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STATUS AND RELATIVE IMPORTANCE OF THE PARASITES OF THE HESSIAN FLY IN THE

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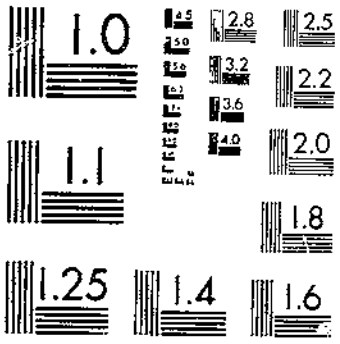


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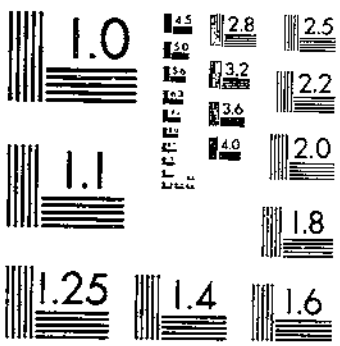


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NATIONAL BUREAU OF STANDARDS 1963-A

TECHNICAL BULLETIN NO. 689 AUGUST 1939

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# STATUS AND RELATIVE IMPORTANCE OF THE PARASITES OF THE HESSIAN FLY IN THE ATLANTIC STATES[1]

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## INTRODUCTION

Since the publication in 1928 of a summarized account of the relative importance of the parasites of the hessian fly (*Phytophaga destructor* (Say)) in the Eastern States,[2] much additional information has been accumulated on the subject, including data not previously reported on from New York, southern Virginia, and North Carolina. Improved technique has also made it possible to obtain truer estimates as to the relative importance of many of the species of parasites involved. It is the purpose of the writers to present herein such data as will revise and supplement previously published accounts.

## METHODS OF PROCEDURE

The hessian fly material which formed the basis of this work was collected from numerous localities sufficiently scattered to represent the various regions under study. On account of differences due to latitude and topography, the spring-generation material was segregated so as to represent four regions, comprising the large wheat-growing area of western New York; the major wheat-growing regions

[1] Submitted for publication February 21, 1939.

[2] HILL, C. C., and SMITH, H. D. STATUS OF THE PARASITES OF THE HESSIAN FLY, PHYTOPHAGA DESTRUCTOR (SAY), IN PENNSYLVANIA, MARYLAND, AND VIRGINIA. Jour. Agr. Research 36 : 151–166. 1928.

of Pennsylvania, Maryland, and Virginia as far south as the thirty-seventh degree of latitude; southern Virginia and central North Carolina; and a comparatively small area of the St. Lawrence Plain in Jefferson County, N. Y. Much of the material from New York was obtained through the cooperation of the late C. R. Crosby of Cornell University.

The samples consisted mostly of hessian fly puparia collected in the fall or early in the winter, with the exception of those taken in New York State, some of those included in the first 10 years' records in table 1, and part of the seasonal-history material.

All the puparia, regardless of their condition, were removed from a given sample of wheat plants or stubble. The living, unbroken puparia were placed in small shell vials, not more than 10 to a vial, in order to rear any parasites that they might contain. The vials were plugged snugly with cotton and the plugged ends of these then fitted into holes in rectangular, moistened plaster blocks. The remaining puparia were dissected and classified according to their condition or the species of parasite they might contain. Living parasitic larvae found in broken hessian fly puparia could not be reared successfully but could usually be classified as to superfamily and in some cases as to species. Host puparia from which chalcidoid parasites had emerged in the field were dissected to obtain the pupal casts and exuviae of the escaped parasites, from which material the species could usually be identified by means of a key developed for this purpose. This key has made possible a much more accurate evaluation of the different parasites than could be made heretofore. In all instances in which the death of the host could not be positively attributed to parasites, the deaths are classified in the accompanying tables as "Mortality from other or undetermined causes." Most of the puparia placed in this category were in such a condition of decay that the cause of their death could not be determined. On rare occasions the contents of a puparium were found to have been eaten by a wheat-stem sawfly larva as it worked its way along the interior of the wheat culm, and very rarely one appeared to have been killed by desiccation.

The puparia of the fall generation were usually collected during November and December, and, instead of being reared, were dissected under the microscope shortly after removal from the plants. Only certain parasites were found in this generation of the host at this time of year, and these could readily be identified in the immature stage without the necessity of rearing.

## PARASITIZATION AND MORTALITY OF THE SPRING GENERATION OF THE HESSIAN FLY

The data presented in table 1 were obtained from numerous collections of hessian fly puparia of the spring generation from over the three larger wheat-growing regions covered by this study. Owing to the many difficulties encountered it was not possible to obtain sufficient numbers of representative samples for all these areas every year to give unbroken series of records. Nevertheless, the writers believe that material collected in a sufficient number of years has been included from each area to show the average annual mortality of puparia due to parasites and other causes. Figures for only the positively recognized parasitizations were included in this table under the heading "Mor-

tality Caused by Parasites." Actual parasitization was probably somewhat greater owing to the death and disintegration beyond recognition of some of the parasites.

It may be noted in table 1 that the differences of parasitization between New York and the central area was slight, but that the total mortality was somewhat less in New York. Between these two regions and the southern area the differences both of parasitization and mortality were much more marked. Moreover, in both the central and southern areas approximately two-thirds of the average annual mortality was due to parasitism. It is possible that differences in parasitic activities may partially account for the lesser degree of mortality in the southern regions under study. In this connection it may be significant that in the southern area, as shown later in this bulletin, there is a conspicuous absence of *Platygaster zosine*, one of the most active parasites in the North, and that *Eupelmus allynii* is also much less in evidence than in the northern regions.

