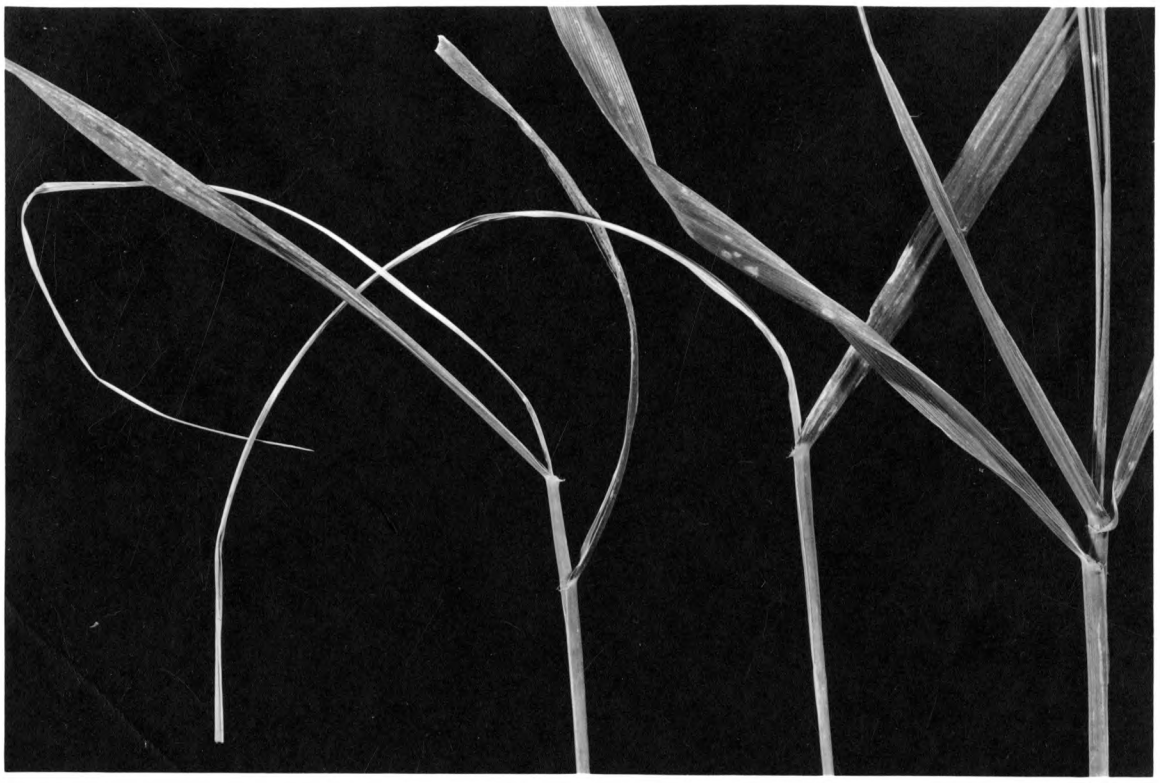

Fig. 1

Fig. 2

Plate IV

Fig. 1. Egg on stem of wheat.

Fig. 2. Maggot feeding within culm of wheat.

Fig. 3. Lacerated and torn plant tissue caused by the feeding of maggots.

Plate IV

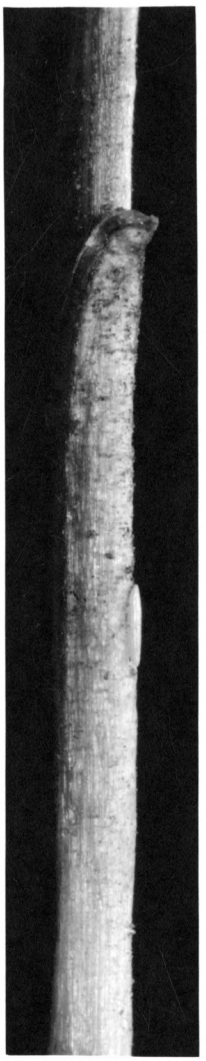

Fig. 1

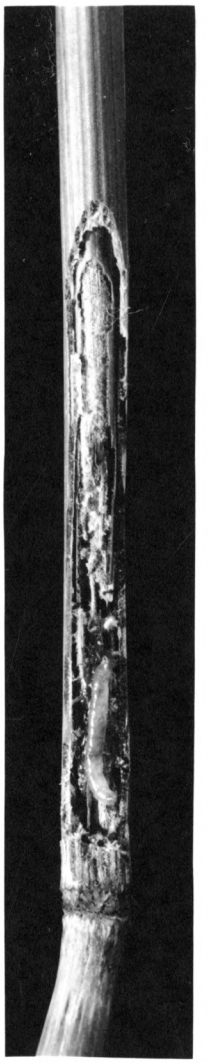

Fig. 2

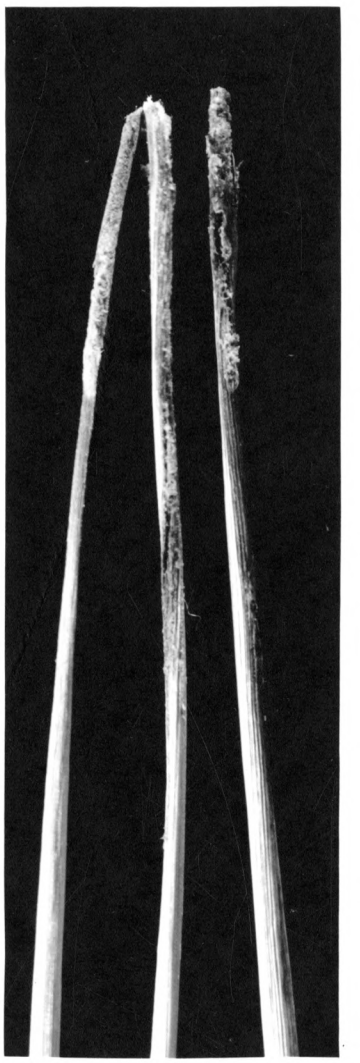

Fig. 3

Plate V

"Blasted heads" contained in the 1/40 acre date of planting-variety plots, Agronomy Farm.

