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The Wheat-Stem Maggot

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SUMMARY

The wheat-stem maggot is the young or larval form of the fly, **Meromyza americana** Fitch. It attacks not only wheat plants, but also rye, barley, emmer, timothy and certain species of native grasses. Records in South Dakota show an annual loss to cereal crops of from less than one to fifteen per cent. Both spring sown and fall sown grain are attacked.

The wheat-stem maggot is widely distributed over South Dakota. The insect occurs wherever it can find certain native grasses or cultivated cereals in which to breed. It is generally conceded that the pest is a native of North America, having had its origin in the southern portion of the continent.

The insect passes through four stages in completing its life cycle: the egg, the larva or maggot, the puparium and the fly. Descriptions of each stage are given in this bulletin.

The adult flies appear about the first of June. After mating, each female lays, on an average, 25 to 30 eggs. These eggs are usually laid singly on different plants, and after four or five days, give rise to maggots. The maggots, after feeding 18 to 22 days, pupate. The pupal stage lasts from 12 to 16 days, and then the puparia give rise to flies, thus completing the life cycle. There may be three generations a year, although in some cases, only two generations are produced annually.

Records in South Dakota show that the wheat-stem maggot is parasitized rather heavily. From 30 to 65 per cent of its numbers are destroyed annually. The parasites can not be relied upon, however, to reduce the numbers of the pest to a point where it is a negligible factor in cereal production. Consequently, control measures must be adopted. Such measures as rotation of crops, trap crops, destruction of volunteer grains and grasses, and the late planting of fall grain aid greatly in suppression of the pest. Poisoned baits are to a degree effective, but, at present, because of labor and expense, are not recommended.

The Wheat-Stem Maggot

G. I. GILBERTSON[1]

A large acreage in South Dakota is devoted to the production of wheat. One of the serious menaces to the wheat growing industry is the wheat-stem maggot,[2] a pest about which little is known. Many questions regarding the insects are constantly arising; with a view to answering these questions, a study was undertaken of the insect to determine the possibilities of lessening the damage it does to the wheat crop of South Dakota.

Through the work which was done with this pest, the distribution of the wheat-stem maggot over South Dakota was determined; its life history and seasonal history under South Dakota conditions were worked out; the species of plants that may serve as food for the insect were determined; the injury that is caused by the pest was ascertained; its natural enemies were studied and the role they play in preventing an unlimited increase of the wheat-stem maggots was investigated; and finally control measures of the insect applicable to South Dakota conditions were worked out.

Synonomy

The wheat-stem maggot was first described by Meigen (7)[3] who, in 1830, gave an European form of this insect the name **Meromyza pratorum.** Fitch (3), however, in his second New York report in 1856, describes the American form under the name **Meromyza americana.** The insect goes by this name in all subsequent literature until 1912. In 1912, Becker (1) in his monograph on the Chloropidae lists the American form, **Meromyza americana,** as a variety of the Eurpean Meromyza pratorum, calling it **Meromyza pratorum var americana.** On this point, Dr. J. M. Aldrich, through correspondence with the writer states, "I now think Becker was wrong in making it a variety and it should be regarded as a distinct species".

The only synonym of **Meromyza americana** Fitch is **Meromyza flavipalpis** proposed by Malloch (6) in 1914 and described from specimens obtained from the vicinity of Champaign, Ill. To quote Dr. Aldrich again, "This species of Malloch's looks quite distinct in the shape of the head when you see the extreme form, but I have

[1]The writer is greatly indebted to Mr. H. C. Severin whose kindly counsel and helpful suggestions throughout the work has made the publication possible. I am also indebted to Mr. A. B. Gahan for the determination of parasites sent him. To Dr. J. M. Aldrich, I am indebted for the synonomy of the wheat-stem maggot.

[2]Meromyza americana Fitch; order Diptera; family Chloropidae.

[3]Reference is made by number to Literature cited page 27.

found all possible intermediate forms to be very common in northern material, especially from Manitoba".

For our purpose then, until taxonomists have decided more definitely the specific status of this insect, we shall retain the original name proposed by Fitch, namely, **Meromyza americana,** leaving it as a distinct species and not a variety of **Meromyza pratorum.**

Common Name

Various common names have been proposed and used by different early authors to designate this insect. The "American Meromyza" was the name selected by Fitch (3), undoubtedly to designate the American species. Later, however, Lintner (5) decided against this name as being too technical and proposed the "wheat-stem maggot".

Forbes (4), in his article on this insect, objected to the aforementioned common names as not being truly characteristic of the nature of the injury and mode of attack and not indicatory of the most serious phase of its work. Because his attention was first called to the injury done by the maggot to the young plant and because the maggot worked only in the base of the stem immediately above the root in spring or fall, Forbes adopted for its common name the "wheat-bulb worm".

Webster (9) in his work on this insect, desiring to indicate the nature of the injury and the place of attack and at the same time to differentiate this form from smaller maggots of related genera, called it the "larger wheat-stem maggot".

The insect, since these earlier writings, has been commented upon in a great many reports and bulletins and in nearly all cases the common name, wheat-stem maggot, has been used. Because of this majority adoption and because the name seems indicatory of the insect's ravages, the name, wheat-stem maggot, shall be used to designate **Meromyza americana** Fitch in discussions in this bulletin.

Nature of Injury

Probably the most common and conspicuous injury that is caused by the wheat-stem maggot is the appearance in a field of wheat, rye, or barley, of apparently ripened heads or spikes during the time the kernels are forming. These white heads appear in rather sharp contrast to the background of green unripened grain. Upon examination, the apparently ripened heads are found to be worthless, yield no kernels and are, in reality, dead. If a dead head be pulled gently, it will be found to slip out easily from the investing sheath of the upper leaf. The broken end of the stem presents a discolored, somewhat withered and ragged appearance as though chewed. Moreover, if the main stalk be carefully split lengthwise at and slightly above the upper node, the section will usually disclose a slender, glassy green, worm-like larva, the wheat-stem maggot, surrounded by the waste of the maggot and bits of corroded plant tissue. This maggot, through its feeding habits upon the stem, has so corroded and severed the fibro-vascular bundles that no sap reaches the head and consequently it dies.

