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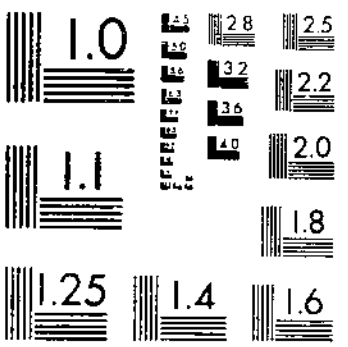

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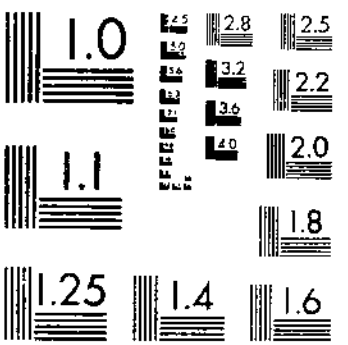

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BIOLOGY AND CONTROL OF THE CORN LEAF APHID WITH SPECIAL REFERENCE TO THE SOUTHWESTERN STATES

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INTRODUCTION

The corn leaf aphid (*Aphis maidis* Fitch) has been observed by many entomological workers on numerous different cultivated plants in various sections of the United States over a period of nearly 75 years. Many articles have been published regarding this insect, but, with the exception of Forbes, who shows the difference between the corn leaf aphid and the corn root aphid (*Aphis*) *Anuraphis maidiradicis* Forbes (*11*, *12*, *13*),[2] no one has attempted to give a complete detailed account of the biology of the species.

This bulletin describes a study begun in 1910 by the senior writer at El Centro, Calif. During that year many field observations were made on *Aphis maidis* as a serious pest of barley. Fields of barley were discovered to be intensely infested with this aphid, and serious injury was noted. Subsequent studies revealed the fact that it was the most serious insect pest of barley in the southwestern part of the United States. In the following year at Tempe, Ariz., life-history studies of this species were begun and have been continued with the assistance of other members of the Tempe laboratory and the junior

[1] The authors wish to express their appreciation of the many courtesies shown them by Joe S. Wade, of the Bureau of Entomology, and of his valuable assistance with the literature of this species. They are especially grateful for access to his bibliography of the species.

[2] Italic numbers in parentheses refer to Literature Cited, p. 20.

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author to the present date. Other workers in the Bureau of Entomology also have made many observations and studies of the species at other points in the United States. The work of R. A. Vickery at Brownsville, Tex., has been particularly helpful.

Our knowledge of the life history of this insect is incomplete in several respects. Even after a continuous study of this species covering a period of 20 years, an oviparous female has never been obtained or observed. Nor has the development of every instar of the male been carefully noted. Males were obtained by rearing only in race cases and never in the field.

HISTORY OF THE CORN LEAF APHID IN THE UNITED STATES

Although this insect was probably well known previous to 1856, the first recorded observation seems to be that of Fitch (*10, p. 318*), who states:

> In August, the person who is selecting soft corn for boiling will sometimes come to an ear, the stem of which is entirely covered with vermin. * * * They occur upon no other part of the stalk except the peduncle or stem which bears the ears.

He recognized this as a new species plainly differing "from one which infests the maize in Europe, the *Aphis zeae*, of Bonafous," and proposed to call it the maize aphid (*Aphis maidis*).

About the end of May, 1861, the attention of Walsh was called to an aphid attacking the roots of corn near Rock Island, Ill. He compared specimens of this with the aphid described by Fitch and states (*21, p. 492*):

> As his description agrees tolerably well with that of the species which I found attacking the roots of corn in June, and as, in particular, he describes the antennae as being not quite half as long as the body, I suspect that they are the same insect, and that its normal habitat is the roots of the corn plant, but that later in the season when these dry up it betakes itself, to avoid starvation, to the stem of the ear.

Thomas (*18*) apparently accepted this determination and reports it as being found on the tassels, ear stalks, and roots of Indian corn.

S. A. Forbes and his assistants began observations on this insect in 1882. For a time they also apparently accepted the theory that the two forms represented the same species, but later they began to have some doubt. In 1891 Forbes (*11*) definitely determined the two forms as distinct species and proposed the name *Aphis maidiradicis* for the root form. Three years later (*12*) he again called attention to this difference and the inability of his assistants, H. Garman, C. M. Weed, and John Martin, to breed one form from the other. He also pointed out a difference in preference of host plants and gave the characters which differentiate the two species.

DISTRIBUTION

Aphis maidis is found throughout the greater part of the world between the latitudes of 40° N. and 40° S. (Fig. 1.) In North America its northern limit is somewhat farther north and coincides fairly well with the latitude of the northern border of the United States. Records in the files of the Bureau of Entomology indicate that it occurs in every State in the Union with the possible excep-

