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THE WHEAT STEM MAGGOTS OF THE GENUS MEROMYZA IN THE PACIFIC NORTHWEST

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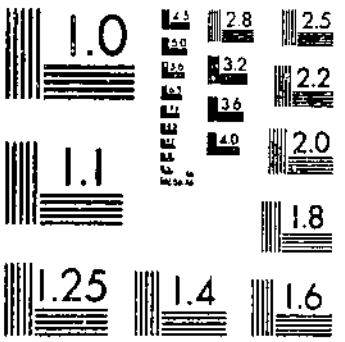


MICROCOPY RESOLUTION TEST CHART
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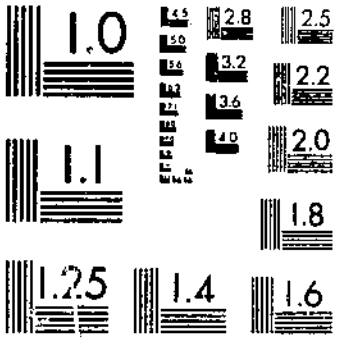


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NATIONAL BUREAU OF STANDARDS-1963-A

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# The Wheat Stem Maggots of the Genus Meromyza[1] in the Pacific Northwest[2]

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## CONTENTS





## SUMMARY

Two species of *Meromyza* occur in the Pacific Northwest, *M. pratorum* Meig. and *M. saltatrix* (L.). Each has seasonal color forms. It is probable that both species are generally distributed over the area, but *M. saltatrix* seems to be limited to localities that have an average annual precipitation of 15 inches or more. The host plants of both are the Gramineae in general, but in this area *M. saltatrix* damages spring-sown wheat in April and May more commonly than does *M. pratorum*, which infests grasses, more often than grains, in May and June. Serious outbreaks of *M. saltatrix* have occasionally occurred on wheat in Europe and Asia and in the Pacific Northwest. Three types of injury to wheat have been noted. Both species may become factors of importance to growers of grass seed.

*Meromyza saltatrix* emerges about 3 weeks earlier in the spring than does *M. pratorum*. The fact that both species select the youngest host plants available accounts for the greater damage to spring-sown wheat by *M. saltatrix*. *M. saltatrix* has but one complete generation in a year, whereas *M. pratorum* has two. The average developmental

[1] Order Diptera, family Chloropidae.
[2] Submitted for publication March 15, 1946.
[3] Nee Keen; resigned.
[4] The writers wish to thank Don C. Mote, of Oregon State College, and L. G. Smith, extension entomologist of the State College of Washington, for permission to refer to their correspondence and Curtis W. Sabrosky, of Michigan State College, for making available to them and permitting them to refer to his unpublished work on the genus *Meromyza*. Former or present associates, whose unpublished notes have been used and to whom the writers express appreciation, are Cecil W. Creel, Frank R. Cole, and Max M. Becher. The sketches were drawn by Arthur Cushman, scientific illustrator, Division of Insect Identification.

period observed for *M. saltatrix*, from egg to adult, was 76.5 days, from late in April into July. The observed mean developmental period for the spring generation of *M. pratorum* was about 85 days, in May, June, and July, but that of the summer generation may be as short as 30 days, in July and August.

The summer emergence of flies of both species takes place in July. Flies of *Meromyza saltatrix* estivate 30 days or more before ovipositing, and die early in October. Those of *M. pratorum* oviposit in July and August on whatever host plants are available, and the fall emergence occurs in September, but some of the flies are in the fields until about October 15. Since little, if any, wheat is up until after October 15 in the Pacific Northwest, neither species seriously damages fall-sown wheat. Self-sown grains and the grasses are usually all the hosts that are available at that time, although in some seasons second growth of grain cut prematurely for hay is an important overwintering host in some areas. The number of available winter host plants depends on late-summer precipitation, and every recorded outbreak was preceded by above-normal precipitation in August or early in September. Weather conditions are the principal factors in natural control, and parasites are of negligible importance, especially in semiarid regions, where the most extensive outbreaks have occurred.

The plowing-under of volunteer and second-growth wheat before April, the close pasturing or plowing under of nearby grasses, and the seeding of quickly maturing varieties of spring wheat are recommended in years when an outbreak is threatened.

## INTRODUCTION

Many notes on the wheat stem maggots of the genus *Meromyza* have been accumulated at the Forest Grove, Oreg., laboratory of the Bureau of Entomology and Plant Quarantine during the last 20 years. These stem maggots attack the Gramineae and have occasionally caused considerable loss to grain growers of the Pacific Northwest. Although but little is known concerning the extent of injury to grasses, these maggots are a potential threat to the expanding grass-seed industry of that region. The purpose of this bulletin is to make available to other workers the information that has been obtained.

## SPECIES, SEASONAL FORMS, AND SYNONYMY

The genus *Meromyza* appears to have few authentic species. These species are difficult to identify by the characters heretofore used by taxonomists, and this difficulty has undoubtedly caused considerable confusion in distributional records and probably also in records of host plants and damage.

Material in the genus *Meromyza* from the Pacific Northwest was originally determined by J. M. Aldrich in 1922-23 as *M. americana* Fitch, *M. punctifer* Becker, and *M. nigriventris* Macq. In a letter dated February 28, 1924, Dr. Aldrich stated that a larger lot of specimens from the Pacific Northwest was "nicely divided among all the N. A. species except that you did not send a typical *americana*." He included a manuscript key for separating the North American species

known at that time. In this key he indicated that he considered *americana* Fitch a variety of *pratorum* Meig., as did Malloch (*13*).[5]

Dr. Aldrich also stated that but for the receding face, *flavipalpis* Malloch is "not otherwise distinct from *americana* and I think not more than a variety of it, as intergrades occur." His key separated *Meromyza* into two groups—one with pale-yellow palpi, only the tips of which are sometimes a little infuscated, and one with black palpi. These characters served the writers very well for separating their northwestern material into two groups which they now consider to represent two species only. In his letter Dr. Aldrich also said: "It would be most interesting to find out whether any of the 'species' are seasonal forms of others; there are so many color variations that I should not be surprised to learn that this takes place. * * * Color of the abdomen is of very little account, less than that of the thorax, I think."