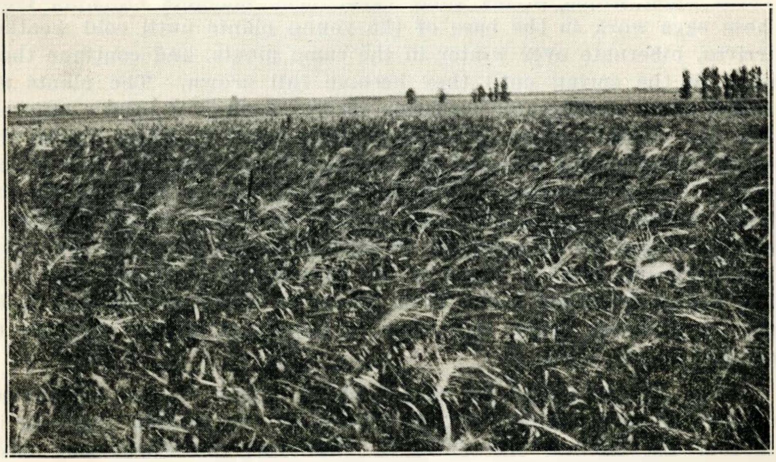

FIG. 1.—FIELD OF DURUM WHEAT ATTACKED BY WHEAT-STEM MAGGOT.

The uninfested plants, including the heads, are green in color, while the infested plants have dead white heads. Author's illustration.

Records taken in South Dakota show that from less than 1 to 15 per cent of the heads in a field of grain may be destroyed by the wheat-stem maggot. The cause for this wide variation in loss of heads is undoubtedly dependent upon the variety of grain grown, upon the season, upon the locality in the state where the grain is grown, etc.

The wheat-stem maggot, however, is not always responsible for the appearance of the white, dead heads in a given grain-field; these may, at times, be caused by a severe infestation of wheat scab (**Gibberella saubinetti** (Mont.) Sacc.). This disease may affect only a few spikelets of a head or the entire head may be attacked. In either case, the diseased parts ripen prematurely, turn yellow and yield no grain at all or produce only shrunken kernels. The disease occurs coincident with the attacks of the wheat-stem maggot and unless care is exercised to distinguish between the two, the injury caused by the fungus is apt to be confused with the damage done by the wheat-stem maggot. However, a head that has been injured by scab may be readily identified as such through the presence of a yellowish or pinkish mold on the glumes and rhachis of the spikelets. In addition to this character, a decided pull on the head will not remove the stem from the investing sheath of the upper leaf.

The southeastern portion of South Dakota is undergoing a transition from spring-wheat culture to winter-wheat production. In these areas, the fall flies of **Meromyza americana** choose winter-wheat upon which to lay their eggs. The maggots hatching from these eggs work in the base of the young plants until cold weather arrives, hibernate over winter in the same plants, and continue their work in the spring until they become full grown. The plants attacked show considerable variation in the amount of injury suffered, only the central leaf of some being killed while in others almost the entire plant except a green leaf or two turns brown. This injury is much more apparent in the spring than late in fall, for the injured plants or parts of plants readily succumb to the rigors of winter. Upon an examination of such plants, a glassy, green, slender, worm-like larva is found in the base of the plant near the root. The injury described varies from slight to heavy in different fields and in different years, but when it occurs, it usually appears as patches in the fields.

The injury caused to young wheat plants by the wheat-stem maggot is very similar to that caused by the smaller maggots of another fly, **Oscinus frit** (Linn.). However, the wheat-stem maggot may be readily distinguished from these by its larger size and through other characters which will be pointed out later when the maggot will be technically described.

Food Plants

Meromyza americana, while in the maggot stage, has been found feeding within the stems of the following plants in South Dakota:

Cultivated crops

Wheat:	Marquis	Castilione
	Preston	Black Don
	Acme	Monad
	Turkey	Pellis
	Minhardi	Mindum
	Minturki	Arnautka
	Prelude	Pierson 999
	Kota	Disco
	Pioneer	Kanred
	Ruby	Kitchener
	Station red	Red bob
	Kubanka	Red rock
	Wild goose	Bluestem
	Ghirka	

Barley: both two- and six-rowed
Rye: fall and spring
Emmer
Timothy
Oats

Grasses

Quack grass (**Agropyron repens** (L.) Beauv.)
Slender wheat grass (**Agropyron tenerum** Vasey)
Western wheat grass (**Agropyron smithii** Rydb.)
Wild barley (**Hordeum jubatum** L.)
Wild rye grass (**Elymus canadensis** L.)
Brome grass (**Bromus inermis** Leyss)
(**Bromus japonicus** Thun.)
Green foxtail (**Setaria viridis** L.)
Yellow foxtail (**Setaria glauca** L.)

The percentage of stems of wheat plants that may be infested with the wheat-stem maggot is dependent to some extent upon the variety of wheat that is grown. As a general rule, the beardless varieties are attacked less often than are the bearded; in fact, in many instances, less than one per cent of the stems of the beardless plants contain the maggots of this pest while as high as 15 per cent of the stems of the bearded plants may be infested. This contrast is very marked in plots of bearded and beardless plants grown side by side as they are on the Experiment Station plots at Brookings, South Dakota. However, not all the beardless varieties of wheat show an equal immunity from the attack of the wheat-stem maggot.

The fact that some varieties of wheat are attacked by the wheat-stem maggot more often than others has been explained in the past in a number of different ways by different writers, but in no instance has an explanation been supported by experimental evidence. We offer two possible explanations, but in neither case do we have any positive experimental data to back up our theories. One supposition is that ovipositing flies are attracted to certain varieties of wheat more strongly than they are to others and that they find such varieties suitable for egg-laying purposes. This explanation presupposes that from the different varieties of wheat emanate slightly different odors and that the flies are more strongly attracted by some odors than by others. According to the other supposition, the ovipositing flies are attracted in like numbers to all varieties of wheat plants and find them all suitable for egg-laying purposes. The different varieties of plants would, therefore, receive approximately the same number of eggs. However, because of a difference in the structure of different varieties of plants, the young larvae that hatch from the eggs have greater difficulty in making their way into the stems of some varieties than of others, or if the larvae are able to make their way into all varieties with the same efforts, then they may encounter more unfavorable conditions in the stems of some varieties than of others. It is quite possible that not one but both of these explanations offer a solution to the problem under discussion.

The injury done to barley varies between two and four per cent, both two-rowed and four-rowed varieties suffering equally.

Rye of both fall and spring plantings may be heavily infested in some localities with wheat-stem maggots, the fall rye suffering the greater damage.

Both emmer and timothy are moderately infested with wheat-stem maggots and, in the absence of small grain crops, furnish the fly with material in which to breed.

Oats are very sparingly attacked in this state by the wheat-stem maggot. However, in nearly all fields of oats, whitened heads are by no means uncommon. But if such plants are examined carefully for the cause of the injury, it will be found to be a caterpillar known as the stalk borer, **Papaipema vitela** Gn. Because we have found only an occasional oat plant attacked by the wheat-stem maggot in spite of a most thorough search for plants that might be infested with the pest, we must conclude that the growing of oats is a negligible factor in maintaining the fly on one's farm in this state.