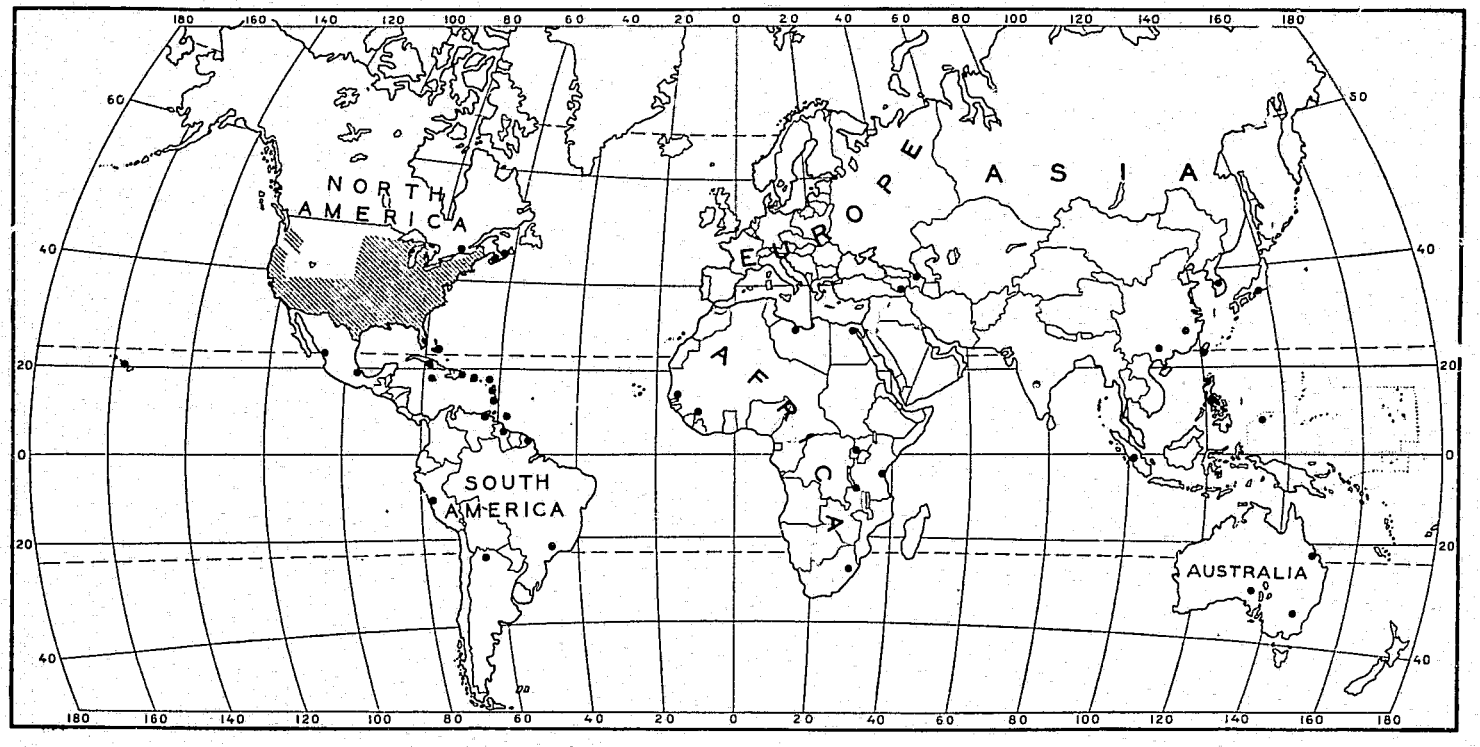

FIGURE 1.—Distribution of *Aphis maidis* Fitch throughout the world

tion of Montana, Idaho, Wyoming, Utah, and Nevada. It may occur even in these States, but no records of such distribution have been found. (Fig. 2.)

The species is apparently of little importance in Canada. Glendenning does not include it in his List of the Aphididae of British Columbia and the supplement thereto. The only records found in literature of its occurrence elsewhere in Canada were from Nova Scotia, Ontario, and Quebec. Spittal (*17*) states that moderate infestations were found at Weymouth, Digby County; Wilmot, Annapolis County; and Berwick, Kings County, Nova Scotia. Caesar and Ross (*5*, *p. 24*) record its presence in Ontario in the following words:

> Dark green aphids were very numerous in most corn fields during August and September. They fed on the new growth in August, and in September were chiefly in the sheltered areas between the stem and the enveloping leaves.

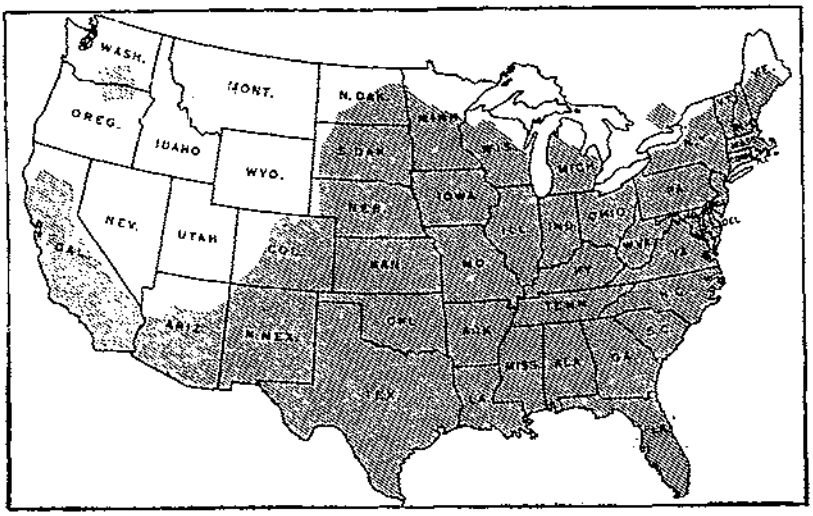

FIGURE 2.—Distribution of *Aphis maidis* in the United States

G. H. Hammond, of the Dominion entomological laboratory at Hemmingford, Quebec, in a letter to the junior author states that he found the species common in a single field of corn at Hemmingford, Quebec, on September 14, 1929. A single specimen was found in the collection of the United States National Museum labeled Montreal.

The records from Mexico are likewise very meager. A single reference was found in the records of the United States insect pest survey and one in literature (*16*), each recording its presence in Mexico but giving no locality. The authors have observed the insect as a serious pest in the United States near the Mexican border from Brownsville, Tex., to San Diego, Calif. A. L. Herrera, formerly in charge of the direction of biological studies in Mexico, in a letter to the authors says, "*Aphis maidis* is a pest in Mexico, in the corn and other plants," and Alfonso Dampf, of the Federal office for the defense of agriculture of Mexico, writes that he has seen the species on sugarcane.

In Europe corn is frequently attacked by *Aphis zeae* Bon., which closely resembles *A. maidis* Fitch, but which is considered a quite distinct species. Del Guercio (*9*) mentions *A. maidis* as new to Italy, but states that he considers the Italian form a variety of *A. maidis* of America and points out that some differences are observed. No other writer has reported its occurrence in Europe. Since this aphid has been shown to be the only known agent in the dissemination of sugarcane mosaic (*6*), it seems possible that it may be present in southern Spain, where this disease was recently found. This species was found in Java and described under the name *Aphis adusta* Zehntner, which appears to be the only synonym.

FIGURE 3.—Plants heavily infested with corn leaf aphids: A, Corn; B, barley; C, parasitized aphids on sorghum

FOOD PLANTS

The recorded food plants of the corn leaf aphid include a great number of the common wild and cultivated grasslike plants and also a few common weeds. In the United States barley, grain sorghums, and corn are possibly the favored food plants, with preference shown in the order named. (Fig. 3.) In the sugarcane-growing regions this insect has attracted considerable attention in late years, as it has been shown to transmit a serious disease of sugarcane known as mosaic. Apparently *Aphis maidis* does not normally feed on the

cane to any great extent, but does this only incidentally or when forced to do so by the destruction of its normal food in the cultivation of the fields. Several investigators, working in foreign countries, have had difficulty in keeping this insect alive on sugarcane. Brandes, however, reports its occasional presence on the sugarcane in large numbers (*1*). It is questionable whether this aphid breeds normally on any host other than species of the botanical group Gramineae. Most records of occurrence on hosts belonging in other groups may be due either to mistaken identity or to the casual resting of migrant forms, although Davis (*8*) records it as feeding normally in his cages on *Polygonum pennsylvanicum* L.