O - Oro.

K - Kanred.

Q - Quivira.

EB - Early Blackhull.

1 - September 14.

2 - September 23.

3 - September 28.

4 - October 5.

5 - October 11.

6 - October 18.

7 - October 25.

Plate V

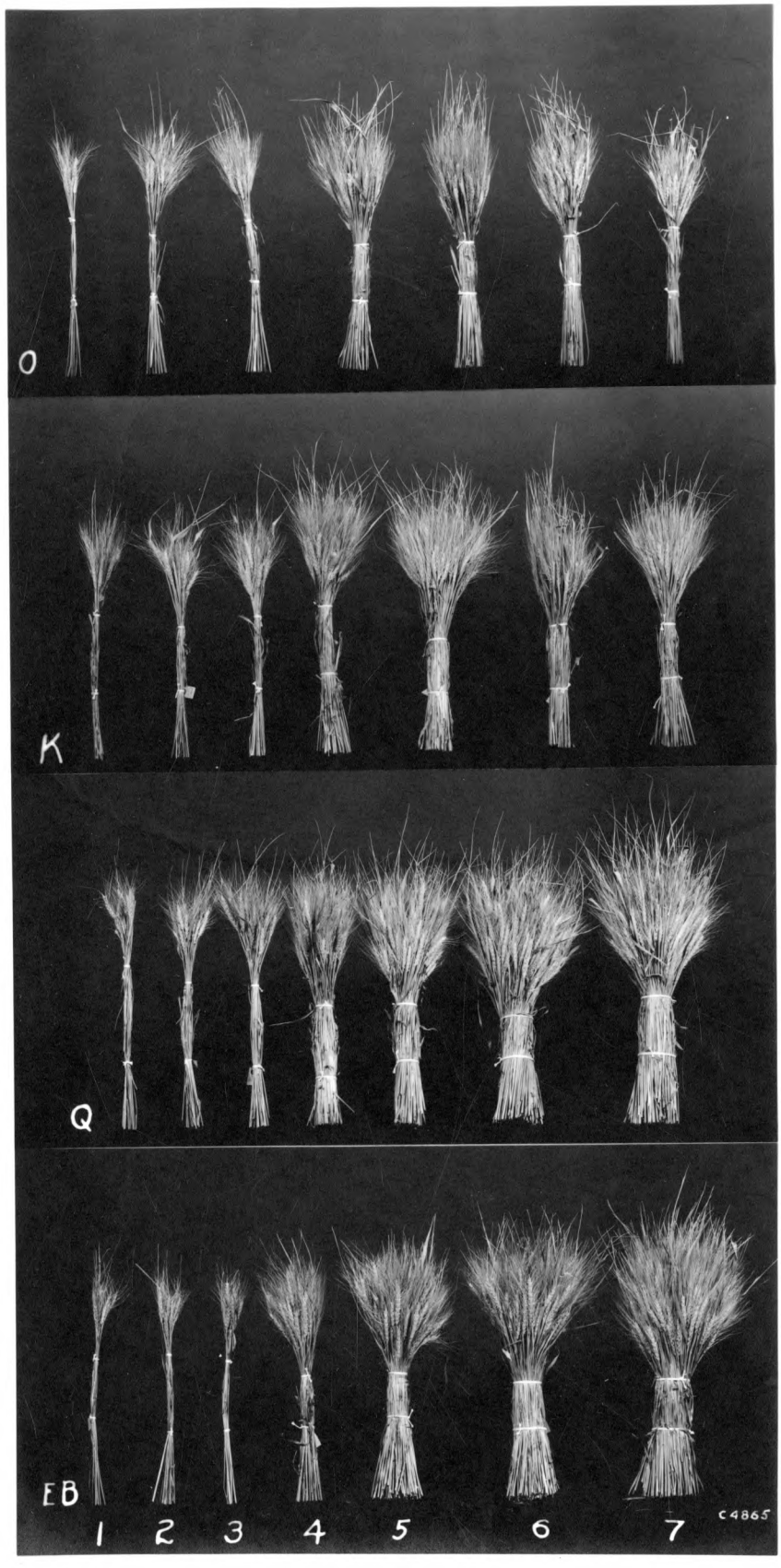

Plate VI

"Blasted heads" contained in the 1/30 acre variety plots, Agronomy Farm.

1. Kharkov Hays #2.
2. Kharkov.
3. Cheyenne.
4. Blackhull.
5. Kanred.
6. Kanred X Marquis (Kans. 2644).
7. Turkey.
8. Harvest Queen.
9. Kawvale.
10. Kanred X Marquis (Kans. 2690).
11. Minturki.
12. Early Blackhull.

Plate VI

1 2 3 4 5 6 7 8 9 10 11 12