TABLE 1.—*Parasitization and mortality of the spring generation of the hessian fly in three different sections of the Atlantic States in indicated years*

WESTERN NEW YORK

| Year | Puparia | Mortality caused by parasites | Mortality from other or undetermined causes | Total mortality | Year | Puparia | Mortality caused by parasites | Mortality from other or undetermined causes | Total mortality |
|---|---|---|---|---|---|---|---|---|---|
| | *Number* | *Percent* | *Percent* | *Percent* | | *Number* | *Percent* | *Percent* | *Percent* |
| 1918 | 396 | 48 | 49 | 97 | 1931 | 1,474 | 70 | 22 | 92 |
| 1919 | 1,470 | 53 | 36 | 89 | 1932 | 2,354 | 68 | 14 | 82 |
| 1920 | 4,724 | 48 | 43 | 91 | 1933 | 104 | 64 | 30 | 94 |
| 1921 | 539 | 70 | 22 | 92 | 1934 | 491 | 60 | 12 | 72 |
| 1922 | 266 | 55 | 31 | 86 | | | | | |
| 1923 | 1,318 | 75 | 14 | 89 | Total or simple average | 14,124 | 62 | 26 | 88 |
| 1924 | 503 | 55 | 31 | 86 | | | | | |
| 1930 | 485 | 72 | 14 | 86 | | | | | |

PENNSYLVANIA, MARYLAND, AND VIRGINIA NORTH OF LATITUDE 37°

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1915 | 1,882 | 57 | 36 | 93 | 1923 | 2,852 | 63 | 32 | 95 |
| 1916 | 4,847 | 59 | 36 | 95 | 1924 | 3,189 | 75 | 20 | 95 |
| 1917 | 1,658 | 54 | 42 | 96 | 1932 | 3,331 | 77 | 15 | 92 |
| 1918 | 1,825 | 59 | 39 | 98 | 1933 | 2,257 | 66 | 29 | 95 |
| 1919 | 6,225 | 58 | 34 | 92 | | | | | |
| 1920 | 6,278 | 59 | 39 | 98 | Total or simple average | 43,758 | 63 | 32 | 95 |
| 1921 | 5,909 | 67 | 30 | 97 | | | | | |
| 1922 | 4,455 | 66 | 29 | 95 | | | | | |

VIRGINIA SOUTH OF LATITUDE 37° AND NORTH CAROLINA

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1921 | 912 | 45 | 31 | 76 | 1934 | 912 | 42 | 22 | 64 |
| 1922 | 138 | 46 | 9 | 55 | | | | | |
| 1924 | 52 | 52 | 27 | 79 | Total or simple average | 2,259 | 47 | 22 | 69 |
| 1932 | 245 | 51 | 22 | 73 | | | | | |

## COMPARATIVE IMPORTANCE OF THE DIFFERENT PARASITES ATTACKING THE HESSIAN FLY

### GENERAL CONSIDERATIONS

A total of 18 species of hymenopterous parasites have been bred from hessian fly puparia collected at one time or another in the eastern coastal States. Among these, nine are of major importance but the

remainder are too scarce to be of appreciable value. The nine significant parasites include the following species:

Serphoidea:
*Platygaster hiemalis* Forbes.
*P. zosine* Walker.
*P. herrickii* Packard.

Chalcidoidea:
*Eupelmus allynii* (French).
*Merisus destructor* (Say).
*M. febriculosus* Girault.
*Tetrastichus carinatus* Forbes.
*Pleurotropis metallicus* (Nees).
*Eupelmella vesicularis* (Retzius).

Among these, the serphoids *Platygaster hiemalis* and *P. zosine* and the chalcidoid *Eupelmus allynii* by far outrank in importance the other parasites. *P. hiemalis* is of especial value because it is the only parasite that attacks the fall generation of the fly in significant numbers, and because it occurs in nearly all sections of the country where the fly is found except in California. *P. zosine* is most effective within the northeastern wheat-growing regions, while *E. allynii*, which competes closely with *P. zosine* even within these regions, has the additional value of a much wider range of distribution. Among the other parasites, *P. herrickii* is important because of its activity in various southern and western wheat-growing regions, and *Merisus destructor* because of its widespread distribution and persistent though moderate abundance. Of the nine important ones, the remaining parasites are of value only when taken as a whole or when certain ones may occasionally become abundant for a season in some restricted locality.

All the species of serphoids mentioned oviposit into the egg stage of the hessian fly. Development takes place within and concurrently with the fly larva, the premature death of which is caused by the feeding parasite.

*Eupelmus allynii*, *Merisus destructor*, and *Eupelmella vesicularis* all deposit their eggs inside the puparium case of the hessian fly, but outside the fly larva, and the parasite larva feeds by piercing the epidermis of the host upon which it rests and sucking out the liquefied contents. *Tetrastichus carinatus* and *Pleurotropis metallicus*, however, deposit their eggs within the body of the host, where they develop throughout their larval stage. The females of these two species can therefore oviposit earlier in the season than the chalcidoids with external habits because they do not have to wait for the formation by the host of the protective covering of the puparium case.

### SOURCES OF INFORMATION

The evaluations of the different species are based primarily on the percentages of hosts killed by each during the season, as shown in tables 2 to 9. These percentages were obtained by extensive rearings and dissections of host material for this purpose.

To obtain data on the seasonal habits of the different species and thereby draw a clearer picture of their relative potentialities, collections of immature fly forms were made periodically during the season and this material reared in the usual manner, except for the very early collections which were dissected at once. Tables 2, 3, and 4 each shows a series of seasonal-history records representing a different year, but in the same general region of Pennsylvania and Maryland. In each series the collections were made each time from the same fields in the designated localities.