During the preparation of this bulletin in 1943, the writers had considerable correspondence with Curtis W. Sabrosky, of Michigan State College, an authority on the Chloropidae. Professor Sabrosky [6] has given the taxonomy of the genus *Meromyza* considerable study, with special emphasis on morphological characters rather than on color, and has seen a great deal of material from all parts of North America. He considers *M. americana* Fitch to be a distinct species, basing his opinion on the form of the head, and considers *M. flavipalpis* Malloch (*13*) and *M. lineola* Curran (*8*) to be synonyms of *M. pratorum* Meig., of which he had European specimens for comparison. He also expressed the opinion that *M. americana* does not occur in the Pacific Northwest.

## PACIFIC COAST SPECIES

For separating the two species of *Meromyza* referred to in this paper the following key may be used for freshly caught specimens:

1. Basic color green (sometimes buff in summer forms); maxillary palpi slender, rodlike, pale green or yellow, only the tips sometimes a little infuscated ..... *pratorum* Meig., p. 3.

2. Basic color brown; maxillary palpi clavate, black ..... *saltatrix* (L.), p. 5.

For sketches of the side view of the heads and the maxillary palpi see figure 1 (*p* in *A* and *B*). Seasonal color variations in both species will be discussed later. It is the opinion of the authors that the size, and perhaps also the coloration, of *Meromyza pratorum* were affected by the host plants on which the specimens were produced. These host plants ranged from slender- to coarse-stemmed Gramineae.

### MEROMYZA PRATORUM Meig.

Specimens collected in the Pacific Northwest are of the form described as *Meromyza flavipalpis* by Malloch (*13*). This form has greenish-white, rodlike maxillary palpi (fig. 1, *B*, *p*) and when alive is predominantly green, except on the dorsum. In the spring the flies

[5] Italic numbers in parentheses refer to Literature Cited, p. 17.

[6] These studies had not been completed when Professor Sabrosky was called to wartime duty with the U. S. Public Health Service.

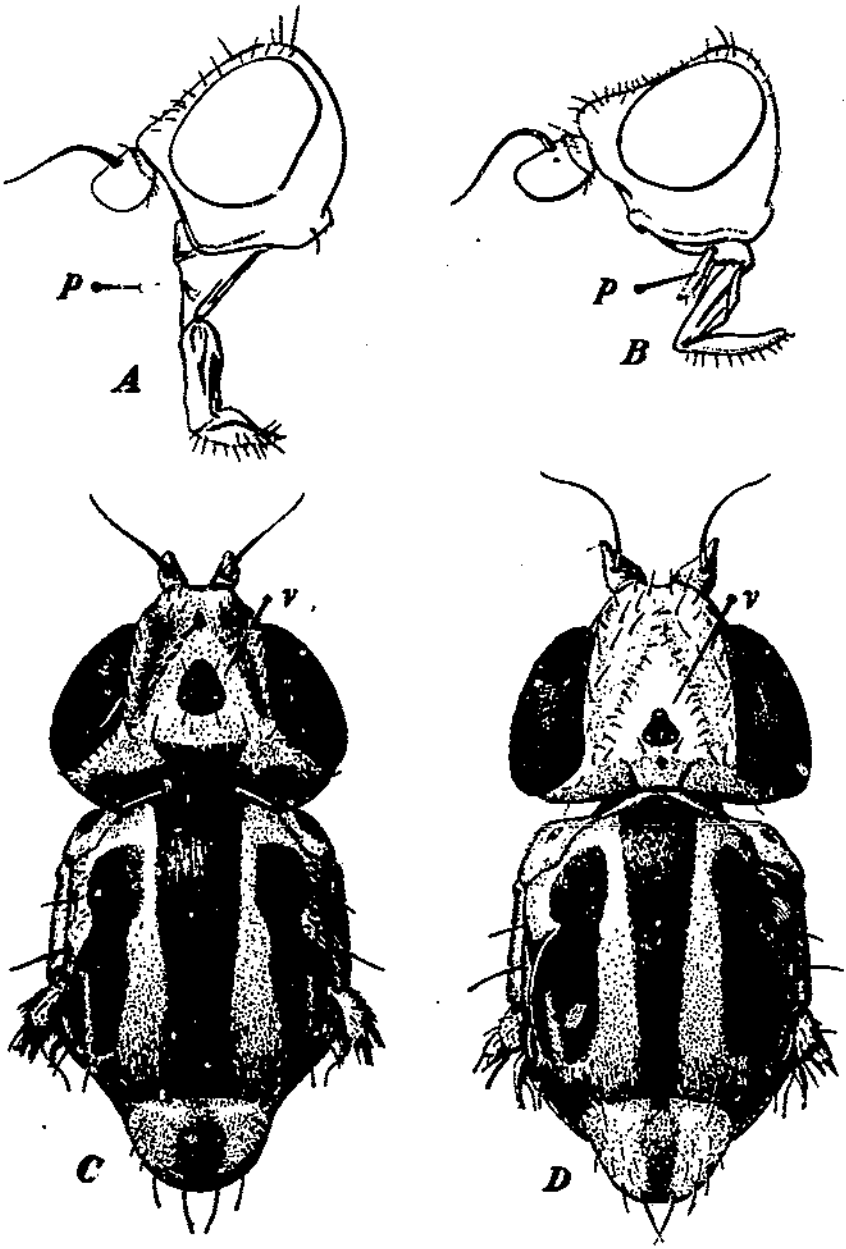


FIGURE 1.—*A*, Head of *Meromyza saltatrix*, side view; *B*, head of *M. pratorum*, side view; *C*, dorsal aspect of head and thorax of *M. saltatrix*; *D*, dorsal aspect of head and thorax of *M. pratorum*; *p*, maxillary palpus; *v*, vertical triangle.

This corrected page is to be inserted in Technical Bulletin 928, The Wheat Stem Maggots of the *Genus Meromyza* in the Pacific Northwest, as a substitute for page 4 to show the maxillary palpus (*p*) in figure 1, A.