The accompanying list of host plants (Table 1) has been compiled from observations by the authors and from notes made by several other members of the Bureau of Entomology, together with a few records, chiefly foreign, from the literature. Many of the foreign hosts listed also occur in the United States, but they did not come under the observation of the authors.

TABLE 1.—*Host plants of the corn leaf aphid*

Scientific name of plant	Common name of plant	Locality	Relative abundance
Ambrosia trifida L.	Great ragweed	United States	Unknown.
Arundo donax L.	Carrizo, giant reed	Peru	Common.
Avena sativa L.	Oat	United States	Rare.
Axonopus scoparius (Flügge) Kuhlm.	Gramalote	Peru	Common.
Cenchrus echinatus L.	Sand bur	Cuba	Rare.
Cynodon dactylon (L.) Pers.	Bermuda grass	do	Occasional.
Cyperus esculentus L.	Chufa	United States	Rare.
Dactyloctenium aegyptium (L.) Richt.	Crowfoot grass	Cuba	Occasional.
Digitaria chinensis (Nees) A. Camus.		Unknown	Rare.
Digitaria debilis (Desf.) Willd.		do	Do.
Digitaria horizontalis Willd.		Porto Rico	Common.
Digitaria pruriens (Trin.) Buese.		Unknown	Rare.
Digitaria sanguinalis (L.) Scop.	Crabgrass	United States	Common.
Echinochloa colonum (L.) Link.	Jungle rice	Cuba	Preferred host.
Echinochloa crusgalli (L.) Beauv.	Barnyard grass	do	Occasional.
Elusine indica (L.) Gaertn.	Goose grass	United States	Do.
Eragrostis pilosa (L.) Beauv.		Chosen	Unknown.
Eriochloa polystachya H. B. K.	Malojillo	Cuba	Common.
Eriochloa punctata (L.) Desv.		United States	Rare.
Hordeum murinum L.		do	Do.
Hordeum vulgare L.	Barley	do	Preferred host.
Leptochloa virgata (L.) Beauv.		Cuba	Occasional.
Miscanthus sinensis Anderss.	Eulalia	do	Rare.
Muhlenbergia mexicana (L.) Trin.		United States	Occasional.
Oralis sp.		do	Unknown.
Panicum barbinode Trin.	Para grass	Cuba	Rare.
Panicum capillare L.	Witch grass	United States	Unknown.
Panicum dichotomiflorum Michx.		do	Rare.
Panicum hemitomon Schult.	Maiden cane	do	Common.
Panicum miliaceum L.	Broomcorn millet	do	Unknown.
Panicum sp. (probably *Paspalum distichum L.*)	Ditch grass	do	Occasional.
Paspalum boscianum Flügge.	Bull grass	do	Do.
Paspalum conjugatum Berg.		Porto Rico	Rare.
Paspalum fimbriatum H. B. K.		Cuba	Do.
Paspalum virgatum L.		do	Do.
Pennisetum glaucum (L.) R. Br.	Pearl millet	do	Occasional.
Phragmites communis Trin.	Reed	United States	Do.
Plantago major L.	Plantain	do	Unknown.
Poa pratensis L.	Kentucky bluegrass	do	Occasional.
Polygonum pennsylvanicum L.	Lady's-thumb	do	Unknown.
Rottboellia exaltata L. F.	Rice grass	Jamaica	Common.
Rottboellia glandulosa Trin.		Sumatra	Occasional.
Rumex altissimus Wood.	Pale dock	United States	Unknown.
Saccharum narenga (Nees) Hack.	Wild sugarcane	Cuba	Occasional.
Saccharum officinarum L.	Sugarcane	United States	Rare.
Scirpus maritimus L.	Bulrush	Hawaii	Unknown.
Secale cereale L.	Rye	United States	Rare.
Setaria aurea Hochst.	Rattail grass	Australia	Common.
Setaria italica (L.) Beauv.	Millet	United States	Do.
Setaria lutescens (Weigel) Hubb.	Yellow foxtail	do	Occasional.
Setaria viridis (L.) Beauv.	Green foxtail	do	Do.

TABLE 1.—*Host plants of the corn leaf aphid*—Continued

Scientific name of plant	Common name of plant	Locality	Relative abundance
Setaria rostratum Dunal	Buffalo bur	United States	Rare.
Sorghum dora Grisch	Sorghum	do	Unknown.
Sorghum halepense (L.) Pers	Johnson grass	do	Occasional.
Sorghum vulgare Pers. (form)	Wonder forage grass (?).	Cuba	Do.
Sorghum vulgare Pers	Sorghum	United States	Preferred host.
Sorghum vulgare var. *caffrorum* (Beauv.)	Kafir	do	Do.
Sorghum vulgare effurum (Hack.)		Peru	Unknown.
Sorghum vulgare var. *eriguum* (Forsk.)	Tunis grass (?)	Cuba	Occasional.
Sorghum vulgare var. *saccharatum* (L.) Boerl	Sorgo	United States	Unknown.
Sorghum vulgare var. *sudanense* (Piper) Hitchc	Sudan grass	do	Occasional.
Sorghum vulgare var. *technicum* (Koern.)	Broomcorn (?)	do	Preferred host.
Sporobolus virginicus (L.) Kunth		Porto Rico	Rare.
Triticum aestivum L	Wheat	United States	Do.
Tripsacum laxum Nash	Guatemala grass	Hawaii	Common.
Typha latifolia L	Cattail	United States	Unknown.
Zea mays L	Corn	do	Preferred host.

FIELD HISTORY

During the summers in the South and Southwest the corn leaf aphid is held in check both by the extreme heat and by its natural enemies. When cool weather appears, it reproduces rapidly on the late corn and sorghums until these either mature or are killed by frosts, and then migrates to the barley and other small grains, ~~when the barley either matures or is killed by frosts~~. During the winter months the aphids multiply rapidly and do their greatest damage in this section to the fall and winter sown barley, sometimes weakening it to such an extent that very little grain is produced. In the cooler sections of the United States this aphid is found chiefly on late corn, broomcorn, and sorghums, rarely doing serious injury because of its late appearance.