The material used as a basis for tables 5, 6, and 7 was collected during the 4-year period 1931–34, from points widely scattered over

the areas represented. Only those fly puparia were used which had been collected at the close of the season after parasite activity had ceased and when all the species involved had reached their maximum seasonal abundance.

TABLE 2.—*Seasonal development of hessian fly parasites, based on dissections of the young host larvae and rearing from host puparia collected* [1] *in 1932 near Cearfoss, Md.; and Carlisle, Dillsburg, and York Springs, Pa.*

| Parasite | Parasitized | | | |
|---|---|---|---|---|
| | May 20–25 | June 24–29 | July 18–20 | Sept. 12–15 |
| | *Percent* | *Percent* | *Percent* | *Percent* |
| *Platygaster zosine* | 45.75 | 27.30 | 27.88 | 18.63 |
| *Eupelmus allynii* | 0 | 6.83 | 25.25 | 36.13 |
| *Merisus destructor* | 0 | 4.75 | 4.00 | 8.90 |
| *Tetrastichus carinatus* | 0 | 1.90 | .88 | .85 |
| *M. febriculosus* | 0 | .13 | 0 | .60 |
| *Eupteromalus fulvipes* | 0 | 0 | .12 | 0 |
| *Pleurotropis metallicus* | 0 | .27 | .12 | 0 |
| *Eupelmella vesicularis* | 0 | 0 | 0 | .12 |
| *Centrodora speciosissima* | 0 | 1.71 | 0 | 0 |
| *Ditropinotus aureoviridis* | 0 | 0 | .12 | 0 |
| Undetermined chalcidoids | 1.00 | 6.40 | 13.00 | 18.92 |
| Hessian fly unparasitized | 40.00 | 30.21 | 4.50 | 6.02 |
| Hessian fly dead, cause undetermined | 4.25 | 20.14 | 23.00 | 7.14 |
| Predators | 0 | .38 | 1.13 | 2.76 |

[1] About 200 fly forms were collected from each locality on each date.

TABLE 3.—*Seasonal development of hessian fly parasites, based on dissections of the young host larvae and on rearings from host puparia collected* [1] *during 1933 near Union Mills, Md., and Carlisle, York, and Arendtsville, Pa.*

| Parasite | Parasitized | | | |
|---|---|---|---|---|
| | June 9–10 | July 8 | July 20 | Sept. 22 |
| | *Percent* | *Percent* | *Percent* | *Percent* |
| *Platygaster zosine* | 28.46 | 23.59 | 21.77 | 9.71 |
| *Eupelmus allynii* | 4.88 | 18.23 | 20.96 | 29.44 |
| *Merisus destructor* | 2.19 | 1.59 | 1.51 | 3.22 |
| *Tetrastichus carinatus* | .69 | 0 | .62 | 0 |
| *M. febriculosus* | 0 | 0 | 0 | .75 |
| *Pleurotropis metallicus* | 1.12 | 0 | 0 | 0 |
| *Eupelmella vesicularis* | .16 | 0 | 0 | .15 |
| *P. hiemalis* | .27 | 0 | 0 | 0 |
| Undetermined chalcidoids | 9.68 | 11.95 | 16.53 | 20.24 |
| Hessian fly unparasitized | 16.62 | 5.01 | 9.71 | 5.41 |
| Hessian fly dead, cause undetermined | 35.53 | 39.09 | 28.10 | 29.34 |
| Predators | .60 | .54 | .71 | 1.74 |

[1] An average of 173 fly forms were collected from each locality on each date.

TABLE 4.—*Seasonal development of hessian fly parasites, based on dissections of the young host larvae and rearings from host puparia collected* [1] *during 1934 near Carlisle, East Berlin, and Shermansdale, Pa.*

| Parasite | Parasitized | | | | |
|---|---|---|---|---|---|
| | June 1 | June 7 | July 11 | July 25 | Dec. 7 |
| | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| *Platygaster zosine* | 60.55 | 47.11 | 35.16 | 29.83 | 21.00 |
| *Eupelmus allynii* | 0 | .65 | 14.50 | 22.83 | 27.16 |
| *Merisus destructor* | 0 | 0 | 6.67 | 6.17 | 6.83 |
| *Tetrastichus carinatus* | 4.88 | 3.60 | 3.17 | 3.33 | .17 |
| *M. febriculosus* | 0 | 0 | .50 | .50 | .67 |
| *Pleurotropis metallicus* | 0 | 1.59 | 0 | .17 | 1.17 |
| *Eupelmella vesicularis* | 0 | 0 | .17 | 0 | .17 |
| *P. hiemalis* | 0 | .16 | 0 | 0 | 0 |
| *Polycelis modestus* | 0 | .16 | 0 | 0 | 0 |
| *Cheiloneurus elegans* | 0 | 0 | .17 | 0 | 0 |
| Undetermined chalcidoids | .32 | 1.95 | 12.15 | 13.83 | 16.67 |
| Hessian fly unparasitized | 29.65 | 38.20 | 6.67 | 5.50 | 3.33 |
| Hessian fly dead, cause undetermined | 4.61 | 6.01 | 20.17 | 17.50 | 18.50 |
| Predators | 0 | .48 | .67 | .34 | .83 |

[1] About 200 fly forms were collected from each locality on each date.