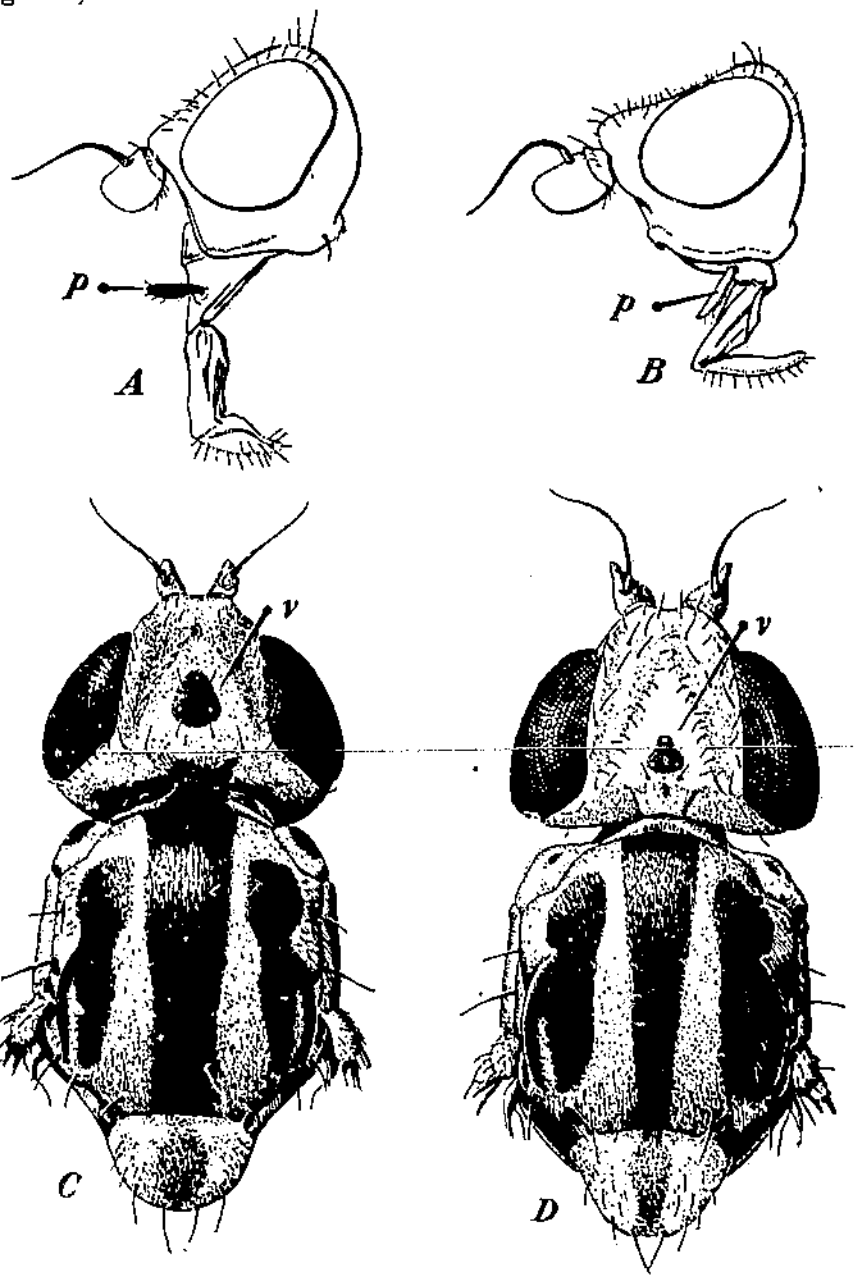


FIGURE 1.—*A*, Head of *Meromyza saltatrix*, side view; *B*, head of *M. pratorum*, side view; *C*, dorsal aspect of head and thorax of *M. saltatrix*; *D*, dorsal aspect of head and thorax of *M. pratorum*; *p*, maxillary palpus; *v*, vertical triangle.

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that emerge earliest are much darker than the typical ones, and have wide black stripes on the dorsum of the thorax, while the dorsal sclerites of the abdomen are mostly dark brown, except for the posterior margins. The writers have a very few specimens that barely show fuscous spots on the tips of the palpi and some that show the vertical triangle (fig. 1, *D*, *v*) faintly outlined with brown. Flies that emerge in July and August are often of a light-buff color (colonial buff, Ridgway,[7] after drying), and the dorsum of the abdomen is mostly light-colored, except that a median dark stripe is usually well defined. The green coloration fades rapidly in collections, and some specimens become brown.

On the Klamath Marsh in south-central Oregon, at an elevation of about 4,500 feet, specimens that were recognized in the living state as green *Meromyza pratorum* averaged smaller and much darker than those found elsewhere. Nearly all these specimens had distinctly fuscous or black tips on the rodlike palpi, but in two specimens these palpi were entirely pale, while the vertical triangle ranged from being outlined with brown to all brown, except for a pale spot in the anterior angle, as in *M. saltatrix* form *nigriventris* Macq. Also as in that form, the dorsum of the thorax is sometimes so infuscated as to obscure completely the pale interstitial areas between the black stripes; and the entire dorsum of the abdomen, except the posterior margins of the sclerites, is blackish brown. These color variations are similar to those observed in *M. saltatrix;* therefore, it is believed that these specimens from the Klamath Marsh are *M. pratorum.* This series of specimens shows much more variation than any other collection. All these forms—melanic, green, and buff—probably are *M. pratorum.*

## MEROMYZA SALTATRIX (L.)

In the Pacific Northwest this brown species, in which the clavate maxillary palpus is always black (fig. 1, *A*, *p*) and the pleural spots are strongly marked, has three color forms. *Meromyza saltatrix* form *nigriventris* Macq. is the typical form emerging in April both east and west of the Cascade Mountains. In western Oregon this form usually has the brown interstitial areas between the black stripes on the dorsum of the thorax completely obscured by fuscous black (Ridgway), and the vertical triangle is mostly brown (fuscous, Ridgway), except for a pale spot in the apical angle.

East of the Cascade Mountains the light-brown interstitial areas on the thorax are often more evident, though narrow, approaching the next form, *marginata* Becker (*4*). Dark forms are the first flies to emerge in the spring near Forest Grove, Oreg., and forms approaching *marginata* and about like eastern Oregon specimens are rarely collected there near the end of the spring-flight period, as they were on May 23 and June 4, 1923. *M. saltatrix* form *marginata* has the vertical triangle pale yellow brown (honey yellow, Ridgway) with a black ocellar spot, and the vertical triangle is outlined by a distinct dark streak, while the black thoracic stripes are well separated from each other by the yellow-brown interstitial

[7] RIDGWAY, R. COLOR STANDARDS AND COLOR NOMENCLATURE. 43 pp., illus. Washington, D. C. 1912

areas. This is the most common summer-generation form emerging in July west of the Cascade Mountains, although there is some intergrading to the next form, *punctifer* Becker (*4*).

*M. saltatrix* form *punctifer* (fig. 1, *C*) has the vertical triangle buff (deep colonial buff, Ridgway) with a black ocellar spot; while the dark stripes of the thorax are red, black only at front and narrowly on each side near the notopleural sutures. In many specimens of this form most of the dorsum of the abdomen is light-colored. This is the most common form emerging in July east of the Cascade Mountains and is occasionally found in July or early in August west of these mountains.