TYPE AND EXTENT OF INJURY

It is difficult to estimate the amount of damage that may be done by this insect. It commonly attacks the corn in the North so late that little injury is possible except on the late corn. Here the heavily infested leaves turn yellow or red following the feeding and may shrivel and die, particularly if the weather is dry. According to Forbes (*13*), there is some evidence that the insect may at times prevent fertilization of the kernel by sucking the sap from the silk or pistillate flower and killing it before it has performed its function. A heavy infestation may also weaken the stalk and delay maturity to such an extent that the plants may be injured by frost.

Farther south corn is attacked much earlier in the season, so that more damage may be done. As has been cited by McColloch (*15*), another more common form of injury to corn in Kansas and southward is that the aphids, by feeding on the tassel, may prevent its function of producing pollen. Also the tassel occasionally becomes so gummed with honeydew as to prevent the shedding of the pollen that is produced. This honeydew forms one food of the adult of the corn ear worm (*Heliothis obsoleta* Fab.) and hence attracts great numbers of the moths to the field, thus being an indirect source of injury. Molds and rots often set in which weaken the stalk, some-

times resulting in the loss of the top and thus destroying the ear or at least reducing its size.

Broomcorn is sometimes considerably damaged by a reddened discoloration of the brush following the feeding puncture. A similar discoloration and small-sized grains frequently follow a heavy infestation of the heads of grain sorghum. Forbes (*13*) considered this to be due to a bacterial infection. Such infection has not yet been definitely shown, however, and in the light of recent work by Wadley (*20*) on the damage caused by the feeding of *Toxoptera graminum* Rond. it seems possible that the injury may be due to an enzyme injected by the aphid.

McColloch (*15, p. 91*) reports that in western Kansas in 1920 "the infestation resulted in shrinking the head, causing a loss of about 33 per cent in weight and 50 per cent in volume" on grain sorghums. Hayes (*14*) shows a rather serious loss in germination from heavily infested heads. The plant is sometimes weakened and the boot injured so that the head does not fully emerge and proper pollination becomes impossible. The heavily infested heads become covered with honeydew, and in humid weather molds and other fungi attack the honeydew, thus giving an unsightly appearance. Much stunting of the growth frequently attributed to dry weather is sometimes more properly due to the feeding of this insect.

The loss on barley in the South and Southwest often reaches considerable proportions. The late-sown barley is always injured more severely than that sown earlier in the season. The leaves become curled and sickly, and frequently an entire field has the appearance of suffering from drought. Occasionally the plants are yellowed and look as if they had been sun-scalded. At El Centro, Calif., more than 600 aphids were counted on one stalk, and a careful estimate indicated the presence of between 400 and 500 aphids on each stalk in three-fourths of the field. It is obvious that such an infestation would practically ruin the entire crop. On Harold Bell Wright's ranch at Meloland, Calif., the aphids were so abundant in 1912 as to cause the complete loss of a 10-acre field of barley. Mr. Wright, in a letter to the senior author, says: "The aphids have been so thick and their honeydew so abundant that one could not walk 10 steps in the field without having pants and shoes a mass of stickiness."

Although this aphid does not normally feed to any great extent on sugarcane, it does go to this crop occasionally, especially when its normal wild hosts in the field are destroyed in the process of cultivation. It has been shown by Brandes (*1*), Chardon and Veve (*6*), and others to be responsible for the dissemination of sugarcane mosaic, which causes a considerable loss to the sugar industry.

LIFE HISTORY

Sweepings of barley and other grains and thorough searches in the fields in the South and Southwest over a period of 20 years have failed to reveal males or oviparous females. The oviparous female has never been observed, or obtained by rearing, and the males have been reared in only a very few cases.

Forbes (*12, 13*) discusses at some length his unsuccessful attempts to find sexual forms or eggs. From 1907 to 1912 E. O. G. Kelly spent considerable time in breeding work and searching in fields

and watching the flights of *Aphis maidis* in the fall in Kansas, but he found no evidence of sexes. Vickery and coworkers reared many thousands of specimens at Brownsville, Tex., without recording any true sexes, although in his notes Vickery described one specimen, secured in January, 1911, that might have proved to be a sexual form had he reared it to maturity. His description of this specimen agrees closely with that given later in this bulletin for the young of the male forms.

Wilbrink (*22*) and Van Breemen (*2*, *3*, *4*) in Java, and Vuillet and Vuillet (*19*) in the French Sudan did considerable breeding work, and each found only the viviparous forms occurring. In fact, with the exception of the few males found in the generation experiments at Tempe, Ariz., no sexual forms have ever been recorded.

From the latitude of northern Texas southward the species winters as viviparous females on barley and other small grains. The method of overwintering in the North is at present unknown. Less than 25 per cent of the aphids were able to withstand the unusual temperature of 13° F., which was recorded at Tempe, Ariz., in 1912. In localities where the temperature falls much below this point the aphid is not known to survive the winter.

Just how the aphid becomes so injurious in the North is not definitely known. It is possible, as suggested by Davis (*8*, *p. 144*), that it may migrate northward much as the green bug (*Toxoptera graminum* Rond.) does, but such migration has not been definitely proved. The writers have observed that at Tempe, Ariz., and San Antonio, Tex., the alate forms appear much more numerous during the six weeks following March 25, and again for six weeks following August 25, than at other times. A note made by the senior author at Tempe, Ariz., on April 19, 1917, is as follows:

> Alate spring migrants are in the air thick the past three days, and this morning they were especially numerous. At sunrise the air was alive with them, and the reflection of the sun upon their rapidly moving wings made a unique lighting effect.

Similar migrations were observed by Van Breemen (*2*, *3*, *4*) in Java. Forbes (*13*, *p. 125*) states: "The species makes its appearance in midsummer, our earliest date being July 9, when specimens were found on young leaves of corn. We have no record whatever to show whence it comes or where it lives preceding this time." This late appearance in the North adds weight to the theory that the species may migrate from the South.

In the summer the fully developed aphids are very small, often scarcely more than one-half to two-thirds the size found during cooler weather. Associated with this reduced size is a much shorter life and the production of a very small number of young.

CAGES USED IN LIFE-HISTORY STUDIES

Barley was found to be the most desirable host plant to use in cages, as it is one of the favorite food plants, is hardy enough to withstand all degrees of temperature imposed, and furnishes a small leaf surface which can be easily examined.

A single barley plant was allowed to grow near the center of a 6-inch flowerpot, and a 4-inch lantern globe with cloth top was

placed over it. The plant was pinched back from time to time to regulate its size. The cloth cover allowed sufficient ventilation to prevent excessive moisture from gathering inside the globe. (Fig. 4.)