The species of grasses that we have found to be infested with the wheat-stem maggot have been already enumerated. All of the grasses listed may become rather heavily infested with the maggots and undoubtedly furnish the pest a food supply independent of cereal crops. Such grasses must be considered when crop rotation is taken under advisement as a means of control of the pest.

A few writers have claimed that they have reared Meromyza flies from Kentucky blue grass (**Poa pratensis** L.), but this they were able to do but rarely. The author has been unable to rear a single Meromyza fly from Kentucky blue grass although numerous efforts were made to do this. An exceptionally large number of plants of this species were found that bore stems with whitened heads and while this injury resembles that produced through the wheat-stem maggot in other plants, a thorough examination disclosed the fact that it was caused by the feeding habits of certain Jassids. H. Osborn (8) noted this injury some time ago and gave to it the name of silver-top.

While we found no evidence that **Meromyza americana** uses Kentucky blue grass for breeding purposes, we did find that the flies themselves are attracted to blue grass for purposes of feeding. A short time after a field of Kentucky blue grass is mowed, an abundance of these flies may be found feeding on the cut stems and grass blades or upon the waxy covering of freshly expanded leaves.

Distribution

The wheat-stem maggot is not confined to any one locality of this state but is generally distributed over the commonwealth. It may be encountered in any area whose flora contains those species of grasses which serve the insects as hosts. While the pest is more abundant in the eastern half of South Dakota, we have collected it in the western half in small isolated grassy basins in the heart of the Bad Lands, in mountainous areas in the Black Hills remote from cereal culture and in stretches of virgin prairie on the cattle ranges. The eastern half of South Dakota is better adapted to growing cereals than is the western half. Because of this fact and because here also the species of grasses which the insect may use as host plants are more abundant, the wheat-stem maggot is more numerous. As one travels westward in South Dakota, the type of vegetation including grasses changes, and the host plants of the wheat-stem maggot become less abundant. As a consequence, the Meromyzas also become less numerous. It is undoubtedly true, however, that climatic factors, especially the amount of rainfall of a region, also influence the numbers of wheat-stem maggots that may occur in a region.

From records in literature, the wheat-stem maggot was probably known as early as 1822 and since then has been recognized as an enemy in wheat growing sections ranging from Mexico through the United States and far into Canada.

Various workers, after studying this insect, have come to the conclusion that it is a native of North America but that its origin was probably in the southern portion of this continent. They further believe that the insect bred in our native wild grasses before cultivated crops were brought into this country. This conclusion is well supported by the fact that when wheat, rye, barley, etc., are inaccessible, the insect readily breeds in these grasses.

Description of Stages

The wheat-stem maggot, like most other Diptera or flies, passes through an egg, larval, pupal and fly stage before completing its life cycle (Fig. 2, A, B, C, D, E). The female flies, after mating with the males, seek out grasses or cereal plants upon which to lay their eggs. From these eggs, worm-like larvae or maggots hatch. The maggots work their way into the stems of the plants and here they feed until they are full-grown. When the larvae are full-grown, their skins shrink and dry, and within the skins they transform to pupae. A pupa, together with its investing skin, is known as a puparium. In the pupal stage, the transformations from a maggot to a fly are completed and when this has taken place, the investing skin of the puparium is broken open and the fly emerges.

The flies, thus formed, mate and then the females start another generation by laying eggs. Usually three generations of these insects are produced during a year.

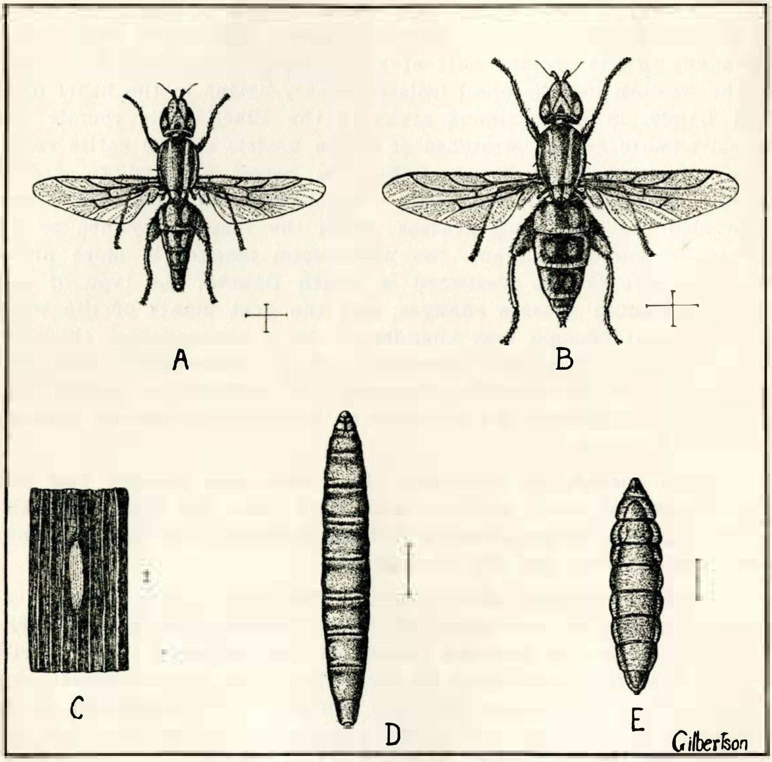

FIG. 2.—THE WHEAT-STEM MAGGOT (MEROMYZA AMERICANA FITCH)

A, male fly; B, female fly; C, egg on portion of wheat leaf; D, maggot; E, puparium. All enlarged. Hair lines indicate actual size. Author's illustrations.

The Eggs

The eggs of the wheat-stem maggot are usually deposited singly and are placed either on the stems or on the leaves of the host plant. In a few cases, the eggs were found shoved in between a leaf sheath and a stem; in others they were cemented to the stem just above the margin of the leaf sheath; while in still others, the eggs were glued to the upper surface of a leaf a short distance from the stem. In all cases, the eggs were found to be fastened parallel to the long axis of the stem or leaf.

The eggs are snow-white in color and vary from 1 to 1.16 mm. in length and from 0.17 to 0.2 mm. in breadth. In shape, the eggs are fusiform-cylindrical throughout the greater part of their length, with the ends gently rounded (Fig. 2, C). Ridges pass lengthwise over the egg-shell, the spaces between the ridges being divided into rectangular areas by fine transverse ridges. The rectangular areas thus formed are slightly depressed.