TABLE 5.—*Percentages of the spring brood of the hessian fly parasitized by the different species of parasites prevalent in western New York*

| Locality | | Date of collection | Total hessian fly puparia | *Platygaster zosine* | *Eupelmus allynii* | *Eupelmella vesicularis* | *Merisus destructor* | *Tetrastichus carinatus* | *Pleurotropis metallicus* | *M. febriculosus* | Undetermined chalcidoids | Total parasitization |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Town | County | | | | | | | | | | | |
| | | | *Number* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Henrietta | Monroe | Oct. 28, 1931 | 500 | 24.20 | 17.60 | 6.60 | 1.60 | 0.20 | 1.00 | 0.80 | 22.20 | 74.20 |
| Batavia | Genessee | do | 250 | 14.00 | 24.40 | 6.80 | 1.60 | 2.63 | 2.00 | 0 | 21.20 | 72.63 |
| Bath | Steuben | Oct. 26, 1932 | 38 | 21.05 | 18.42 | 5.27 | 5.26 | 2.63 | 2.63 | 0 | 21.05 | 76.31 |
| Pony Hollow | Tompkins | Sept. 10 1932 | 183 | 18.03 | 14.21 | 8.74 | 3.83 | 5.47 | 0 | 0 | 35.52 | 85.80 |
| Jacksonville | do | Oct. 26, 1932 | 150 | 31.33 | 18.67 | 2.00 | 1.33 | .67 | .66 | 1.09 | 30.67 | 86.42 |
| Henrietta | Monroe | Oct. 22, 1932 | 200 | 26.50 | 30.50 | 3.00 | 1.50 | .50 | .50 | .50 | 27.50 | 90.50 |
| Total | | | 1,321 | | | | | | | | | |
| Average | | | | 22.52 | 20.63 | 5.40 | 2.52 | 2.02 | 1.13 | .40 | 26.36 | 80.98 |

TABLE 6.—*Percentages of the spring brood of the hessian fly parasitized by different species of parasites prevalent in Pennsylvania, Maryland, and parts of Virginia*

| Locality | | Date of collection | Puparia | *Eupelmus allynii* | *Platygaster zosine* | *Merisus destructor* | *M. febriculosus* | *Tetrastichus carinatus* | *Pleurotropis metallicus* | *Eupelmella vesicularis* | Undetermined chalcidoids | Total parasitization |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Town | County and State | | | | | | | | | | | |
| | | | *Number* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Jersey Shore | Lycoming, Pa | Oct. 27, 1932 | 200 | 21.00 | 43.50 | 0 | 0.50 | 3.00 | 1.00 | 0.50 | 22.50 | 92.00 |
| Butler | Butler, Pa | Nov. 16, 1932 | 200 | 22.50 | 28.50 | 4.50 | 0 | .50 | .50 | 0 | 14.50 | 71.00 |
| Ruff Creek | Greene, Pa | Nov. 15, 1932 | 200 | 33.00 | 9.00 | 5.00 | 0 | 0 | 1.00 | 1.00 | 26.00 | 75.00 |
| Shelocta | Indiana, Pa | Nov. 17, 1932 | 200 | 32.50 | 12.50 | 6.50 | .50 | 0 | 0 | 0 | 23.00 | 75.00 |
| Fleming | Center, Pa | Feb. 15, 1934 | 157 | 25.48 | 5.73 | 1.28 | 1.91 | 0 | 1.91 | 0 | 19.11 | 55.42 |
| Shermansdale | Perry, Pa | Mar. 16, 1934 | 150 | 28.67 | 13.34 | 2.67 | .66 | 0 | 0 | 0 | 18.66 | 64.00 |
| Cearfoss | Washington, Md | Sept. 12, 1932 | 198 | 46.46 | 3.03 | 9.60 | 0 | 2.02 | 0 | 0 | 19.19 | 80.30 |
| Frederick | Frederick, Md | Sept. 13, 1932 | 198 | 37.37 | 8.08 | 4.55 | 2.02 | .51 | 0 | 0 | 18.18 | 70.71 |
| Union Mills | Carroll, Md | Sept. 22, 1933 | 170 | 14.71 | 11.18 | 1.78 | .59 | 0 | 0 | .59 | 28.24 | 57.09 |
| Hagerstown | Washington, Md | Mar. 15, 1934 | 200 | 32.50 | 13.00 | 4.00 | 1.00 | .50 | 0 | 0 | 29.00 | 80.00 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Frederick | Frederick, Md | do | 200 | 33.00 | 13.50 | 3.50 | .50 | 0 | 0 | 0 | 25.00 | 75.50 |
| Woodstock | Shenandoah, Va | Sept. 22, 1932 | 200 | 30.50 | 6.50 | 9.50 | .50 | 0 | 0 | 0 | 27.00 | 74.00 |
| Middleburg | Loudon, Va | Dec. 5, 1932 | 111 | 31.51 | 2.70 | 3.61 | 0 | 0 | 0 | 0 | 19.82 | 57.64 |
| Fairfield | Rockbridge, Va | Sept. 22, 1932 | 200 | 31.50 | 12.00 | 8.50 | 0 | 0 | 0 | 0 | 19.00 | 71.00 |
| Manassas | Prince William, Va | Nov. 20, 1933 | 500 | 21.20 | 6.00 | 8.40 | 1.00 | 0 | 0 | 0 | 35.20 | 74.80 |
| Leesburg | Loudon, Va | do | 105 | 22.85 | 22.86 | 1.91 | 3.81 | 0 | 0 | 0 | 20.95 | 72.38 |
| Total | | | 3,189 | | | | | | | | | |
| Average | | | | 29.23 | 13.21 | 4.71 | .81 | .41 | .28 | .13 | 22.83 | 71.61 |