*M. saltatrix* is predominantly brown, never green, and averages smaller than the green or buff *M. pratorum*.

In April 1924 Miss Keen observed the emergence and subsequent maturity of a fly in the laboratory. When it emerged, at 9 a.m., the head was lemon yellow, with red-brown eyes, the outline of the vertical triangle and part of the antennae and palpi were black or nearly so, the thorax was light yellowish brown with three dark-brown stripes, the abdomen was brilliant green, and the legs were yellowish at base and grayish beyond. The thorax and abdomen gradually darkened: by 11:20 a.m. the vertical triangle began filling with fuscous, and by 5:30 p.m. the dorsum of the thorax and the vertical triangle were overcast with fuscous, as is typical for *Meromyza saltatrix* form *nigriventris*. These changes indicate the sequence of color development and may suggest an explanation for the different color forms found in this species.

In cages on young wheat in the laboratory it was proved that *Meromyza saltatrix* forms *marginata* and *punctifer* are color forms of *nigriventris*. All the cages were started late in April or early in May with the dark, spring-emerging form, *nigriventris*, and in July offspring were produced as follows: *marginata*, 27; intermediate, 10; *punctifer*, 8. Mesnil (*14*) considered *nigriventris* to be the melanic, winter form of *M. saltatrix* and stated that *M. ceralium* Reut., described from Finland, was identical with the summer form of *M. saltatrix* in France. Balachowski and Mesnil (*5*, pl. 4) illustrated three color forms, none of which appear to be as dark as the spring forms from western Oregon. Apparently temperature or humidity, or both, affect the pigmentation in this species, and also in *M. pratorum*, as Aldrich (*1*) suggested is the case in *Cercdonta dorsalis* (Loew). It seems evident that the name for all the above-mentioned brown forms with black clavate palpi should be *M. saltatrix*.

## DISTRIBUTION

*Meromyza pratorum* has been recorded from Europe and western Siberia. Sabrosky stated in correspondence that he had specimens from Washington, Oregon, California, and Utah, and from as far east as northern Michigan and western Kansas. *M. lineola* Curran (*8*), which Sabrosky considers to be this species, was described from "Fort Simpson, Northwest Territories, Canada."

The writers have specimens from the following localities: Oregon —Albany, Corvallis, Drewsey, Elgin, Forest Grove, Gaston, Imbler,

Klamath Marsh (a melanic form), La Grande, McMinnville, and Tillamook; Washington—Molson, Oroville, Waterville, and Yakima; Idaho—Grangeville.

In the European literature *Meromyza saltatrix* has been recorded from Europe and Asia as far east as the Amur region. In North America, where the records have been confused by misidentification, this species has been recorded as follows: Beaver River, Alberta (*11, p. 219*), *M. marginata*; Montana (*7*), *M. nigriventris*. Essig (*9, p. 610*) recorded *M. punctifer* from the Yakima Valley (in 1919) on the authority of Cole and Lovett, but the latter authors (*6, p. 336*) mention only *M. americana* as present in the Yakima Valley in 1919, and the present writers have a specimen (Riker mount of an injured wheat culm and a fly) which was collected and mounted by Cole at that time and labeled "*Meromyza americana* Fitch, Ahtanum Valley, Yakima, F. R. Cole." This specimen is the buff form of *M. pratorum*. It is probable that the form commonly found on bluegrass lawns in California (*9, p. 610*) was this species also. The specimen recorded by Sabrosky (*17, pp. 215-216*) from Kansas as *M. marginata* had yellow palpi and was probably not *M. saltatrix*. Becker (*4*) gave the following localities for *M. punctifer:* Moscow, Idaho, Pullman, Wash., and Battle Creek, Mich.; for *M. nigriventris:* Moscow, Idaho, and Pullman, Wash.; for *M. marginata:* Moscow, Idaho, and Corvallis, Oreg. Becker's record from Battle Creek appears to be in error, and the present writers have been unable to find any authentic record of the occurrence of *M. saltatrix* east of Montana or Alberta.

The writers have specimens of *Meromyza saltatrix*, listed according to form, from the following localities: *nigriventris*, Oregon—Corvallis, Drewsey, Elgin, Forest Grove, Gaston, Imbler, and La Grande; Montana—Arlee (C. W. Creel June 14, 1917); *marginata*, Oregon—Albany, Canby, Elgin, Forest Grove, Gaston, Imbler, and La Grande; Idaho—Grangeville; *punctifer*, Oregon—Elgin, Forest Grove, Imbler, and La Grande.

In a survey in 1921 injury by *Meromyza* to spring wheat (with little doubt caused by *M. saltatrix*) was observed in fields of the great Wheat Belt of eastern Washington wherever the average annual precipitation approximated 20 inches or more, especially near timber. No signs of it were observed in wheatfields where the average annual precipitation was less than 15 inches. *Meromyza pratorum*, however, is known to occur in irrigated sections and in marshes where the average annual precipitation is less than 15 inches, and flies may spread out from such areas, especially in years when the precipitation in August is above normal.

## HOST PLANTS AND DAMAGE

*Meromyza saltatrix* and *M. pratorum* have varied host plants among the Gramineae. Balachowski and Mesnil (*5, p. 970*) recorded *M. pratorum* from *Ammophila* (*Psamma*) *arenaria* L. in France. The present writers have reared *M. pratorum* from wheat, barley, and *Bromus carinatus* Hook. and Arn. *M. saltatrix* has been recorded in the European literature as occurring in wheat, rye, barley, oats, *Agropyron repens* (L.) Beauv., *Festuca ovina* L., *Alopecurus praten-*

*sis* L., species of *Poa* and *Dactylis*, and timothy. We have reared *M. saltatrix* from wheat and *Lolium perenne* L.

The following host plants have been observed to be damaged by *Meromyza* larvae or have had *Meromyza* eggs on them, but in many cases the species was not determined: Barley, rye, timothy (rarely), *Lolium perenne*, *Agropyron repens*, oats (rarely), *Poa nervosa* (Hook.) Vasey (including *oluegae* Piper) (Grande Ronde Valley, Oreg., determined by F. W. Gail), *Muhlenbergia asperifolia* (Nees and Mey.) Parodi (?) (Forest Grove), *Hordeum nodosum* L. (Grande Ronde Valley, determined by F. W. Gail), *Poa pratensis* L. (Klamath Marsh and near Klamath Falls).