Towards the end of the incubation period, the eggs lose their snow-white appearance and become more or less translucent. At this time, if the eggs are examined with a lens or microscope, the outline of the young larvae or maggots may be distinguished.

The Larvae or Maggots

The maggots when first hatched are small, slender, headless and footless larvae, whitish in color, although semi-transparent. They are about 1 mm. in length and about 0.1 mm. in width. The body is cylindrical and composed of 13 segments. At the forward end, the maggot tapers to a dull point, the four anterior segments narrowing rather rapidly. The posterior end of the body also tapers somewhat but not as much as the anterior (Fig. 2, D). The last or anal segment of the body is divided into two lobes. In the center of each lobe is a breathing pore or spiracle guarded by a ring of spines.

Through how many molts and instars the maggots pass during their life, the author has been unable to determine. In the last instar, the larva is full-grown. It is now pale glassy-green in color, and varies in length from 6 to 7 mm. and in width from 0.8 to 1.3 mm. The dorsal and lateral aspects of the maggot present a smooth shiny appearance, while the ventral surface is provided with very fine transverse ridges. These ridges undoubtedly are of value to the insect in locomotion. On each side of the second segment and close to its posterior edge is a small, bilobate organ, the thoracic spiracles. Each lobe of the spiracles is divided into six tuberculate parts. The more or less sucker-like mouth is located on the under surface of the first segment and from it usually protrudes a pair of black toothed hooks, the mandibles. The mandibles are supported by and connected to a "wishbone"-like structure which extends back into the second and third body segments. This structure is known as the cephalo-pharyngeal skeleton and is usually visible through the integument of the larva as a brownish or blackish object. The shape of this structure is distinctive of **Meromyza americana** and may be used as a means of identifying larvae of this species of fly (Fig. 3).

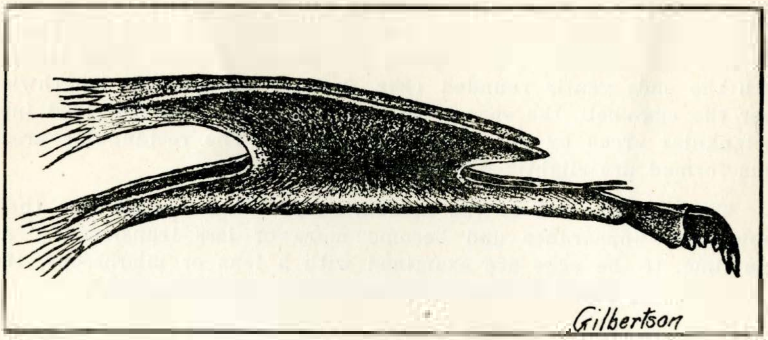

FIG. 3.—CEPHALO-PHARYNGEAL SKELETON OF THE WHEAT-STEM MAGGOT.

The small, pointed, serrated structures at the right of the figure are the mandibles. Figure greatly enlarged. Author's illustration.

The Puparia

After becoming full-grown, the maggots empty their food tube. The larvae of the fall brood pupate in the spring at the base of the plants above the roots. The maggots of the spring and summer broods pupate in the summer and fall respectively, but before doing so they migrate upward between the leaf sheath and culm and come to rest with the anterior end of the body upward at a point within an inch below the ligula on the junction of the leaf sheath and blade. In the majority of cases, a slight bulge at this point indicates the presence of a Meromyza larva or puparium.

When a maggot has reached the spot where it desires to pupate, it comes to rest and undergoes the transformation into a puparium. The last larval skin, instead of being shed, is retained as a protective envelope for the developing pupa within.

The puparium is about 5 mm. long and about 1.4 mm. in width. Because of its position between the leaf sheath and the stem, it is flattened dorso-ventrally. In color, the puparium is greenish but the shade of green is variable, for this depends largely upon the age of the puparium. A clear, transparent, unoccupied area is found at either end of the puparium. The anterior area is somewhat larger than the posterior and within it may be seen the cephalo-pharyngeal skeleton.

The puparium shows 10 clearly defined divisions, the anterior one being made up of the head and first segment of the larval integument. The second and third divisions are not clearly divisible owing to the shrinkage, discoloration and corrugations which have taken place when the last larval skin dried. The remaining divisions, up to the ninth, are well defined and of about equal length. They are separated by wide trough-like sutures which are distinct at first but which become obliterated towards the end of the pupal existence, owing to the pressure exerted by the developing fly. The ninth and tenth divisions taper, the tenth terminating in a rounded wrinkled eleventh division (Fig. 2, E).

As the developing fly acquires its adult structure, the eyes, wing pads, etc., may be easily made out through the transparent integument of the puparium.

The Flies

When the flies have completed their development within their puparia, they move forward and exert pressure against the anterior end of the puparial cases. As a result of this pressure, the anterior three divisions of the cases are split along their lateral sides midway between the upper and under surfaces. The upper portion of these three divisions is then pushed upward and backward, and through the opening thus made, the flies escape. After the flies are free from their cases, they continue to work their way upward between the leaf sheaths and stems of the plants that they infest until finally they reach the open air. Now a short period of rest follows, but during this time the wings expand and harden and when this has taken place, the insect is ready to fly.

The male and female flies differ in size especially, the male being much the smaller. The abdomen of the female fly is swollen, while in the males it is more or less cylindrical and tapers posteriorly to a dull point (Fig. 2, A, B). The recently emerged flies are colored a light green but as they grow older, the green fades into a pale yellow or straw color.

Following is a technical description of the flies by S. A. Forbes (4):

"About .18 inch long by .08 wide, pale yellowish-green; head produced in front of the eyes, broadly rounded anteriorly, marked above with delicate longitudinal 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 longitudinal 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 anteriorly 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 longitudinal 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."

Life History and Habits

In order that the life history of the wheat-stem maggot might be determined as accurately as possible, much of the work dealing with this phase of the study was done out-of-doors. This was supplemented with cage work carried on both out-of-doors and indoors, but the cage work was checked with actual field conditions whenever this was possible.

The Flies

Appearance: The appearance of the first flies in spring is regulated largely by the weather. Under average spring conditions, the first flies make their appearance on June 1 in the vicinity of Brookings, but this date will be a little earlier or later with an early or late spring. We have captured Meromyza flies as early as May 27 near Brookings. Ordinarily, the adults may be swept up abundantly with an insect net after June 1 from grassy areas, but they may be taken in still greater numbers from meadows which have been recently mowed.

Longevity: The average Meromyza fly lives from 20 to 25 days. In some indoor experiments, flies were reared and placed in glass vials containing fresh succulent grass or wheat stems and narrow strips of moist blotting paper. The open ends of the vials were closed with cheese cloth. These flies were fed with a sugar solution in addition to any food that they might have obtained from the grass or wheat stems. Whenever the plant food became dry or moldy, it was replaced with fresh material. The majority of the flies kept in this manner lived about 20 days. Some of the insects lived from 10 to 20 days while others lived from 20 to 44 days.

