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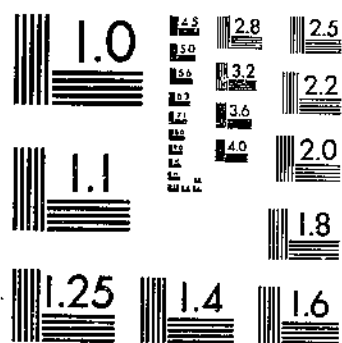
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DOUGENIE, C. F. ET AL.

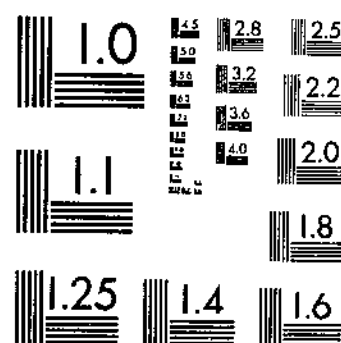
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**UNITED STATES  
DEPARTMENT OF AGRICULTURE  
WASHINGTON, D. C.**

# Biology of the Narcissus Bulb Fly in the Pacific Northwest<sup>1</sup>

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## INTRODUCTION

The establishment of the narcissus bulb fly (*Morion equestris* (F.))<sup>4</sup> in important bulb-producing areas in the United States has presented problems to the commercial bulb growers in particular as well as to others who are interested as gardeners. Climatic conditions in the

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The narcissus bulb fly has been one of the major insects under investigation at the Summer, Wash., laboratory of the Bureau of Entomology and Plant Quarantine. A number of individuals have been associated with various phases of the investigation, and acknowledgments are due them for their valuable assistance. F. J. Spruijt assisted in 1928 and 1929, R. H. Nelson assisted in 1931 and 1932, and Everett S. Bonn assisted, particularly in collecting population samples and in the infestation surveys, from 1931 to 1940. Also, serving under temporary seasonal appointments, T. R. Hansberry, Victor E. Scheffer, Paul M. Scheffer, Dudley Young, and Ernest Brockman assisted in various ways in the accumulation of the data on which this bulletin is based. Appreciation is due the growers in Washington and Oregon for granting to the laboratory staff full freedom and opportunity for visiting their plantings and warehouses, and for their sincere interest in the investigation.

<sup>2</sup> Order Diptera, family Syrphidae.

Pacific Northwest have been found well suited for the production of high-quality bulbs of the hardier types of narcissus. As a consequence this region has become the principal producing section in the United States for these types. The narcissus bulb fly apparently has become well established in this area, and its control is one of the principal difficulties confronting the growers in their efforts to maintain an excellent quality of the product for their markets. This insect has been studied to some extent in certain sections of the world, but detailed information on its life and habits under conditions equivalent to those in the Pacific Northwest has not been available. A knowledge of an insect's biology is of primary importance in determining and applying suitable control measures. This bulletin presents information on the biology of the narcissus bulb fly in the Pacific Northwest obtained in the recent research at the Summer, Wash., field laboratory of the Bureau of Entomology and Plant Quarantine.

### HISTORICAL RÉSUMÉ

The first record of the narcissus bulb fly which occurs in literature appears to be the report by Réaumur (30, r. 4, p. 499)<sup>4</sup> in 1738. He stated that a few years previously he had received in November some narcissus bulbs in each of which a large worm was feeding, and that in some cases two worms were present. These were kept under observation, and adults were obtained the following April. The source of the bulbs is indicated only as France. The species was named and described by Fabricius (16) in 1792 as *Syrphus equestris*. Meigen (26, r. 3, pp. 349-367), in 1822, described a number of species on the basis of color pattern, presumably from museum specimens, which were later considered synonyms of *Merodon equestris*. Bouché (6), in 1845, reported that infestation had been present in his garden [at Berlin] for several years. Bos (5) indicated the time of establishment of the insect in the Netherlands as around 1840, perhaps earlier, stating that it was so prevalent in 1847 near Haarlem that the "new malady" was discussed at a meeting of the growers, and in 1849 the growers' organization initiated a general questionnaire on the problem. An anonymous article in the *Gardeners' Chronicle* in 1842 (1) reported the collection of adults in England "a few years back," but larval attack on bulbs in that country had apparently not come to the attention of that writer.