There have been indications that in the Pacific Northwest *Meromyza pratorum* breeds more commonly on grasses than on grain in May and June, and on volunteer and early fall-sown grain, as well as on grasses, in the summer and fall. *M. saltatrix* commonly breeds on wheat in April and May and on grasses and early volunteer and second-growth grain late in the summer. The discovery of the host relationships of the respective species is complicated by the fact that specific characters for the larval stages have not yet been found; hence there is much confusion as to the identification of the species and their hosts at different periods. These obscurities might be cleared up by extensive rearings from identified host plants.

Serious damage to wheat occurred in the Grande Ronde Valley, Union County, Oreg., in 1921. The late A. L. Lovett and the senior writer found infestations ranging from 10 to 75 percent of the tillers in individual fields of spring-sown wheat on June 30, 1921. At the same time fall-sown wheat showed only 2 to 3 percent of infested culms with white heads. The average damage to spring-sown wheat was estimated (by County Agricultural Agent H. G. Avery) at 25 percent reduction in the crop for the county. The worst infested fields yielded 12 to 15 bushels per acre, about one-half of a normal crop, notwithstanding otherwise favorable conditions. Of 116 *Meromyza* flies reared from infested wheat tillers collected during this outbreak and placed in emergence cages without soil, only one was *M. pratorum*, the rest being *M. saltatrix*. In addition to the *Meromyza*, the following Diptera were reared: *Oscinella frit* (L.) var. *nitidissima* (Meig.) 7; *Madiza cinerea* (Loew) (determined by C. W. Sabrosky) 4.

On June 22, 1923, considerable damage by *Meromyza* larvae to wheat tillers and to kernels in the heads of spring-sown wheat was observed in 2 fields in Scoggin's Valley west of Gaston, Oreg. From culms and heads collected in these fields, 100 *M. saltatrix*, 4 *M. pratorum*, and 1 *Oscinella frit* var. *nitidissima* were reared. All those reared from damaged wheat heads were *M. saltatrix*. On June 7, 1927, 31 percent of the tillers on a wheat plot seeded on March 29 at Forest Grove were infested with *Meromyza* larvae, and *M. saltatrix* adults were reared from this material. *Meromyza* damage to late fall-sown wheat was conspicuous in a small field in Hood River Valley, Oreg., on June 21, 1927, and also on volunteer wheat (50 percent of the tillers infested) near White Salmon, Wash. Some damage to spring-sown wheat also occurred in Union County, Oreg., in June 1927, one early spring-sown field having 25 percent of the tillers

infested. On May 25, 1928, Don C. Mote, of the Oregon Agricultural Experiment Station, reported (in correspondence) damage to spring-sown wheat near Drewsey, Harney County, Oreg. His correspondent stated that 50 percent of the wheat had been destroyed. Specimens of flies sent in for determination from this outbreak were 16 *M. saltatrix*, 2 *M. pratorum*, and 1 *Thaumatomyia glabra* (Meig.); hence it seems probable that most of the damage in this case was caused by the first-named species.

Damage to wheat in the Warner Valley of Lake County, Oreg., was reported on July 10, 1940, through Dr. Mote, and that *Meromyza* was the cause was confirmed by specimens of wheat with white heads, showing typical *Meromyza* injury to headed culms. The owner stated that from 3 to 4 percent of the wheat was so damaged. L. G. Smith reported to the United States Extension Service that an outbreak of wheat stem maggot occurred in Grant County in June 1941. He stated that R. L. Webster saw specimens of the insect that caused the damage and identified it as *Meromyza*.

Economic damage to grain by *Meromyza saltatrix* has been reported frequently in Europe and in Siberia, mostly by Russian workers. Rakhmaninov (*15*) stated that, owing to dry conditions, *M. nigriventris* is not usually a serious pest, although it was unusually abundant in 1923. Rakhmaninov and Induichenko (*16*) reported that about 50 percent of the ears of winter wheat were damaged in the Smolensk area in 1927, and that the resulting loss was from 30 to 40 percent of the grain. Vereschagin (*19*) reported that from 28 to 30 percent of the wheat plants in the Amur area, in the Russian Far East, were often damaged by this species.

The writers' observations indicate that *Meromyza saltatrix* is by far the most important species causing damage to wheat, especially spring-sown wheat, in the Pacific Northwest but that serious outbreaks are not common. The paucity of references to *M. pratorum* in the European literature, in comparison with those to *M. saltatrix*, indicates that this is also true for Europe and Asia.

*Meromyza pratorum* may cause appreciable damage to unseasonably late spring-sown wheat in the Pacific Northwest, as it did in experimental wheat plots at Corvallis, Oreg., in August 1920. It may also damage early fall-sown wheat in the fall. Cole and Lovett (*6*) reported 1 percent of "white head" damage to wheat in the Ahtanum Valley, near Yakima, Wash., in 1919 by this species, and the white-head injury to wheat in Lake County, Oreg., in 1940, in central Washington in 1941 (reported by L. G. Smith), and in Deschutes County, Oreg., in 1934 (reported by Dr. Mote in correspondence) may have been caused by this species. Barley may be damaged by one or both species of *Meromyza*.

On May 26, 1937, large numbers of a dark form of *Meromyza pratorum* were swept from *Poa pratensis* on the Klamath Marsh in Oregon at an elevation of 4,500 feet, and there were many white heads on the bluegrass in June. A grower at Klamath Falls, Oreg., who had extensive seed meadows of bluegrass, stated that about 10 percent of the headed culms in his meadows showed white heads. As factors other than *Meromyza* may cause white head in bluegrass, it should be determined whether this condition is predominantly due to *Mero-*

*myza* infestation. On the other hand, no investigation has ever been made of the infestation of unheaded culms of bluegrass or other grasses, and, by analogy with *Meromyza* infestation of wheat, this might cause much more serious damage than white head. L. G. Smith has stated (in correspondence) that County Agricultural Agent George M. Delany, of Grant County, Wash., reported that *Meromyza* infestations (presumably white heads) were observed in nearly every stand of crested wheatgrass from Wilson Creek to Coulee Dam in 1941. The extent of damage to grasses by *Meromyza* and other genera of Diptera should be determined. The growing of various grasses for seed is a rapidly expanding industry in Oregon and Washington and *Meromyza* already may be, or may become, an important factor in grass-seed production.