An out-of-door experiment was also conducted to determine whether the length of life was in any way different under these conditions from what it was indoors. In this experiment, fine-mesh wire-cloth cages, 12x12x36 inches, were constructed and placed in wheat fields. Each cage housed a few plants and a pair of Meromyza flies. It was found through this experiment that the length of life of the flies was the same as it was indoors.

Mating: Mating may take place shortly after the flies emerge. Sunlight seems to act as a stimulus to bring about mating. In our indoor experiments, we found that the flies, as a general rule, mate more than once and that a female may mate several times either with the same male or with different males.

Preoviposition: Considerable time elapses after mating takes place before the female flies deposit eggs. This period of time seems to be extremely variable, for while some females begin to lay eggs 3 days after the first mating, the majority begin ovipositing in 5 or 6 days, while a few do not lay eggs until 10 to 15 days have elapsed. In our cage experiments, we found the average preoviposition period of the flies to be 5 to 6 days.

Oviposition: The female flies prefer to lay their eggs upon the upper surface of the leaves close to the culm, upon the stems close to and above the leaf sheaths or between the leaf sheaths and the stems. However, under cage conditions and especially when the host plants are not sufficiently abundant, the eggs may be deposited upon almost any part of the plant as well as upon the cage itself. Under normal field conditions, the flies lay their eggs upon the host plants so that the long axis of the eggs runs parallel with the veins or fibrovascular bundles of the leaves or stems.

It is exceedingly difficult to observe in detail the process of egg-laying; first, because it takes only a few seconds to lay an egg; and second, because the fly is readily disturbed even while engaged in oviposition. In the process as we observed it, the last three segments of the abdomen are extended backward to form a soft telescopic tube, the posterior end of the tube just touching the plant. After feeling about for a few seconds with the tip of this tube, the fly chooses a spot to receive the egg and within a second or two the egg makes its appearance in the tube. The egg is rapidly worked down and out of the tube and glued in place. Evidently a small amount of secretion accompanies the egg as it leaves the body of the fly, and through this secretion the egg is cemented to the host plant.

Number of eggs laid: The number of eggs that are laid by each female Meromyza is difficult to ascertain; first, because the eggs are laid singly; and second, because the egg-laying period extends over many days. Through cage experiments in which we duplicated out-of-door conditions as much as possible and in which we supplied each female fly with fresh wheat stems daily and with an active male fly, we obtained an average deposit of 25 to 30 eggs from each fly. The largest number of eggs that were laid by a single fly was 54. The eggs were deposited at the rate of one to four daily or every other day for a period of two to three weeks. Under actual field conditions we have never found more than two eggs upon a plant, but in our cage experiments the eggs laid during a day were usually deposited on the stem furnished the fly.

The Eggs

Duration of egg stage: The incubation period of the eggs is greatly influenced by weather conditions, warm weather shortening and cool weather lengthening the period. Under favorable conditions, hatching of the eggs takes place four or five days after the eggs were laid but this period may be extended to 10 or 11 days or longer through unfavorable conditions.

When an egg is first laid, it is snow-white in color but towards the end of the incubation period it loses some of its snow-white appearance and becomes more or less translucent. At this time, the outline of the young maggot becomes discernible microscopically through the egg-shell.

Hatching of the egg: The maggot, after being fully formed and when ready to hatch from the egg, moves towards the anterior end of the egg-shell. Through pressure brought to bear upon it from within by the larva, this end of the shell splits, the split extending backward on each side about one-third of the length of the egg. Through the opening thus made, the larva escapes. The egg-shell then collapses and remains as a thin, flat skin.

The Maggots

How maggots reach feeding areas: The maggots, after hatching from the eggs, make their way into the plants. If the stem of the plant is well formed, the larva migrates downward from the place where it hatched to the region where a leaf-sheath clasps the stem and here it makes its way between the sheath and the stem. The larva does not stop but continues to move downward until it reaches the node. As a rule, the maggot girdles the stem of the plant before it reaches the node. The severing of the fibro-vascular bundles causes a characteristic, dead, white head to develop, an injury already discussed in this bulletin.

If the plant is young and the stem not formed, the larva migrates to the bulbous base above the root and here it feeds until it is full-grown. After a short time, such a plant will show one or more withered leaves, an indication that the plant may be infested with the wheat-stem maggot.

Feeding of the maggots: The mouth of the maggot is located on the under surface of the head segment. The mandibles are a pair of black hook-like mouth-parts and these are kept retracted within the head when they are not being used. When they are used, they are protruded through the mouth opening. By means of the mandibles, the maggot rasps and tears the plant tissue and from

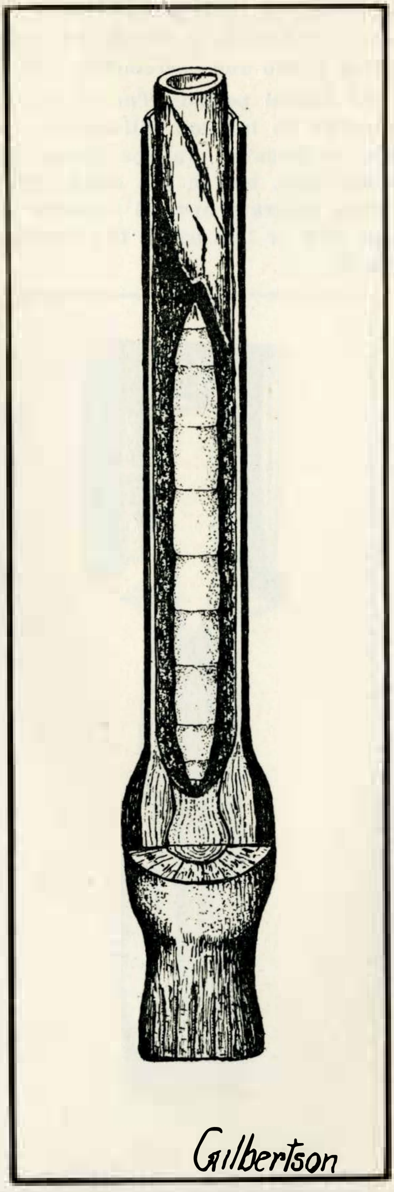

FIG. 4.—MAGGOT IN FEEDING POSITION

Wheat-stem split lengthwise to show wheat-stem maggot above the first node in feeding position. Enlarged. Author's illustration.

the area thus injured sap exudes. This sap and undoubtedly some of the rasped tissue itself is then sucked up by the larva and serves as food. The space in the stem in which the maggot works becomes filled with dead plant tissue and excrement of the larva (Fig. 4).