The earlier accounts report that bulbs received in the more northern sections of Europe from the Mediterranean region carried infestation. Eeden (14) indicated Marseilles as a possible source of the infestations received in the Netherlands, and Bouché (6) reported that infested bulbs of *Narcissus nirens* were received by him from southern France and from Italy. The information in the earlier reports indicates that the insect was probably a native of Italy and southern France and possibly of southern Spain, and that it moved into the northern part of Europe as the culture of narcissus developed there and bulbs were imported from the infested regions.

In the Netherlands, where narcissus culture was developing rapidly as a commercial venture about 1840, concentration of plantings made conditions favorable for a rapid increase of the insect, as evidenced by its recognition as a serious pest by 1850. In England reports of definite damage are lacking until 1869, when Verrall (36) recorded

<sup>4</sup>Italic numbers in parentheses refer to Literature Cited, p 64.

having found a specimen in his garden, adding that since then the species appeared to have increased in numbers in Britain to an enormous extent. This was the period when the culture of narcissus was being taken up by many amateur gardeners in England, and commercial production for flowers and bulbs was also increasing considerably. Several reports of serious injury in the period from 1880 to 1900 confirm the statement of Verrall, and the insect has continued to be an important pest of narcissus in that country.

Jack (21) reported the presence of the insect at Brookline, Mass., in 1879, stating that just previous to 1897 the damage was more severe than usual and that the insect appeared to have been present in more or less abundance every season since it was first noticed in the place nearly 20 years before. The first accounts of extended injury in North America, however, refer to infestations in British Columbia. Osburn (28) refers to the infestation in that area in 1908, and it is further discussed by Hewitt (18) in 1911 and Treherne (33) in 1914. The presence of the insect in California was reported by Childs (10) in 1914, and Essig (15, p. 325) in 1915 and Davidson (12) in 1916 stated that it was apparently established in central California. Mackie (25), in 1925, reported it as present from San Diego to Humboldt Counties, Calif. Wilcox and Mote (39) state that in 1926 a survey indicated that it was present in practically all the commercial plantings in Oregon. Weigel<sup>6</sup> surveyed the principal narcissus-growing regions of the United States in 1925 and found rather general infestation in California, Oregon, and Washington, but no infestation in North Carolina, Virginia, Maryland, or Mississippi.

As in other regions, the period of increase of the bulb fly to serious proportions on the Pacific Coast has coincided in a general way with the period of development of the commercial aspects of the narcissus industry. The fly is definitely established on Long Island, New York, and, while not yet very abundant, it seems to be definitely on the ascendancy. Dearing and Griffiths (13) stated in 1930 that the insect was of no consequence in the bulb-growing areas of the coastal plain of North Carolina. They stated that infested bulbs had been imported into experimental plantings there up to 1927, but that the insect had entirely disappeared. Narcissus plantings are rather extensive in South Carolina, Florida, and Texas, but as far as known these plantings have apparently remained free from infestation.

### SYNONYMY

The narcissus bulb fly was originally described by Fabricius (16) as *Syrphus equestris*, but later the species was placed in the genus *Merodon*. Because of the extensive color variations a number of forms have been considered and described as separate species. The generally accepted synonymy is that given by Kertész (23, v. 7, p. 275) and Sack (31), which, in order of priority, is as follows:

- Syrphus equestris* Fabricius, 1794, Entomologia Systematica, v. 4, p. 292.
- Syrphus flavicans* Fabricius, 1794 (var.), Entomologia Systematica, v. 4, p. 292.
- Syrphus fuciformis* Fabricius, 1794, Entomologia Systematica, v. 4, p. 290; Schellenberg, 1803, Gattungen der Fliegen, pp. 54-55, pl. 11, fig. 1.
- Merodon equestris* (Fabricius) Latreille, 1805, Histoire Naturelle, générale et particulière, des Crustacés et des Insectes, v. 14, p. 360.
- Eristalis narcissi* Fabricius, 1805, Systema Antliatorum, p. 239.