## TYPES OF INJURY

Injury to wheat by *Meromyza pratorum* and *M. saltatrix* is of two common types. When young tillers are attacked before the culm is well formed, the central shoot is cut off by the feeding of the larva inside the tiller. The shoot withers and turns yellow, then brown, precluding the possibility of head formation, and eventually the tiller dies. This type of injury became evident in cages 25 days after *M. pratorum* eggs were laid (July 18 to August 13, 1933), although wilting of the terminal leaf was noted within 13 days, when the larvae must have been rather small. This is the type of damage that Forbes (*10*) and Webster (*30, pp. 43-51*) reported for *M. americana* as occurring in the fall in the Middle West, and is the type found in May on spring-sown wheat in the Pacific Northwest. When headed culms are attacked, the entire head is killed and remains nearly white (actually buff) and empty of kernels because the larvae have severed the vessels of the stem near the last node before or shortly after the wheat head emerged from the boot and before it blossomed; while the rest of the culm, below the node, is green. In bearded wheat the awns are stiff and dry and have a characteristic spreading appearance instead of being held in a normal upright position. Both these types of injury are described and well illustrated by Allen & Painter (*3*) in their paper on the wheat stem maggot in Kansas. Similar injury occurs on rye, barley, and the grasses.

In addition to the two common types of injury to wheat which have been described, Max M. Reeher once observed larvae on wheat heads that had emerged from the boot, blossomed, and begun to form seed. Many flowers, glumes and all, had been destroyed, and the heads had a very ragged appearance. On some heads about half the head, from the tip down, had been destroyed; on others comparatively few flowers near the tip were damaged. This type of injury was noted on early spring-sown wheat in Scoggin's Valley, west of Gaston, Oreg., on June 22, 1923, and was caused by larvae of *Meromyza saltatrix*. Mesnil (*14*) mentioned injury by *M. saltatrix* to wheat ears of a type similar to that noted by the present writers, and Balachowsky and Mesnil (*5, pl. 5*) illustrated it and stated that such injury is frequent

in France. Aldrich (*2*) noted somewhat similar injury to wheat kernels by larvae of *Oscinella* (*Oscinis*) *frit* (L.).

## LIFE HISTORY

### Meromyza pratorum Meig.

It was observed that in western Oregon *Meromyza pratorum* remained in the puparium as long as 20 to 32 days in the spring (April 11 to May 13), but only 9 to 11 days in July. The period for incubation of the eggs was 5 to 7 days between August 20 and September 2, and is undoubtedly longer in May. The total period from egg to adult was 81 to 88 days on wheat in cages between April 26 and July 24, 1923; 29 to 36 days between July 21 and August 26, 1926; and 48 to 49 days between August 1 and September 29, 1923.

### Meromyza saltatrix (L.)

Tzuigankov (*18*) gave the incubation period for the eggs as 3 to 10 days and stated that the spring- and summer-generation females laid from 10 to 60 eggs. He also stated that adults of the spring generation lived 14 to 60 days and those of the summer generation slightly longer, that the pupal period of the summer generation lasted 25 days, and the complete life cycle of this generation required about 50 days.

In 1923 the overwintered larvae spent from 16 to 28 days in the puparium in the laboratory in April and May. In cages over young wheat at Forest Grove 2 females of this species, which emerged on April 12, 1927, laid an average of 58 eggs each in 32 days. The eggs hatched in about 10 days. The complete life cycle lasted from 60 to 90 days. The mean for all rearings in the period 1923 to 1929 was 76.5 days. Thus, the life cycle in Oregon is more prolonged than in Russia, probably because of lower mean temperatures in summer.

The eggs of *Meromyza saltatrix* are usually laid on the sheaths that cover the stems, near the ground, but sometimes on the leaves near the ligules or under the sheaths against the stems. The eggs appear to be indistinguishable from those of *M. americana* and *M. pratorum*. Ordinarily only 1 to 4 eggs are found on a single tiller, but in the 1921 outbreak in the Grande Ronde Valley in Union County, Oreg., 20 or more eggs were present on a single wheat tiller, extending from ground level to 2 inches or more above the ground, and sometimes overlapping like shingles. The eggs of *M. pratorum* are laid in similar locations, but it has been the writers' impression that this species lays its eggs on the leaves more often than does *M. saltatrix*.

The larva on hatching makes its way to the point where the last leaf emerges from the sheaf, and then crawls down to the node, where it feeds inside the shoot, severing the vessels to the shoot just above the node. The writers have observed indications that an individual larva may move from one tiller to another, destroying both, as Allen and Painter (*3*) noted in the case of *Meromyza americana*. The puparium is formed between the sheathing leaf and the shoot, usually not far from where the shoot emerges from the sheathing leaf, as Gilbertson (*12*) noted for *M. americana*.

## SEASONAL HISTORY

### MEROMYZA PRATORUM Meig.

*Meromyza pratorum* passes the winter in the larval stage in the stems of the host plants. Records kept by the authors show that pupation took place from April 7 to May 9. In the insectary adults from overwintered larvae emerged from April 27 to May 31. According to records of systematic sweepings, adults first appeared in the fields near Forest Grove, Oreg., on the following dates: June 15, 1922 (a late season); April 26, 1923; April 28, 1924; April 27, 1926; April 27, 1927. In 1923 adults were not swept in numbers until May 16, and the flight was nearly over by June 15. Flies emerging at this time congregated on the latest spring-sown grain they could find, and also on grasses. They showed a decided preference for the younger plants; thus, on May 16, 1923, 16 were swept from a small plot of late spring-sown wheat, but only 1 was swept from fall-sown wheat nearby. The eggs, usually laid on the leaves, hatched in about 10 days. In 1923, in the laboratory, the larvae of the spring generation began to pupate about July 4 and began to emerge on July 16. In the field this emergence reached a peak about August 1, when the flies were abundant on volunteer barley on creek-bottom land. In cages started on July 21, 1926, with 4- to 6-inch wheat transplanted from outdoors and oviposited on about 10 days before, the first adult of the second generation emerged on August 19 and emergence continued to August 26; but other adults, from larvae dissected from this material, emerged as early as August 7 in cells in the laboratory. In 1923 cages started with adults on young wheat seedlings on August 1 produced adults from September 11 to 29. These records afford definite proof of a second generation of *M. pratorum* in this area; however, flies emerging in July would find no grain on which to breed, and even grasses in a suitable condition for breeding would usually be scarce because the summers in the Pacific Northwest are normally dry. Probably the only available host plants at this time would be on irrigated land, in swampy areas, or on land that had been under water until late in the spring. Adults were swept in considerable numbers from *Bromus carinatus* (?) on creek-bottom land on August 20, 1925. The seasonal history of *M. pratorum* in the Pacific Northwest is practically the same as that which Forbes (*10*) found for *M. americana* in Illinois.