DIFFICULTIES ENCOUNTERED

It was often difficult to examine the cages during cold weather because of the aphids' habit of crawling deep into the center whorl of the plant, making it almost impossible to count the number present without injuring either the plant or some of the aphids. The number could sometimes be determined by holding the plant between the observer and the sunlight or, better, a 40-watt electric light; the aphids would then appear as shadows within the whorl.

Perhaps the greatest difficulty encountered in the generation experiments was due to the tendency for the plant to develop a wilt dis-

FIGURE 4.—Cages used in life-history studies

ease under conditions of high temperature and humidity, such as prevailed in the spring. A plant that appeared healthy when the cage was examined on one day would often be wilted the next day and the aphids scattered beyond recovery.

Another serious difficulty was caused by a fungous disease which attacked the aphids and killed large numbers of them at times when the temperature and humidity were high. Fortunately for the continuity of the series, the female was not usually killed until she had produced one or more young, although she often died within a day or two thereafter. Since this disease was most prevalent during April, May, and June, when reproduction was at its height, the average number of young was considerably reduced.

GENERATION EXPERIMENTS

Losses from the various causes mentioned above made it impossible to carry all the generation experiments through the entire year. Of approximately 50 series of cages run at Tempe, Ariz., to determine the maximum number of generations by using the first-born each time, only 7 were carried through the entire year. Even in these

cases other individuals of the same age as those used to start the cage were occasionally substituted in order that the series might be continued through the year. Only two series were carried for more than a year, one of these for a year and nine months.

Approximately 30 series of cages were started to determine the minimum number of generations by using the last-born each time, but none was successfully carried through an entire year even with substitution. Five cages were carried successfully for 10 months or more and so gave an indication of about what could be expected. In these series 1,141 individuals were kept throughout their entire lives. The maximum age for these individuals was 86 days, and the maximum number of young was 95.

Table 2 summarizes only the few series of cages which were carried for 11 months or more for first-born generations and approximately 10 months for the last-born. The maximum number of generations in a year varies from 35 to 40, with an average of 37. If allowance is made for a probability of about 2 more generations during the approximate six weeks not shown for the last-born, the minimum number of generations would vary from 13 to 20, with an average of 16.

TABLE 2.—*Generation data*

Age		Maximum young	Average young	Generations	Time
Maximum	Average				
Days	*Days*	*Number*	*Number*	*Number*	
DETERMINED FROM FIRST-BORN					
61	22	57	16	36	1 year.
57	22	69	25	37	Do.
68	26	57	26	37	Do.
64	27	72	23	35	Do.
67	26	63	21	37	Do.
75	31	65	24	36	1 year, 24 days.
79	29	76	20	61	1 year, 9 months, 12 days.
55	28	75	20	35	11 months, 14 days.
62	26	65	35	38	11 months.
59	26	66	35	40	11 months, 14 days.
Mean 66.7	26.3	66.5	26	----------	
DETERMINED FROM LAST-BORN					
42	21	47	23	18	10 months, 5 days.
60	34	54	36	11	10 months, 7 days.
72	25	76	24	12	10 months, 11 days.
79	30	63	24	11	10 months, 3 days.
55	16	57	14	17	9 months, 26 days.
Mean 61.8	25.2	59.4	24.2	----------	

The milder winters and cooler summers occurring at Brownsville, Tex., enabled Vickery to carry 14 series of cages for one year and 12 series for two years for the maximum number of generations, and 9 series for one year and 4 series for two years for the minimum number of generations. He found the maximum number of generations in one year to range from 39 to 50, with an average of 45.1, and the minimum number to range from 16 to 20, with an average of 17.2.

The number of generations in the North would be much smaller owing to the short season. Davis (*8, p. 149*), working in Illinois, says: "* * * from my experiments, it may be definitely said that there were not more than 9 generations after June 26," the earliest date of its appearance.

LENGTH OF INSTARS

The length of the several instars varies considerably, depending on a number of factors, although temperature is the dominant one. Fourteen individuals were carried through to the adult stage and observed for molts during March and April, and nine individuals during July and August. (Table 3.) The observations were made at 6-hour intervals. These individuals molted four times, and one specimen molted five times.

TABLE 3.—*Length of instars in days*

First	Second	Third	Fourth	Fifth	Total
OBSERVATIONS DURING MARCH AND APRIL					
2.50	3.50	3	4	----------	13
3.25	2.50	4.25	5.25	----------	15.25
2.50	3.50	3	3	----------	12
2.50	1	5.50	4	----------	13
2.75	2.75	2	2.50	----------	10
2	3	2.50	4.50	----------	12
2.75	3.75	2.50	5	----------	14
1.50	1	2.50	2.25	3.75	11
3	2	2	3	----------	10
3	2.25	2.75	2	----------	10
2	1.75	2.25	2.75	----------	8.75
2	1	2.75	2	----------	7.75
3	1.25	2.25	2.50	----------	9
2.50	2	2	2.50	----------	9
Mean 2.51	2.25	2.80	3.23	----------	11.05
OBSERVATIONS DURING JULY AND AUGUST					
1.25	1	1.25	1.25	----------	4.75
1.25	1.75	1	1	----------	5
1.25	1	1.75	1	----------	5
1.50	1.50	1	2	----------	6
1.50	1	1	1	----------	4.50
1	1	1	1.50	----------	4.50
1	2	1	2	----------	6
1.50	1.50	1.50	2	----------	6.50
1.50	1.50	1	1	----------	5
Mean 1.30	1.36	1.16	1.41	----------	5.25

The time required to reach the adult stage varied from 4.50 days as a minimum in July and August to 15.25 days in March and April. Alate forms required a day or two longer than apterous forms. No record was made of molts during the winter months, but the generation cages show that the total length of the instars would have increased to from 18 to 22 days, depending on the temperature.

VIVIPAROUS FORMS

The viviparous forms have been fully described by Davis (*8*), and it seems unnecessary to repeat these descriptions here.

SEXUAL FORMS

The sexual forms of *A. maidis* occur very rarely in the United States, and thus far have not been recorded from any other country. Various entomological workers have spent much time and carried the species through many generations without having obtained a specimen of either of the sexes.

While running a series of generation experiments at Tempe, Ariz., in 1920, the junior author obtained two specimens that were later determined by A. C. Baker as alate males of *A. maidis*. Since that time 40 or more males have been reared by the same author. With the exception of 2 males born November 29, all were secured during December, January, and February. The writers have not yet been able to secure the oviparous females.