<sup>6</sup> WEIGEL, C. A. PRESENT STATUS OF ESTABLISHMENT IN THE UNITED STATES OF IMPORTED BULB PESTS. REPORT OF BULB PESTS SURVEY. 8 pp. [1925.] [Minicographed.]

*Eristalis ferrugineus* Fabricius, 1805, *Systema Antliatorum*, p. 240.  
*Merodon nobilis* Meigen, 1822 (var.), *Systematische Beschreibung der bekannten europäischen zweiflügeligen Insekten*, v. 3, p. 353.  
*Syrphus constans* Wiedemann in Meigen, 1822, not Rossi, 1794, *Systematische Beschreibung der bekannten europäischen zweiflügeligen Insekten*, v. 3, p. 354.  
*Merodon transversalis* Meigen, 1822 (var.), *Systematische Beschreibung der bekannten europäischen zweiflügeligen Insekten*, v. 3, p. 354.  
*Merodon validus*, Wiedemann in Meigen, 1822, *Systematische Beschreibung der bekannten europäischen zweiflügeligen Insekten*, v. 3, p. 365.  
*Merodon bulborum* Rondani, 1845, [Bologna] *Nuovi Ann. delle Sci. Nat.* 2 (4): 256.  
*Merodon tuberculata* Rondani, 1845, [Bologna] *Nuovi Ann. delle Sci. Nat.* 2 (4): 256.  
*Merodon nigrithorax* Bezzi, 1900, *Soc. Ent. Ital. Bol.* 32: 89.

## DISTRIBUTION IN NORTH AMERICA

Inspection records compiled by plant quarantine units of the United States Department of Agriculture for 1931, 1932, and 1933 (35) state that *Merodon equestris* was reported in narcissus in California, Illinois, Michigan, New York, North Carolina, Ohio, Oregon, Pennsylvania, Rhode Island, Utah, Virginia, and Washington. Statements by Jack (21) and Johnson (22) definitely indicate the establishment of the insect in several parts of Massachusetts. Weiss (38) reports that larvae were found in New Jersey in 1913. Metcalf (27 p. 217) reports an infestation in Maine. Britton (7) states that it occurs in Connecticut.

Whether or not the insect is definitely established in all these States is not known. Where narcissus bulbs are not produced commercially the only trouble would be in garden plantings, which would not ordinarily be scrutinized very carefully, and hence an infestation might escape recognition for some time. In the Pacific Coast area the insect is known to be definitely established in California, Oregon, and Washington, and in the Province of British Columbia.

## DESCRIPTIONS OF THE STAGES

### THE EGG

The egg (fig. 1) is chalk-white, elongate-oval, subcylindrical, and slightly narrower at the micropylar (anterior) end. Its length is 1.5 mm. and its greatest diameter 0.6 mm. The chorion has a netlike appearance when viewed under magnification. The surface is covered with polygonal elevated areas, somewhat rugose and of very regular shape. The separating lines which form the apparent pattern are depressions between the elevated areas.

### THE LARVA

#### THE NUMBER OF LARVAL INSTARS

In the course of several years many thousands of larvae of *Merodon equestris* have been handled in experimental treatments and in developmental studies. Throughout all these observations molting has been observed at two distinct stages of development, namely, at about the lengths of 3.4-4.0 and 8.5-9.0 mm. Freshly molted larvae are easily discernible because of the very light coloration of the posterior spiracular process. These observations therefore indicate that the larval development proceeds through three instars. Hodson (19) states that there are four instars, describing them briefly, but present-