Flies of the fall flight frequent the volunteer grain and grasses that have sprung up following the first fall rains, which normally occur in September in the Pacific Northwest. These flies are at the peak of their abundance in September (September 11-13 in 1922), and can be taken with an insect net until well into October (October 17 for the last flies in 1922). The progeny of these flies pass the winter as larvae. Larvae that hatched from eggs laid as early as August 20, 1925, in a cage over *Bromus carinatus* did not produce flies until May 15, 1926. Overwintering on wheat was also observed, and larvae probably overwinter on barley and various grasses.

### MEROMYZA SALTATRIX (L.)

Like *Meromyza pratorum*, *M. saltatrix* passes the winter in the larval stage in the stems of the host plants. These larvae begin to pupate in March and early in April. The writers have pupation records of overwintered larvae as follows: A well-colored pupa taken from volunteer wheat on April 4, 1924, emerged as an adult on April 9 and probably pupated as early as March 26; prepupae taken from volunteer wheat on March 26 and April 7, 1927, emerged as adults on April 19; from three prepupae taken from *Lolium perenne* on March 29, 1927, the first adults were out on April 12. According to records of frequent sweepings, the first adults appeared in the fields near Forest Grove on the following dates: May 23, 1922 (a backward season); April 14, 1923; April 9, 1924; March 29, 1926 (an early season); April 12, 1927; April 23, 1929; April 11, 1930; April 23, 1931; and March 19, 1934 (an exceptionally early season).

A comparison of these records with those for *M. pratorum* shows that the first appearance of *M. saltatrix* in the fields was from 12 to 32 days (with a mean of 3 weeks) earlier than that of *M. pratorum*.

Adults of the spring emergence of *Meromyza saltatrix* were most abundant on April 25 in 1923, April 24 in 1924, April 29 in 1926, April 14 in 1927, and April 26 in 1929. In 1923 *M. pratorum* adults outnumbered those of *M. saltatrix* for the first time on May 16. *M. saltatrix* declined rapidly thereafter, the last flies of this species being taken on June 8. Female flies of the spring generation are often long-lived. In 1923 one of five females in a cage lived 63 days. Flies emerging in March and April congregate on spring-sown wheat, seeded at the normal time, both east and west of the Cascade Mountains. They show a preference for the younger wheat, but are sometimes swept in some numbers in April from wheat seeded in November or later, and the latest tillers of fall-sown wheat are sometimes infested with larvae.

There is little doubt that the activity of adults of *Meromyza saltatrix* in spring, approximately 3 weeks earlier than that of *M. pratorum*, is responsible for the fact that this species is more damaging to spring-sown wheat, seeded at the normal time, than is *M. pratorum*. In the Pacific Northwest by the time the latter species emerges in numbers such wheat is too far along to be attractive to them.

The eggs hatched in about 10 days in April. In 1923 larvae of the spring generation began to pupate in cages about June 24 and continued pupating until July 10. In cages over wheat, adults were produced as follows: In 1922 from July 3 to July 16, in 1923 from July 12 to July 25, in 1926 from July 3 to July 20, and in 1927 from July 1 to August 3. In the field, or from field-collected material, adults of this generation were first found as follows: In 1921, June 30 (La Grande); in 1922, July 3; in 1923, July 19; and in 1924, June 30.

The newly emerged adults of *Meromyza saltatrix* did not lay eggs on proffered wheat seedlings at once, as did the flies of *M. pratorum*, but estivated for a considerable period. In cages over spring wheat in 1921, flies that emerged about July 17 were fed diluted honey and remained alive but showed no signs of reproductive activity up to August 11, when the wheat seedlings had died. On September 5

mating and oviposition were observed in this cage, and the first flies (probably males) died. This indicated an estivation period of about 45 to 50 days. In 1922, in a cage over late spring-sown wheat of a true winter habit of growth, adults emerging up to July 8 began to lay eggs before August 15, when some eggs had just hatched. Assuming that 7 days were spent in the egg stage, the estivation period was about 31 days. In 1923, in cages over seedling wheat of a spring habit of growth, seeded in July, flies that had emerged up to July 16 (beginning July 3) laid eggs by August 2, after an estivation period of 30 days, but in this case the host plants were entirely suitable. In 1926, female flies were offered cut wheat stems in vials at regular intervals, and those from a cage where mating had been observed on July 16 estivated 38 days (from July 19 to August 26) before they began ovipositing. In the same year flies placed in a cage over seedling wheat under a lantern globe on July 12 laid their first eggs on August 13, an estivation period of 32 days under ideal host-plant conditions. In 1929 flies that emerged between July 17 and July 26 laid their first eggs on September 30, an estivation period of 66 days or more, but September was a very dry month. One of the female flies in this cage lived 83 days. One female, probably unmated, emerged on July 18, 1927, and was kept alive in a vial until January 13, 1928, a period of 179 days.

It seems evident that there is a natural estivation period of at least a month, and usually more, in the adult stage of *Meromyza saltatrix* in the Pacific Northwest, as was noted in Russia (*15*). Adults cannot be collected in the fields after about August 1, but in case of precipitation late in the summer they again become abundant about September 1. Where the flies pass this estivation period is unknown. The peak of the fall flight at Forest Grove came about September 7 in 1922, on September 27 in 1923 (a very dry August and September, when this species was scarce), on September 11 in 1925, on August 27 in 1926 (precipitation was much above normal in August, beginning on the 17th), and on September 9 in 1927. The fall flight of this species, as indicated by periodic sweepings, was finished on October 3 in 1922, on October 12 in 1923, on October 1 in 1925, on October 2 in 1926, and on October 1 in 1927. Our cage experiments also showed that there is but one complete generation in a year, even though adults can be swept in numbers in three well-separated periods, namely, from March to May, in July, and in September.

The peak of the fall flight and the end of the flight period of *Meromyza pratorum*, which has two complete generations per year, are about two weeks later than those of *M. saltatrix*, which has but one complete generation per year. Hence, as fall wheat is rarely seeded before October in the Willamette Valley, Oreg., there is no chance for *M. saltatrix* to breed on fall-sown wheat in the fall. It must be restricted, therefore, to volunteer grains, second growth on prematurely cut grain, and the grasses. Unless there are rains in August or early in September, there is very little, if any, volunteer wheat before the last of September or early part of October, and even grasses in a suitable condition for breeding of the insects may be scarce and local. On the other hand, there is some chance of *M. pratorum* getting into fall-sown grain if this is seeded before October 15.