Duration of the larval period: The larvae require from 18 to 22 days on an average to become full-grown. At the end of this time, they prepare to pupate. In the young plants, the maggots pupate in the crown area, but in the older plants with a well defined stem, the larvae migrate upward between the leaf sheath and stem and pupate an inch or less below the junction of the leaf blade and the stem (Fig. 5).

FIG. 5.—PUPARIUM OF WHEAT-STEM MAGGOT.
Puparium of wheat-stem maggot in normal position between the leaf sheath and stem of wheat plant. Enlarged. Author's illustration.

The Puparia

After a period which usually varies from 12 to 16 days but which averages about 14, the puparia are broken open as previously described, and the flies which developed within them escape.

Seasonal Cycle

The work with the wheat-stem maggot in South Dakota indicates that there are two full generations of these insects per year although a third generation is produced by a large proportion of the flies.

The first flies of the year make their appearance in early June. They soon mate and after five to six days begin to lay eggs. Since the bulk of the spring flies appear at this time, most of the egg-laying takes place in the first two or three weeks in June. Throughout the latter half of June and the first week in July, larvae may be found in the stems of wheat, rye, barley and grasses. These larvae begin to transform to puparia about July first and about a week later most of the larvae have transformed. Beginning about July 20, the adults of the second generation appear (Fig. 6).

The flies resulting from the first brood of maggots seek succulent plants such as volunteer wheat, barley, rye and certain grasses and upon these deposit their eggs. These eggs may be found in late July and early August. Some of the larvae that hatch from these eggs feed throughout the greater part of August and pupate towards the end of that month or early in September. The remainder of the larvae remain as such in the stems throughout the fall and winter and after pupating in the spring give rise to flies in June.

The puparia that were formed in late August and early September begin to yield flies about the middle of September. These flies, in turn, lay eggs on grasses and on volunteer wheat and barley and on fall wheat and rye, and the maggots hatching from these eggs feed upon these plants. In sections of South Dakota where fall-wheat and rye are grown, severe losses may result from an attack of this brood of maggots. In the spring-wheat sections of the state, the fall brood of flies deposits its eggs on volunteer wheat, rye and barley and on grasses and these plants carry the maggots over winter. The maggots hibernate over winter and pupate in the following spring; but if they are not full-grown in the spring, they feed until mature and then pupate. From these puparia, flies begin to emerge about the first of June.

This, in the main, constitutes the seasonal cycle of Meromyza americana in South Dakota. However, breeding and field work has shown that not all flies follow this cycle, but that in many instances

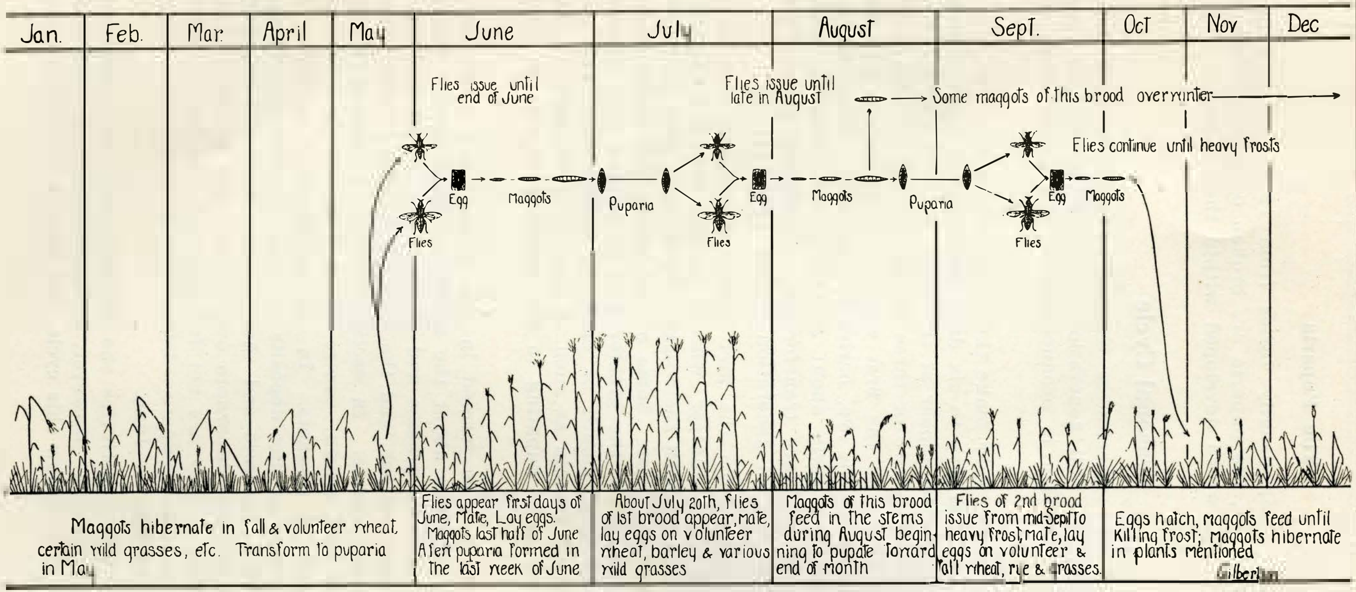

FIG. 6.—SEASONAL CYCLE OF THE WHEAT-STEM MAGGOT.

only two generations are produced per year. This may be explained, in part, because of the long life of the flies and their consequent prolonged egg-laying period, and the failure of some of the maggots of the second brood to pupate until the following spring.

That three broods of flies appear during a year was determined not only through breeding work but also through daily systematic collecting of the flies. Daily sweepings were made with an insect net through the same wheat fields and grassy areas. The same individual conducted this experiment throughout the year and each day at the same hour, he swept 100 strokes with an insect net over each field. The numbers of Meromyza flies captured were recorded daily and at the end of the year a curve was plotted to show the relative abundance of the flies throughout the year. This curve showed that while there were flies present throughout the season, there were three distinct peaks in numerical abundance. This clearly indicated three broods of flies.

Natural Enemies

The wheat-stem maggot seldom appears in overwhelming numbers, probably because of the parasites which hold it in check. While there is some variation in numbers of the insect from year to year, we have not found it to be subject to the wide numerical oscillations so characteristic of many other species.