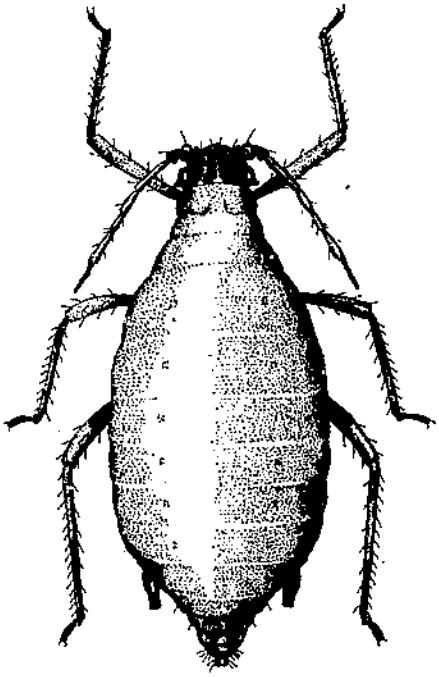

FIGURE 5.—Apterous viviparous female *Aphis maidis*

No definite statement can yet be made concerning the factors influencing the occurrence of sexual forms. The first 4 males produced were the first and second born of certain given females, while the next 8 males secured were the last 8 born of a single female. In another case there was an indiscriminate mixing of males and apterous and alate viviparous individuals after 36 normal viviparous young had been born. (Figs. 5 and 6.)

In each of the three seasons, 1919–20, 1921–22, and 1923–24, in which males were found, the average temperature ranged from nearly normal to 8.4 degrees above normal for each month, with no abnormally low temperatures (a minimum of 30° F.). During these three years 40 series of cages were run through the season, and males appeared in 6 of them. The average temperature during the winter of 1924–25 was also above normal, although there were occasional low temperatures, with a minimum of 23° F. Nineteen series of cages were run during this season without any sexual forms appearing. During the six years 1911 to 1917, 27 series of generations were carried through the winter seasons without sexual forms appearing. Four of these six seasons averaged below normal; the other two averaged above normal, although there were unusual cold spells in which the temperatures dropped to 27° F. While all the males thus far observed were secured during very mild winters, the number of cages under operation is too small to show definitely that temperature is a controlling factor. Other workers have carried *A. maidis* through the winter in greenhouses, in heated rooms,

and in the Tropics without producing sexual forms. There seems to be no correlation between the number of males secured and the prevailing humidity or a combination of temperature and humidity. The greatest number of specimens developed during two of the seasons when the work was carried on under an open shed where some of the light was cut off, but they were not secured in other seasons under the same shed. They also developed in a third season when the work was done in the open with full daylight. Other workers have carried them through in inclosed sheds and rooms where the light was greatly reduced without securing sexual forms, so that a reduction of daylight does not seem to account for this occurrence.

The writers have been unable to find any other factor or group of factors that may be said to influence the occurrence of sexual

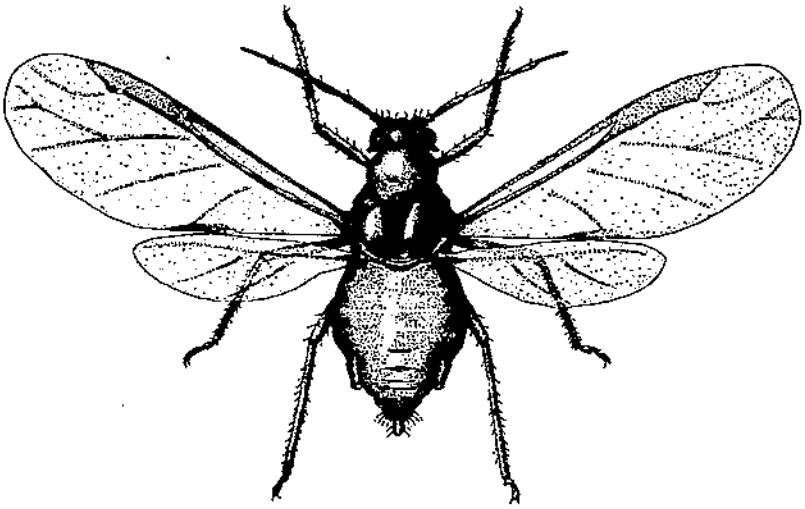

FIGURE 6.—Alate viviparous female *Aphis maidis*

forms. It seems probable that in the process of evolution *Aphis maidis* has developed to a point where the sexual forms are no longer necessary and the species can indefinitely continue to reproduce parthenogenetically.

MALES

Unfortunately, no males were observed closely enough to permit definite conclusions concerning the number of instars, the length of each instar, etc. A general statement can be made, however, that males required from two to nine days longer to reach maturity than the normal apterous, viviparous female born at the same time.

In all but one case the males were recognized as different in some way from normal young as soon as they were found. The second time they were found they were retained to start a cage of first-borns and were not recognized as males until they became adults.

Since no technical description of the young male is available, it seems desirable to incorporate here some extracts from the notes

made by the junior author at the time the young were found. The first note appears on February 11, 1920, and is as follows: "Two larvae are found to-day. These are extremely dark colored." These two larvae were isolated for observation, and on March 1 appears the following:

Both are now winged adults. These are much more slender than the average winged female and the abdomen is much darker; the average winged female having a black thorax and a greenish abdomen while these have both thorax and abdomen black.

These two specimens were observed for a few days, then preserved in alcohol and sent to A. C. Baker, who determined them as alate males of *Aphis maidis*. Another note, under date of December 21, 1921, is as follows:

One young is so different that it is isolated to watch developments. It is of a dull black color, so that when first seen on a yellowed leaf I thought it dead. It is comparatively broad across the thorax, and the sides of the thorax and abdomen are parallel. The tip of the body does not extend beyond the cornicles at this time. (Age about 3 days.)

DESCRIPTION OF MALE APHIS MAIDIS (FIGS. 7, 8, 9, 10)

The following description is from five specimens reared by the junior author, which are now deposited in the United States National Museum (No. 19328).

Head and thorax black; abdomen dark bluish green, appearing almost black, with a slightly darker spot on the side of each abdominal segment. Antennae 6-segmented, reaching nearly to the cornicles. Third antennal segment with 12 to 47 circular sensoria irregularly distributed; fourth with 9 to 25 similar sensoria irregularly distributed; fifth with 6 to 15 sensoria; sixth with 1 large sensorium at the apex of the basal portion and none to 2 small sensoria on the basal portion. Legs black. Cornicles black, largest in the middle and somewhat dilated at the apex.