TABLE 7.—*Percentages of the spring brood of the hessian fly parasitized by the different species of parasites prevalent in Abingdon in southern Virginia and in parts of North Carolina*

| Locality | | Date of collection | Puparia collected | *Eupelmus allynii* | *Platygaster herrickii* | *Merisus destructor* | *M. febriculosus* | *P. zosine* | *Tetrastichus carinatus* | *Centrodora speciosissima* | Undetermined chalcidoids | Total parasitization |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Town | County and State | | | | | | | | | | | |
| | | | *Number* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Thomasville | Davidson, N. C | Dec. 15, 1932 | 173 | 30.06 | 0 | 8.09 | 1.16 | 0 | 0 | 0 | 26.01 | 65.32 |
| Asheboro | Randolph, N. C | Nov. 19, 1931 | 200 | 4.50 | 22.00 | .50 | 0 | 0 | 0 | 0 | 4.00 | 31.00 |
| Lexington | Davidson, N. C | Nov. 17, 1934 | 200 | 15.50 | 0 | 5.50 | .50 | .50 | 0 | 0 | 34.50 | 56.50 |
| Abingdon | Washington, Va | Sept. 21, 1932 | 300 | 27.66 | 1.00 | 7.00 | 0 | .33 | .66 | .33 | 18.66 | 55.64 |
| Total | | | 873 | | | | | | | | | |
| Average | | | | 19.43 | 5.75 | 5.27 | .42 | .21 | .17 | .08 | 20.79 | 52.12 |

### PLATYGASTER ZOSINE

*Platygaster zosine* is an internal, primary parasite of the hessian fly. It oviposits into the hessian fly egg, and the embryos always develop within the midintestine of the host. The adults emerge in the spring for oviposition, embryos may be found throughout the month of May, and larvae during the last of May, all of June, and the first part of July. Cocoons are spun during June and July, and pupation takes place during July and August. All transformations into adults are usually completed by the end of September, but with rare exceptions the adults remain within their cocoons until the following spring. The insect is polyembryonic, and from 2 to 12 embryos may develop from a single egg, with an average of 8 per host reaching final development.

In the course of the season it is subject to rather high mortality. This is due partly to the premature death of both host and parasite with disintegration of the latter beyond recognition, and partly to complete consumption of *zosine* larvae by later developing chalcidoids acting as facultative hyperparasites. Such hyperparasitism has been substantiated by many laboratory observations. In dissecting hessian fly puparia it is very common to find a live early-instar chalcidoid inside the same host larva with dead and liquifying *zosine* larvae; or to find the larva of an external feeder such as *Eupelmus allynii* attached to the outside of a host larva already parasitized by *zosine*, the larvae of which have been fatally affected by this external feeder.

The oviposition period of *Platygaster zosine* is limited to the comparatively brief spring egg-laying period of its host, whereas oviposition by many of the chalcidoid parasites continues throughout the summer. Thus the gradual replacement of *P. zosine* by chalcidoids as the season progresses increasingly obscures the effectiveness of the former. Evidence of this substitution is given in tables 2, 3, and 4, in which the percentage of parasitization by *P. zosine* decreases as the percentage of chalcidoid parasitization increases. Table 2 shows that 45.75 percent parasitization by *zosine* at the beginning of the season was reduced to 18.63 percent by fall; table 3 shows a reduction from 28.46 percent to 9.71 percent; and in table 4 there was a reduction from 60.55 percent to 24.00 percent, less than half. In table 4 the gradual diminution of *zosine* in the course of the season is clearly indicated by the steadily decreasing percentage figures on the consecutive dates from June 1 through June 7, July 11, July 25, and December 7.

In spite of this heavy mortality *Platygaster zosine* has maintained its abundance of population. Many factors have probably contributed to this, among which should be noted a high potential rate of reproduction, polyembryonic development, and the habit of attacking the host during a most vulnerable stage of the latter's life history. In further explanation of the last-mentioned factor it should be noted that by ovipositing into the egg stage of its host *P. zosine* is able to parasitize many fly larvae that finally become located in positions inaccessible to the chalcidoids, such as in stem bases below the soil line, or the inner sides of close-standing tillers.

In order to make a fair comparison between *Platygaster zosine* and its closest competitor, *Eupelmus allynii*, consideration should be given to their respective seasonal histories. *P. zosine* attains its maximum parasitization at the outset of the season in the limited

period early in the year during which it attacks its host (tables 2, 3, and 4). On the other hand, *E. allynii*, which passes through more than one generation and attacks the later stages of the host, does not reach its maximum parasitization until the end of the season. Consequently, when evaluating the two parasites by the data included in the seasonal-history tables it is necessary to compare the figures at the beginning of the year for *P. zosine* with those at the end of the year for *E. allynii*. The usual superiority of *zosine* in the localities represented is thereby brought to light. This is particularly shown in tables 2 and 4, in which *zosine*, at the beginning of the season, shows a decidedly higher parasitization record than does *allynii* at the end of the season. In 1932 (table 2) this amounted to a difference of 9.62 percent, and in 1934 (table 4) *zosine* exceeded *allynii* by as much as 33.39 percent. In further comparing *P. zosine* with *E. allynii* it is significant that the maximum parasitization by *E. allynii* ever found by the writers amounted to not more than 48 percent, in a collection of 110 hessian fly puparia made at York, Pa., September 22, 1933. Much higher parasitization by *P. zosine* is not uncommon, and an examination of hessian fly larvae collected May 19, 1919, in a wheat field at Mount Holly Springs, Pa., showed 85 percent of them attacked by this species. Other instances have been recorded [3] where hessian flies from different fields in Pennsylvania and Maryland have been parasitized by *zosine* to the extent of 51.00, 57.55, 76.09, and 79.31 percent. In general the data show that *P. zosine* usually takes a larger toll of hosts than does *E. allynii* in the northern and central regions under discussion, and for that reason may be considered the more valuable within these areas. Furthermore, *P. zosine* does not have the defect of acting as a hyperparasite upon occasion, as do *E. allynii* and most of the other chalcidoids.