Tzuigankov (*18*) stated that in Poltava, in the Ukraine, the overwintered generation of *Meromyza saltatrix* emerges during the first 3 weeks in May and the summer generation emerges early in July. He noted that flies of the summer generation lived longer than those of the overwintered generation, and stated that the oviposition period of the summer generation lasted 2 months. Rakhmaninov (*15*) stated that the larvae of *M. nigriventris* hibernated in self-sown plants. Adults appeared at the beginning of May, and toward the end of the month eggs were found, mainly on the leaves of autumn-sown wheat, though a few were also found on spring-sown wheat and barley. A second flight of adults took place near the end of June. These individuals laid eggs in August and continued to oviposit throughout most of September.

## NATURAL CONTROL

*Coelinidea meromyzae* Forbes (determined by A. B. Gahan) has been reared by the writers several times from overwintering *Meromyza* larvae in puparia in March and April. This is a parasite of both species. An external parasite, *Microbracon meromyza* Gahan, was reared in August from *Meromyza pratorum* larvae taken from barley at Forest Grove on July 26, 1923. The writers failed to rear either of these species from heavily infested wheat collected in the Grande Ronde Valley on June 30, 1921. This collection produced a few miscellaneous parasites, some of which, notably several *Eupteromalus* sp. and a few *Eupelmus allynii* French, may have come from the spring generation of *M. saltatrix*. It is very doubtful whether parasites are factors of much importance in natural control of *Meromyza*, at least in the area east of the Cascade Mountains. The fungus *Empusa muscae* (Fr.) Cohn, sometimes killed adults in cages, and under humid conditions probably kills some in the fields.

The principal factors influencing the abundance of *Meromyza saltatrix*, and probably also of *M. pratorum*, are doubtless climatic. This is particularly true in the semiarid area of the Pacific Northwest east of the Cascade Mountains, where the most serious outbreaks of *Meromyza* have occurred. Unseasonably early rains in August bring up an abundance of volunteer grain, second-growth grain in areas cut prematurely for hay, and an abundant new growth of grasses. These host plants afford opportunities for the production, late in the summer, of large numbers of *Meromyza* larvae, which will give rise to a heavy flight of flies in the spring.

The great outbreak of *Meromyza saltatrix* in the Grande Ronde Valley in 1921 was preceded by unusually heavy rains in August and early in September 1920, which interfered with harvest, and the spring of 1921 was cool and rainy. An abundance of early volunteer wheat was scattered throughout the fields, and much second-growth wheat had come up in the margins of the fields that had been cut for hay in June 1920. All these had been heavily infested by *Meromyza* in the fall of 1920 and had produced great numbers of flies in the spring of 1921. In all other observed or reported outbreaks (1923 in Washington County, Oreg.; 1927 in Washington, Union, and Hood River Counties, Oreg.; 1928 in Drewsey, Oreg.; 1941 in central Washington)

precipitation had been heavy in the preceding August or September. There is therefore some basis for forecasting such outbreaks in the Pacific Northwest.

In the more humid area west of the Cascade Mountains these species do not appear to fluctuate so greatly in numbers from year to year as they do in the semiarid area. Serious *Meromyza* injury west of the Cascades is rare, and there are no records of any widespread outbreaks. It therefore appears that serious outbreaks are most likely to occur in the marginal areas, which are less favorable as habitats for the species than are the more humid areas. The observations of Rakhmaninov (*15*) in the Union of Soviet Socialist Republics suggest the same hypothesis.

The writers observed, in the Grande Ronde Valley and elsewhere, that low, poorly drained, swampy spots and marshes are foci from which *Meromyza* spread into nearby fields, and in semiarid areas such places are probably habitats where *Meromyza* can survive, even where the average annual precipitation is less than 15 inches.

*Meromyza* larvae that are well up in the stems are probably killed by severe cold, but those in the crowns of the plants probably survive. At Forest Grove on January 16, 1924, following a minimum temperature of 4° F. on January 1, Miss Keen found five dead *Meromyza* larvae in tillers in clumps of volunteer wheat and five living larvae in the lowest part of the stems near the roots, under 1 inch of snow.

## CONTROL MEASURES

Other writers, notably Forbes (*10*), Webster (*20*), and Allen and Painter (*3*), have observed that some varieties of wheat are more severely injured by *Meromyza americana* than others, early maturing varieties being least infested.

A. L. Lovett and the senior writer observed that in the great outbreak of *Meromyza saltatrix* in Union County, Oreg., in 1921, the early maturing spring-wheat variety Hard Federation was very little damaged by *Meromyza* larvae, while the midseason variety Goldcoin (Fortyfold) was very severely damaged. Hence in years when an outbreak of *Meromyza* threatens, quickly maturing varieties of spring wheat should be sown. At the same time it was noted that fall-sown wheat was very little injured, and this injury was almost all of the white-head type, while spring-sown wheat was badly damaged in the unheaded-tiller stage. Both *M. saltatrix* and *M. pratorum* select the youngest wheat available for breeding in April and May. In western Oregon wheat is sometimes seeded late in November or in the winter months. Such wheat usually shows more *Meromyza* injury in June than does wheat seeded at the normal time, in October.

In western Oregon, the fall flight of *Meromyza saltatrix* is over before any wheat is planted. There may be some fall infestation by *M. pratorum*, but little wheat is up until after October 15, and by that time the fall flight of this species is practically over. Hence fall damage by *Meromyza* in the Pacific Northwest is negligible.

On the basis of knowledge of *Meromyza saltatrix* in the Pacific Northwest, it is recommended that all volunteer wheat and all second-growth wheat in areas cut early for hay be plowed under soon after harvest, or, if left, be plowed under in March, before the spring flies

emerge in April. No volunteer wheat should be allowed to come up in fields that are to be seeded, before the normal time for fall seeding. In the 1921 outbreak in Union County, Oreg., it was evident that the great abundance of *M. saltatrix* could be traced directly to the large numbers of early volunteer wheat plants, which were scattered through all the fall-sown fields, and to abundant second growth that had sprung up after the August 1920 rains in the field margins that had been cut for hay.

All grass in the vicinity of grainfields should be plowed or pastured closely in August and September or turned under in March or early in April, because in some areas grasses may produce enough *Meromyza* flies to damage wheat growing nearby.

It is probable that the above-mentioned precautions need be taken only in years when precipitation is unusually abundant in August or early in September. If damage by either or both species of *Meromyza* should eventually be such as to require control measures on grass-seed meadows, further research will be necessary to ascertain what measures would be effective.

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