Measurements (average specimens in alcohol): Length of body, 1.456 mm; width, 0.572 mm; wing expanse, 6.29 mm. Antennae (Table 4), basal segment, 0.0624 mm; segment 2, 0.0624 mm; segment 3, 0.3299 mm; segment 4, 0.1788 mm; segment 5, 0.1726 mm; segment 6, 0.0936+0.2080 mm; total, 1.1077 mm. Cornicles, 0.104 mm.

TABLE 4.—*Measurements of male antennae*

Individual No.	Segment 1	Segment 2	Segment 3		Segment 4		Segment 5		Segment 6	
			Length	Sensoria	Length	Sensoria	Length	Sensoria	Length	Sensoria
	Mm	*Mm*	*Mm*	*Number*	*Mm*	*Number*	*Mm*	*Number*	*Mm*	*Number*
1	0.0624	0.0624	0.3288	47	0.1664	25	0.1456	6	0.104 + 0.2288	1
2	.0624	.0624	.3288	34	.1664	24				
	.0624	.0624	.3744	36	.1872	15	.2080	6	.104 + .2496	3
3	.0624	.0624	.2912	25	.1872	17	.1872	15	.104 + .2288	
	.0624	.0624	.3952	42						
4	.0624	.0624	.3744	21						
	.0624	.0624	.2288	12	.1872	9	.1456	6	(?)	(?)
5	.0624	.0624	[1].4784	[1]47			.1768	14	.0624 + .1248	1

[1] Segments 3 and 4 united.

NATURAL CHECKS

Like many other injurious insects, *Aphis maidis* is ordinarily held in check by adverse weather conditions and the natural enemies which prey upon it. Often, however, weather conditions may be favorable for its rapid multiplication where its natural enemies are few in number, and then severe injury may be expected.

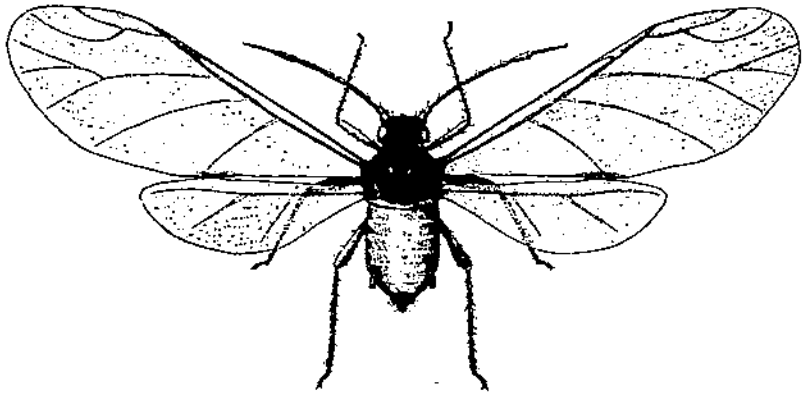

FIGURE 7.—Male *Aphis maidis*

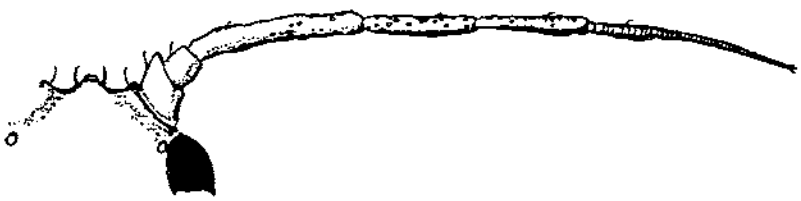

FIGURE 8.—Antenna of male *Aphis maidis*

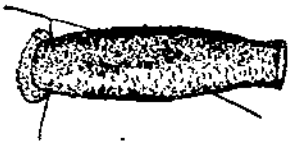

FIGURE 9.—Cornicle of male *Aphis maidis*

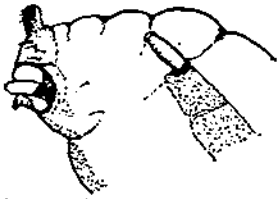

FIGURE 10.—Cauda of male *Aphis maidis*

ADVERSE WEATHER CONDITIONS

As has been shown previously, both extremes of temperature are detrimental to the welfare of this aphid. The aphids are unable to survive the cold winters of the North as viviparae even on the favored hosts. Less than 25 per cent were able to survive the unusual cold of 13° F., at Tempe, Ariz., in 1912. On the other hand, the extreme summer heat in the Southwest reduces the size of the aphids one-third to one-half, shortens the span of life, and greatly curtails the number of young produced.

Hard, beating rains frequently destroy large numbers of the aphids, although not so many of them as of many other species, because *Aphis maidis* is well protected within the plant.

Warm, humid weather is favorable to a fungous disease which often causes the death of large numbers of these aphids.

INSECT AND OTHER ENEMIES

Aphis maidis is attacked by a large number of natural enemies. In the United States alone the known list includes 13 coccinellids, 7 syrphids, 2 other Diptera, 2 lacewing flies, 1 hymenopteron, 1 reduviid, and many small spiders, several of which have not been specifically determined. Certain small lizards and birds also occasionally feed on this insect.

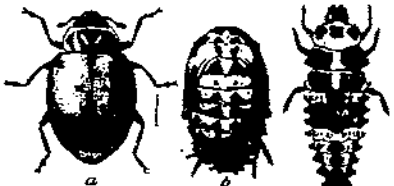

FIGURE 11.—*Hippodamia convergens*: *a*, Adult; *b*, pupa; *c*, larva. (Webster and Phillips)

LADYBIRD BEETLES

Probably a large percentage of the species of ladybird beetles can, and do at times, feed on *Aphis maidis*. Thirteen species have been recorded as feeding commonly on this aphid. Two species in particular, *Hippodamia convergens* Guer. (fig. 11) and *Ceratomegilla fuscilabris* Muls., are very widely distributed and are nearly always in evidence during an aphid outbreak. Both larvae and adults of this group feed on aphids and other soft-bodied insects.

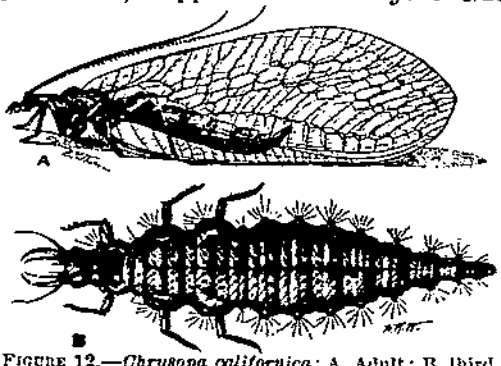

FIGURE 12.—*Chrysopa californica*: A, Adult; B, third instar. (Wildermuth)

In 1912 Vickery obtained the ladybird beetle *Chilomenes sexmaculata* Fab. from India and attempted to establish it near Brownsville, Tex., to help control this aphid. The beetles fed readily on these aphids, but the attempt seems to have failed, since no specimens have been recovered.