*Platygaster zosine* showed an average parasitization of 22.52 percent in western New York, 13.21 percent in Pennsylvania, Maryland, and part of Virginia, and only 0.21 percent in southern Virginia and parts of North Carolina (tables 5, 6, and 7). As all the material that formed the basis of these tables was collected at or after the end of the season, much of the evidence of parasitization by *P. zosine* had been obliterated, and the figures do not represent the full extent of its activity. They are valuable, however, for comparing the abundance of *P. zosine* in the three regions represented. As will be seen, this was greatest in New York and insignificant in southern Virginia and North Carolina.

Notwithstanding many factors of influence, both unfavorable and favorable, for the continued existence of this parasite, and also in spite of regional fluctuations in host density, *Platygaster zosine* has maintained within the areas of its normal distribution a status of equilibrium that has shown no definite trends of either decrease or increase in the percentage of hosts attacked during the years from 1915 to 1934.

### EUPELMUS ALLYNII

*Eupelmus allynii* is a solitary, external parasite of the hessian fly but is not specific to it. It oviposits into the host puparium, is

[3] HILL, C. C. PLATYGASTER VERNALIS MYERS, AN IMPORTANT PARASITE OF THE HESSIAN FLY. Jour. Agr. Research 25: 31–42, illus. 1923.

monembryonic, and hibernates in the larval stage within the puparium of the host. It passes through more than one generation during the year and parasitizes the hessian fly puparia in increasing numbers throughout the growing season. This is clearly shown in the seasonal-history tables 2, 3, and 4, in which it will be seen that during June a very low percentage of hosts are parasitized by it. This number increases rapidly during July and reaches its maximum amount by the end of the season.

The full value of *Eupelmus allynii* was not recognized prior to the application of improved technique in 1931, and from the standpoint of the country as a whole it may prove to be the most valuable of the parasites because of its wide distribution and consistently high rate of parasitization.

The different rates of parasitization by *Eupelmus allynii* in each of the three sections of the country under study are shown in tables 5, 6, and 7. These averaged 20.63 percent in New York State (table 5), 29.23 in Pennsylvania, Maryland, and part of Virginia (table 6), and 19.43 percent in southern Virginia and part of North Carolina (table 7). In these tables 26 localities are represented, and the range of parasitization was between a maximum of 46.46 percent at Cearfoss, Md., and a minimum of 14.21 in Tompkins County, N. Y., with the one exception of the unusually low parasitization of 4.50 percent which occurred at Randolph, N. C.

In cases of multiple parasitism with other hessian fly parasites, *Eupelmus allynii* has been found to have survived at the expense of six other species, including *Platygaster zosine*, *Tetrastichus carinatus*, *Pleurotropis metallicus*, *Merisus destructor*, *Ditropinotus aureoviridis*, and *Eurytoma* sp.

### PLATYGASTER HERRICKII

*Platygaster herrickii* is a solitary, internal, primary parasite of the hessian fly. It emerges in the spring, oviposits into the eggs of the hessian fly as does *P. zosine*, and passes through one generation a year. It hibernates as an adult within its cocoon inside the hessian fly puparium.

Its effective range in the eastern coastal States is limited to regions south of latitude 37°. Within its range it is particularly important because, by its habit of attacking the host in the egg stage, it partially compensates for the scarcity of *Platygaster zosine* and, like the latter, usefully supplements the work of the parasites that attack only the later stages of the host.

Like *Platygaster zosine*, it suffers a heavy mortality in the course of the season from hyperparasitism. For this reason collections made at the end of the season do not reveal the full extent of its parasitization. The figures in table 7 showing the percentages of hosts parasitized by *P. herrickii* are therefore misleading unless the factor of mortality is taken into consideration, because all the collections upon which they were based were made at the end of the season, as shown by the dates in the table. The absence of *herrickii* from both of the Davidson County samples was probably due to hyperparasitization, as there is no reason to believe that this parasite does not occur in normal abundance in that county. The high showing of 22 percent in rearings from Ashboro, Randolph County, may have been due to the scarcity of chalcidoid hyperparasitism. It will be observed that the

chalcidoids were reared from only 9 percent of the hosts as compared to 65.32, 56.00, and 54.31 percent, respectively, in the other rearings. The record from Abingdon, Va., showed only 1 percent of hosts infested by *herrickii*, but material from exactly the same location, taken early in the season before hyperparasitism had begun, showed evidence of a 20-percent parasitization by this species. The high mortality it undergoes is a more serious handicap to *herrickii* than to *zosine* owing to the solitary parasitic habit of the former as compared to the polyembryonic development of the latter.

Comparing *Platygaster herrickii* with *Eupelmus allynii* (table 7), in three out of four rearings *E. allynii* far outranked *P. herrickii* in number of hosts occupied by the end of the season. This hardier survival gives *E. allynii* a numerical advantage over *P. herrickii* which would promise greater reliability from season to season.

In most of the rearings shown in table 7 *Platygaster herrickii* even appears to be eclipsed by *Merisus destructor*, but in consideration of the high potentiality *herrickii* shows early in the season it would seem best to recognize *herrickii* as the more valuable parasite of the two in these southern localities.

It is apparent, from its much lower average percentage of abundance, that *Platygaster herrickii* does not entirely compensate in effectiveness for the scarcity of *P. zosine* in the southern area, for it parasitized only 5.75 percent of the spring brood of the hessian fly in the southern area, whereas *P. zosine* parasitized 13.21 percent in the central area (table 6) and 22.52 percent in western New York (table 5). This difference may also partially account for the lower mortality of the hessian fly in the South as compared to that in the more northern regions. As has been pointed out (table 1), this amounted to an annual average of 69 percent in the southern as compared to 95 percent in the central area and 88 percent in the northern area.