In breeding cage work, we found that from 30 to 65 per cent of the Meromyza maggots were parasitized by two species of hymenopterous insects. One of these parasites (**Microbracon meromyzae** Gahan) began to appear in the adult form (Fig. 7) as early as July third in the vicinity of Brookings. Adults of this species of parasite continued to emerge throughout July. The other hymenopterous parasite (**Coelinidea meromyzae** Forbes) made its appearance in the adult state (Fig. 8) towards the end of July and the fore part of August.

Both of these parasites destroy the Meromyza maggots upon which they feed. The parasites pass through an egg, grub, pupal, and adult state in completing their life cycle, but it is in the grub stage when they attack and kill the Meromyza maggots. One Meromyza maggot furnishes sufficient food for a parasitic grub to reach maturity. A study of these parasites disclosed the fact that **Coelinidea meromyzae** outnumbered **Microbracon meromyzae** three to two. Consequently, **Coelinidea meromyzae** must be looked upon as the most important natural control of the wheat-stem maggot.

Another important enemy of the wheat-stem maggot in South Dakota is the mite, **Pediculoides ventricosus** Newport. In our work with the wheat-stem maggot, we split open more than 1800 stems of plants that were infested with this pest. Quite often we would encounter Meromyza maggots that were being destroyed by one or more mites of the species mentioned. These mites are minute, globular animals and they kill the maggots by sucking out their blood.

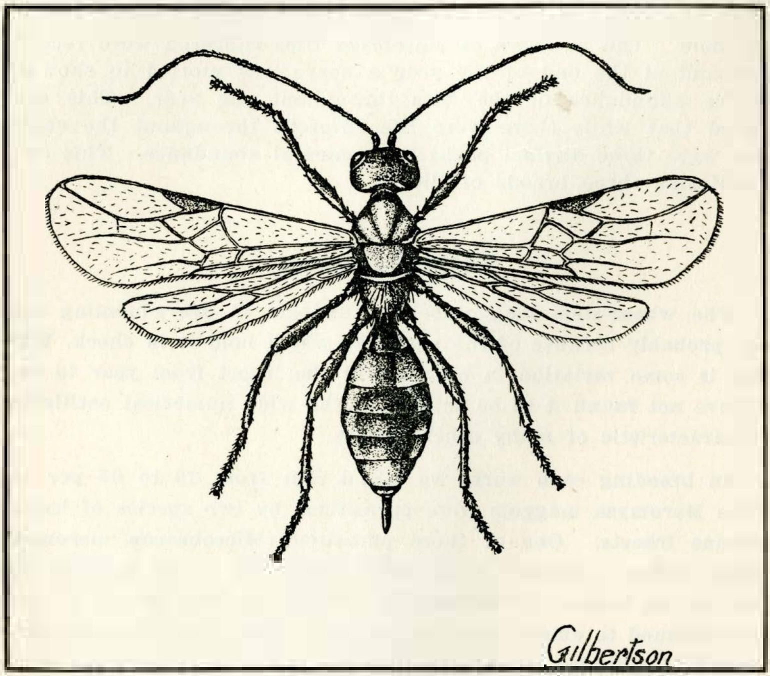

FIG. 7.—HYMENOPTEROUS PARASITE OF WHEAT-STEM MAGGOT. This parasite (**Microbracon meromyzae** Gahan) is very important in reducing the numbers of the wheat-stem maggot. Enlarged. Author's illustration.

An unidentified fungus is often found associated with dead maggots in the stems of plants. Whether or not this fungus is the primary cause of the death of the maggots we are unable to state.

Of the thousands of Meromyza flies that were captured by sweeping wheat, barley, rye and grass with an insect net, only a few specimens were found to be attacked by a small, reddish, unidentified mite. These mites were usually fastened to the body of the flies near the base of the wings. The fact that these mites were rarely encountered and the fact that the mites did not seem to affect the activity of the flies, led to the belief that this parasite is a negligible factor in reducing the numbers of the wheat-stem maggot to any considerable extent.

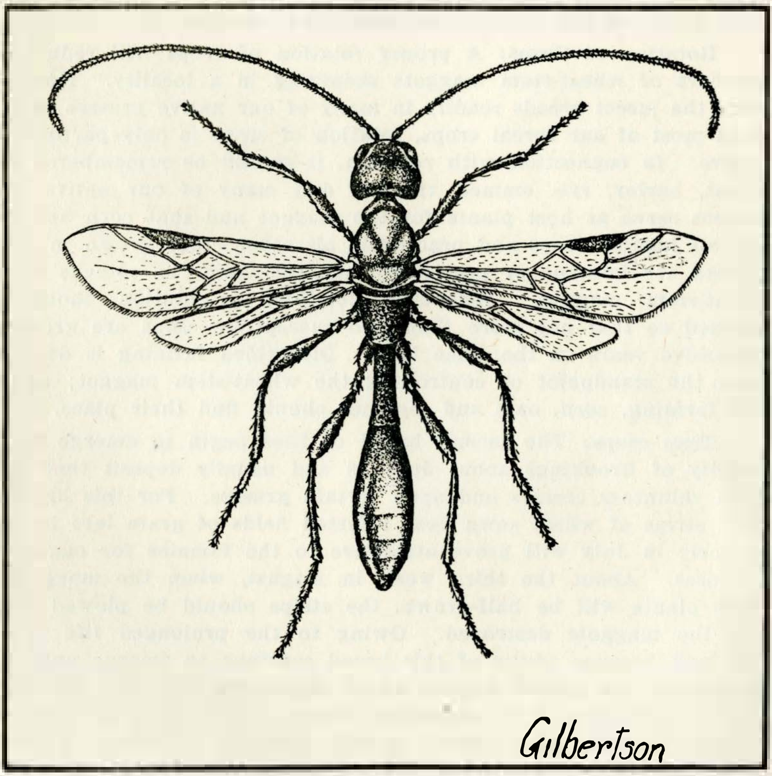

FIG. 8.—HYMENOPTEROUS PARASITE OF WHEAT-STEM MAGGOT.
This parasite (**Coelinidea meromyzae** Forbes) is the most important enemy of the wheat-stem maggot in South Dakota. Enlarged. Author's illustration.

Control

The measures of control of the wheat-stem maggot discussed in this bulletin are grouped into two classes; first, cultural measures; and second, poisoned baits.

Cultural Control

The cultural measures of value in holding the wheat-stem maggot in check are a rotation of crops, a use of trap crops, a destruction of volunteer grain, a destruction of grasses, and a late planting of fall grain. Since the wheat-stem maggot produces more than one brood of insects per year and since it breeds in native grasses as well as in cereal crops, the effectiveness of cultural practices as a means of control is not as great as it would be if only one brood were produced and if only one crop were attacked.