LACEWING FLIES

In the Southwest *Chrysopa californica* Coq. (fig. 12) is the most important of the neuropteron group. The senior author has carefully worked out the life history and habits of this insect and shown that it will eat from 75 to 150 or more mature aphids or from 400 to 500 aphids of all sizes during its lifetime. It feeds only during

the larval stages, grasping an aphid and completely draining it of its body contents before discarding it and taking another. In cage work the adults were not observed to feed; they lived only two or three days until the complement of eggs was laid.

SYRPHID FLIES

The larvae of syrphid flies form another important group of natural enemies of *Aphis maidis*. Seven species have been recorded as feeding on this aphid. Davidson (*7*) credits *Allograpta fracta* O. S. as being chiefly responsible during certain years for the control of *A. maidis* in the Imperial Valley of California. This species is also common in Texas, Oklahoma, and Kansas. Other species seem to be more common farther east.

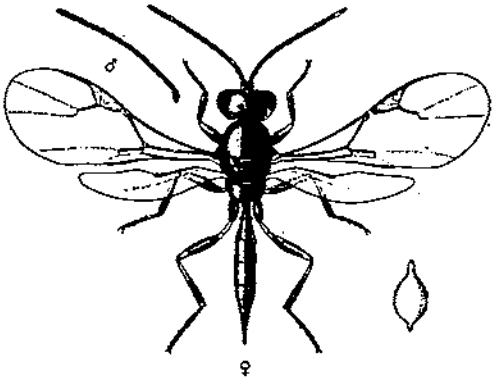

FIGURE 13.—*Lysiphlebus testaceipes* (Cress). (Webster and Phillips)

INTERNAL PARASITES

The internal hymenopterous parasite *Lysiphlebus testaceipes* (Cress.) (fig. 13) is probably the most widely distributed and at the same time the most important parasite of *Aphis maidis* in the United States. Nearly every colony of aphids observed was found to have a number of infested individuals. While the weather remains warm entire colonies are destroyed, but during the cooler weather the aphids are able to more than hold their own with this parasite, as the temperature at which the parasite develops most readily is somewhat higher than that required by the aphid for rapid multiplication.

LIST OF INSECT ENEMIES OF APHIS MAIDIS FITCH

Coleoptera:
- *Adalia bipunctata* L.
- *Ceratomegilla fuscilabris* Muls.
- *Coccinella novemnotata* Hbst.
- *Cycloneda rubripennis* Casey
- *Cycloneda sanguinea* L.
- *Hippodamia convergens* Guer.
- *Hippodamia glacialis* Fab.
- *Hippodamia parenthesis* Say
- *Hyperaspis signata* Oliv.
- *Olla abdominalis* Say
- *Psyllobora 20-maculata* Say
- *Rodolia cardinalis* (Muls.)
- *Scymnus* sp.

Diptera:
- Syrphids—
  - *Allograpta fracta* O. S.
  - *Allograpta obliqua* Say

Diptera—Continued.
- Syrphids—Continued.
  - *Baccha clavata* Fab.
  - *Eupeodes volucris* O. S.
  - *Mesogramma polita* Say
  - *Sphaerophoria cylindrica* Say
  - *Syrphus americanus* Wied.
- Other Diptera—
  - *Aphidoletes meridionalis* Felt
  - *Leucopis nigricornis* Egger

Lacewing flies:
- *Chrysopa californica* Coq.
- *Chrysopa* sp.

Hymenoptera:
- *Lysiphlebus testaceipes* (Cress.)

Hemiptera:
- *Reduviolus ferus* L.

CONTROL

TIME OF PLANTING

Since this insect does its greatest damage to late corn and sorghums in the North and to late-planted barley in the South, it is obvious that much can be accomplished in the way of reducing the injury by early planting and by thorough cultivation, where possible, to hasten the maturity of the crop. In the North early-planted corn usually is nearly mature before the aphid becomes abundant enough to injure the crop seriously. The early crops are not so succulent as the later planted crops and are not so attractive to the migrant forms. Early-planted barley is seldom hurt in the South, although the late planting is often seriously injured.

Any condition which causes the crop to grow in a thrifty manner will reduce the damage from this insect. Fields that are to be planted to crops susceptible to injury from this insect should be well tilled, preferably by deep plowing and thorough preparation of the seed bed, and they also should be maintained in a high state of fertility. Attention to these details will produce a rapidly growing crop and one that will outgrow much of the damage that may be caused by the feeding of these little insects. It is lack of this thrift and rapid growth in late-planted barley that enables the insect to cause serious damage in such fields.

PASTURING

In the South and Southwest barley is commonly sown in the fall and pastured during the winter. This pasturing is of threefold benefit, in that it supplies an abundance of green feed, causes a greater tillering of the plant, and at the same time helps to control the aphid. The aphid crawls deep into the whorl of the plant and is eaten by the cattle along with its host plant. When thus located, the insect has but little opportunity to fall from the plants while the stock are grazing on them. Thus, even a heavily infested field may be almost completely freed of the pest.

SPRAYING AND DUSTING

Although it is possible to kill many of the aphids on barley by spraying or dusting with insecticides, the comparatively low value of the crop and the high cost of the operation make this method inadvisable as an ordinary procedure. On the grain sorghums and corn the aphids hide in the head and deep within the growing tips, where it is difficult for ordinary sprays to reach them in an efficient manner.

SUMMARY

Aphis maidis was described by Fitch in 1856 and was confused with (*Aphis*) *Anuraphis maidi-radicis* Forbes until 1891, when Forbes showed the two to be distinct species.

Aphis maidis is quite generally distributed throughout the world between the parallels of 40° N. and 40° S.

It does its greatest damage in the United States when feeding upon barley, grain sorghums, and corn, and in the transmission of the mosaic diseases on sugarcane.

It is not known how or whether this aphid overwinters in the North. It has been suggested that it may migrate from the South.

Cage records show the maximum number of generations to vary from 9 in central Illinois to from 35 to 41 at Tempe, Ariz., and from 39 to 50 at Brownsville, Tex.

Males are recorded for the first time (Tempe, Ariz.) and are illustrated and described herein.

This insect can be controlled on corn and grain sorghums by early planting and on barley by early planting and pasturing the infested fields in case of an outbreak.

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