### MERISUS DESTRUCTOR

*Merisus destructor* is a solitary, external, primary chalcidoid parasite of habits similar to those of *Eupelmus allynii*, and it is found attacking the hessian fly throughout the latter's range of distribution in this country. In Pennsylvania and Maryland (tables 2 to 4) it begins actively to parasitize its hosts shortly before the middle of June, increases in numbers during the season, and reaches its maximum abundance by September. It passes the winter as a mature larva within the host puparium as does *Eupelmus allynii*.

In New York State (table 5) it was exceeded in abundance by three other parasites, *Platygaster zosine*, *Eupelmus allynii*, and *Eupelmella vesicularis*, and its average parasitization came to 2.52 percent. In the central and southern areas (tables 6 and 7), however, it reached third in abundance, with averages of 4.71 and 5.27 percent, respectively. Its maximum amount in any one locality came to 9.60 percent in a sample collected at Cearfoss, Md., shown in table 6.

### MERISUS FEBRICULOSUS

*Merisus febriculosus*, like *M. destructor*, is a solitary, external, primary, chalcidoid parasite of the hessian fly. As will be seen from the seasonal history tables 2 to 4, it is seldom found attacking the fly prior to the month of June. Among the parasites of the spring

generation of the fly it ranked seventh in importance in New York State (table 5), being exceeded in abundance by *Eupelmella vesicularis*, *M. destructor*, *Tetrastichus carinatus*, and *Pleurotropis metallicus*, as well as by *Platygaster zosine* and *Eupelmus allynii*. In the central and southern areas, shown in tables 6 and 7, it ranked fourth in importance.

#### TETRASTICHUS CARINATUS AND PLEUROTROPIS METALLICUS

Both *Tetrastichus carinatus* and *Pleurotropis metallicus* belong to the Chalcidoidea, and are solitary, internal, primary parasites of the hessian fly. The mature larvae of both these species are characterized by comparatively heavy, curved mandibles, and the first-instar larva of *metallicus* is easily distinguished by a caudal star-shaped, flexible, prehensile apparatus not found on that of *carinatus*. Both attack the hessian fly earlier in the season than do the other chalcidoids, and prefer to lay their eggs in the host larvae prior to the formation of puparia. Sometimes, late in the summer, *T. carinatus* develops a second generation that attacks a summer or early-fall generation of the hessian fly in volunteer wheat. In New York (table 5) and in the central area of Pennsylvania, Maryland, and parts of Virginia (table 6) *carinatus* ranked fifth and *metallicus* sixth in abundance. In the southern area of Virginia, shown in table 7, *carinatus* ranked sixth among the parasites, but *metallicus* occurs only rarely in southern Virginia and has never been taken in North Carolina.

#### EUPELMELLA VESICULARIS

*Eupelmella vesicularis* is a chalcidoid characterized by its abortive wings bent near their middle and by the brownish-black to cupreous tinge of the body. It is an external feeder with habits and nature somewhat like those of *Eupelmus allynii* and has been reared from a variety of hosts besides the hessian fly. It reaches its maximum parasitization by the end of the season. Although it has a wide distribution, it is most effective as a parasite of the hessian fly in regions north of Pennsylvania. Southward it becomes scarcer and in the eastern coastal States it has not been collected farther south than Wythe County, Va. It ranked third in importance in New York, with an average parasitization of 5.40 percent, (table 5), which was more than twice that of *Merisus destructor* in that area. In the collection made at Pony Hollow, in Tompkins County, N. Y., it had parasitized 8.74 percent of the hessian fly. In the central area (table 6) it dropped to seventh place in importance, and was unrepresented from all the localities south of Union Mills, Md.

#### PARASITES OF LESSER IMPORTANCE

Among the rarer parasites that attack the hessian fly in the wheat-growing districts of the eastern coastal States are the following chalcidoids: *Eupteromalus fulvipes* (Forbes), which commonly assumes a subapterous form and which resembles *Eupelmus allynii* in its habits; *Merisus mordellistenae* Girault, in habits and appearance much like *M. febriculosus; Cheiloneurus elegans* (Dalman), which is an internal parasite with a range from Lake Ontario on the north to Frederick County, Va., on the south; *Polyscelis modestus* Gahan, another ordi-

narily rare parasite reared only from hessian fly puparia collected in Pennsylvania and Maryland, but which in the spring of 1928 was found parasitizing abundantly overwintering fall-brood puparia near Carlisle and Mount Holly Springs in Cumberland County, Pa.; *Callitula bicolor* Spinola, a solitary, external parasite of wide distribution, and a common parasite on Diptera of the genera *Oscinella* and *Chlorops* in Europe; *Centrodora speciosissima* Girault, the smallest in size of the chalcidoid hessian fly parasites, gregarious within its host, and widely distributed through the wheat-growing districts of the Northeastern States west of the Hudson River; *Ditropinotus aureoviridis* Crawford, which is a primary parasite of *Harmolita;* and two parasites, *Tumidiscapus flavus* Girault and *Decatoma amsterdamensis* Girault, whose attacks occur too rarely to be considered more than cases of incidental parasitism.

## PARASITES OF THE ST. LAWRENCE PLAIN IN NEW YORK

The fauna in the St. Lawrence Plain is distinctly different from that farther south and for this reason data from collections made within this district have been segregated and presented in table 8. The collections taken in 1918 were from Theresa and Evans Mills in Jefferson County, N. Y. Those in 1932 were taken from Mannsville, farther south in the same county.