Rotation of Crops: A proper rotation of crops will reduce the numbers of wheat-stem maggots occurring in a locality. However, since the insect breeds readily in many of our native grasses as well as in most of our cereal crops, rotation of crops is only partially effective. In connection with rotation, it should be remembered that wheat, barley, rye, emmer, timothy and many of our native, wild grasses serve as host plants for the maggot and that corn and oats and all legume crops and practically all other crops grown in South Dakota are immune or practically immune from the attacks of the wheat-stem maggot. Whenever possible, a rotation should be planned so that not more than two susceptible crops are grown in successive years on the same land. Diversified farming is desirable from the standpoint of controlling the wheat-stem maggot; and in this farming, corn, oats and legumes should find their place.

Trap crops: The second brood of flies begin to emerge in the vicinity of Brookings about July 20 and usually deposit their eggs upon volunteer cereals and upon certain grasses. For this brood of flies, strips of wheat sown near infested fields of grain late in June or early in July will prove attractive to the females for egg-laying purposes. About the third week in August, when the maggots in these plants will be half-grown, the strips should be plowed under and the maggots destroyed. Owing to the prolonged life of the flies and because adults of this brood continue to emerge until late in August, the period during which egg-laying flies are present is much longer than is the attractive period of the trap crop. Because of this, the trap crop remedy is only partially effective. However, if the trap crop is planted at the time suggested, the plants will be in a condition to attract the flies at a time when a majority of the insects are ready to oviposit. The flies that appeared before the trap crop was effective, and the flies that appear after the crop is plowed under, are, of course, not influenced by the trap crop and these lay their eggs elsewhere.

If a trap crop is used in fighting the wheat-stem maggot, it should be cared for properly, otherwise it serves as an ideal means of increasing the numbers of the wheat-stem maggots.

Destruction of volunteer grain: If this cultural practice is to be of maximum value, it is essential that volunteer grain that is infested with the wheat-stem maggot be destroyed when the larvae are in a half-grown condition or younger. Since the largest number of volunteer plants are infested with half-grown larvae usually during the second and third weeks in August in the vicinity of Brookings, plowing under such plants at this time is advisable. If other necessary farm work makes it impossible to plow at this time, much of the volunteer grain which springs up after harvest may be kept down through the agency of sheep.

It will be noticed in this connection that the destruction of infested volunteer grain is recommended at a time of year when the largest numbers of Meromyza maggots may be destroyed.

Destruction of grasses: Since the flies of the second and of the partial third brood may deposit their eggs upon several of our native species of grasses, some provision must be made for the destruction of this vegetation. These grasses are usually to be found along roadsides, field borders, fence rows, hedge rows, etc. For the suppression of these grasses, a few sheep may be used very profitably.

If the grassy areas mentioned have not been eaten down by sheep, they should be burned over late in fall after the first heavy frost has occurred. This has for its object the destruction of the maggots hibernating in the stems of the grasses.

Late planting of fall grain: A comparison of fields of late sown wheat and early sown wheat, indicated that the late sown fields showed less injury by the wheat-stem maggot. This was also true of fall rye.

Ordinarily these fall grains are planted in South Dakota from the first to the tenth of September. However, according to Evans (2), plantings at Highmore up to September 20 gave good yields. It is recommended that fall grains should be sown at as late a date as is consistent with tested agronomy practices. This will eliminate as much as possible the attack of the wheat-stem maggots in the fall.

Poisoned Baits

Numerous baits were tried in the course of our experiments for some material which might prove attractive as a food to the Meromyza flies. By poisoning this attractive food material and placing it out at the proper time where a great many flies might feed upon it, it was hoped that such flies would be destroyed.

The following materials were used as attractive agents: oils of citronella, pennyroyal, lavender, lemon, orange, anise, fennel, tansy, bergamot, turpentine, thyme, sweet birch, eucalyptus, nutmeg, cloves and kerosene; amyl, methyl and ethyl alcohols; acetic, butyric and valeric acids; cane sugar, honey, saccharine, coumarin, amyl acetate, vanilla extract; fermenting bran; fermented and unfermented molasses; and sweet clover infusions, both fermented and unfermented.

The above mentioned materials were tested as attractants in pans and in regular cone fly-traps. The fields in which the experiments were made were first tested for an abundance of flies by sweeping through them with an insect net.

In this experiment in which pans were used to hold the bait and catch the flies, the pans were suspended at several levels. Some pans were placed directly on the ground, others were raised a foot above the ground, while others were placed at two and still others at three foot levels. The pans were of white granite and measured eight inches across the top, five inches across the bottom and three inches deep. A galvanized sheet-iron cover was fitted over the top of each pan by means of a wire mechanism so that an open space of one-half inch existed between the cover and the pan. The object of the cover was to shed rain, to prevent the sun from shining directly upon the contents of the pan and to prevent too rapid evaporation of the bait. The bait was then poured into the pan.

The cone fly-traps were made of wire screen having 24 meshes to the inch. These traps were nine inches high, four inches in diameter at the top and six inches in diameter at the base. The baits were placed in small, flat, glass containers on the baiting base. These traps were placed at the same levels as were the pans but in another set of fields.

Sodium arsenite, cobalt, or formaldehyde were used to poison the baits that were tested. However, experiments showed that, on the whole, sodium arsenite gave the best results.

Of all the materials with which we experimented, very few gave any promise of worth. A bait made according to the following formula gave the best results:

Molasses	¼ pint
Water	1 gallon
Sodium arsenite	¼ ounce
Fleischman's yeast	½ cake

The bait was prepared by adding the molasses to the water and then the yeast was added. This mixture was allowed to stand for 24 to 48 hours in order that fermentation might take place, for through previous experiments we had learned that the fermented bait was more efficient. At the end of this time, the sodium arsenite was added.

Several modifications of the above bait were made in an attempt to get a bait that was still more effective. In one instance vinegar was substituted for the yeast, and in another, coumarin (new-mown hay ester) was added to the bait in place of the yeast. However, both of these modified baits were less attractive to the flies than was the original.

When it had been determined that the fermented molasses bait was the most effective one for destroying Meromyza flies, it was decided to try out the bait in several practical field applications. The bait was sprayed over several portions of several wheat-fields with a compressed-air sprayer. The spray was applied early in the morning before 8 A. M. for it was found that the bait applied at this time of day gave the best results.

Shortly after the bait was applied, flies were found feeding in small numbers upon the minute droplets of the bait and such flies when captured and confined in cages soon died. However, the bait did not attract the flies from long distances. Because of this fact it would be necessary to spray a large share of the grain fields and at repeated intervals. This would entail a large amount of labor and considerable expense and, therefore, even though the flies might be destroyed through the baiting method, it is not recommended.

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