It will be observed that both *Platygaster zosine* and *P. hiemalis* were present, but only in insignificant numbers; that *Eupelmus allynii* was much less abundant than farther south; that in Evans Mills and Theresa *Merisus febriculosus* and *Pleurotropis metallicus* assumed more important roles than in the more southern regions; and that in the collections made at Mannsville *Tetrastichus carinatus* was by far the dominant parasite.

## PLATYGASTER HIEMALIS, THE MAJOR PARASITE ATTACKING THE FALL GENERATION OF THE HESSIAN FLY

*Platygaster hiemalis* is of most importance as a parasite of the fall generation of the hessian fly and is specific to this fly. It oviposits into the egg of the hessian fly and develops polyembryonically, usually by twinning. An average of about six adults develop in a single host. Diapause occurs at an advanced embryonic stage of growth, in which stage the parasite normally hibernates. *P. hiemalis* embryos of this sort may be found throughout the year, but as a rule growth is resumed early in the spring. In eastern Pennsylvania pupation reaches its peak during the middle of August, and adults are formed within their cocoons in maximum numbers by the latter part of that month. Occasional adults may be found abroad in wheatfields during most of the summer, but the peak of emergence is reached about the last of September, in time to catch the major wave of fall oviposition by the hessian fly.

In northern New York, contrary to its usual habits, *Platygaster hiemalis* commonly parasitizes the spring generation of the hessian fly, and it has been occasionally reared from the spring generation in other parts of the East.

TABLE 8.—*Percentages of the hessian fly parasitized by the different species of parasites prevalent in the St. Lawrence Plain in Jefferson County, N. Y.*

| Locality | Year | Puparia | *Platygaster hiemalis* | *P. zosine* | *Tetrastichus carinatus* | *Merisus febriculosus* | *M.* (probably) *febriculosus* | *Pleurotropis metallicus* | *Eupelmus allynii* | *Eupelmella vesicularis* | *M. destructor* | *Eupteromalus fulvipes* | Undetermined chalcidoids | Dead Platygasters | Total parasitization |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Number* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Evans Mills | 1918 | 464 | 1.08 | 0.65 | 0.43 | 4.74 | 0 | 5.60 | 6.04 | 0.86 | 2.59 | 0 | 34.48 | 0 | 56.47 |
| Theresa | 1918 | 124 | 2.42 | 0 | 1.61 | 12.90 | 0 | 9.68 | 6.45 | 7.26 | .81 | .81 | 40.32 | 0 | 82.26 |
| Mannsville | 1932 | 100 | 0 | 0 | 34.00 | 2.00 | 0 | 3.00 | 4.00 | 0 | 2.00 | 0 | 28.00 | 0 | 73.00 |
| Brownville | 1935 | 205 | 2.93 | 3.90 | .49 | 0 | 8.29 | 22.44 | 12.69 | 5.85 | 0 | 0 | 19.03 | .98 | 76.60 |
| Total | | 893 | | | | | | | | | | | | | |
| Average | | | 1.61 | 1.14 | 9.13 | 4.91 | 2.07 | 10.18 | 7.30 | 3.49 | 1.35 | .20 | 30.46 | .25 | 72.09 |

This parasite is of economic importance, not only because it is the principal parasite in this country to attack the fall generation of the hessian fly, but because of its wide distribution through all regions where the fly occurs except California. Efforts are now being made to establish it in that State. As may be seen in table 9, in the areas under study it does its most effective work in the wheat-growing districts of western New York, being about half as effective in the central area and much less effective in North Carolina.

TABLE 9.—*Percentages of larvae and puparia of the fall generation of the hessian fly parasitized by* Platygaster hiemalis *in the Atlantic States*

| Region | Years represented | Samples | Hosts | Parasitization |
|---|---|---|---|---|
| | *Number* | *Number* | *Number* | *Percent* |
| New York | 13 | 79 | 2,790 | 43 |
| Pennsylvania, Maryland, Delaware, and Virginia | 19 | 1,081 | 59,078 | 22 |
| North Carolina | 9 | 28 | 867 | 8 |

## SUMMARY

Investigations conducted over a number of years showed that the spring generation of the hessian fly undergoes an average annual parasitization of about 62 percent in the wheat-growing districts of western New York; 63 percent in those of Pennsylvania, Maryland, and part of Virginia; and 47 percent in southern Virginia and North Carolina. These figures represent about two-thirds of the total mortality of the spring brood from all causes in each of the three areas mentioned. The lower mortality in southern Virginia and North Carolina may be partly attributed to the lesser abundance of the chalcidoid parasite *Eupelmus allynii* and the practical absence of the serphoid parasite *Platygaster zosine*.

In all, 18 species of hymenopterous parasites have been found parasitizing the hessian fly in the wheat-growing areas of the eastern coastal States. By far the most important among these were the serphoids *Platygaster hiemalis* and *P. zosine*, and the chalcidoid *Eupelmus allynii*. Other parasites of varying importance were *P. herrickii, Merisus destructor, M. febriculosus, Tetrastichus carinatus, Pleurotropis metallicus*, and *Eupelmella vesicularis*. The remaining species were of insignificant value.

*Platygaster hiemalis* is of special value because it is the principal parasite that attacks the fall generation of the hessian fly, and because it has a wide distribution. The average annual parasitization by this species amounted to 43 percent in New York, 22 percent in Pennsylvania, Maryland, and Virginia, and 8 percent in North Carolina. It was found to parasitize to a slight extent the spring generation of the hessian fly in the St. Lawrence Plain in Jefferson County, N. Y.

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