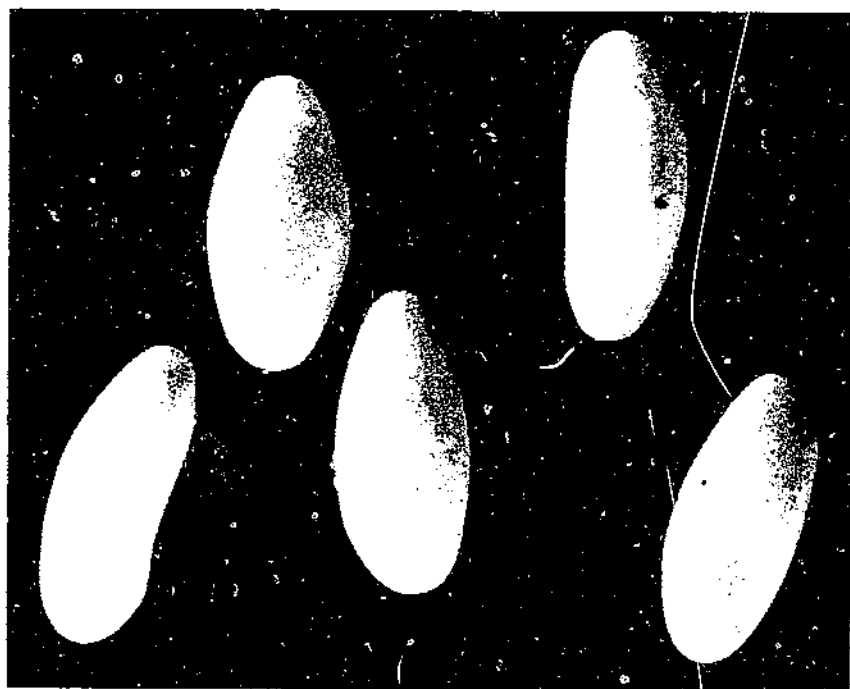


FIGURE 1. Eggs of the narcissus bully fly.  $\times 20$ .

ing no positive identifying characteristics except length measurements. For the supposed four instars he gives lengths of 1.5-2 mm., 2-5 mm., 5.5-8.5 mm., and 9.5-19 mm., respectively. Inasmuch as head-capsule width has been utilized for instar differentiation with numerous types of larvae, it was thought that measurements of the posterior spiracular process might furnish information concerning the number of larval instars.

Accordingly, measurements have been made of the body lengths and the widths of the spiracular processes of a series of larvae. The body lengths were measured with a vernier scale on a mechanical microscope stage, while the widths of the spiracular process were measured on a scale set in the microscope ocular. On the spiracular process of the older larvae a prominent ridge about two-thirds back from the end was the point of measurement. This was used because measurements from the edge of the end were rendered difficult in that it was rounded. On first instars such a ridge is absent, but the sides of the process are nearly parallel in this stage and a point just back of the rounded ends was used for measurement on these larvae. The same microscope set up was used throughout the series. Preserved larvae were measured, and any that seemed unduly contracted or distended were omitted from these studies. Larvae of all sizes were included in the series. For convenience, since they were whole numbers, the process widths are given in scale units.

As will be observed in table 1, the larvae fall into three distinct groups according to the widths of the spiracular processes, very distinctly indicating that three instars are involved, and corroborating the general observations on these larvae.



TABLE 1.—The widths of the posterior spiracular process of larvae of *Merodon equestris* of all sizes <sup>1</sup>

| Width of spiracular process |                | Larvae with length, in millimeters, of— |         |         |         |         |         |         |         |         |           |           |           |           |           |           |           |           |           | Total larvae |
|-----------------------------|----------------|---|---------|---------|---------|---------|---------|---------|---------|---------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|--------------|
|                             |                | 1.0-1.9                                 | 2.0-2.9 | 3.0-3.9 | 4.0-4.9 | 5.0-5.9 | 6.0-6.9 | 7.0-7.9 | 8.0-8.9 | 9.0-9.9 | 10.0-10.9 | 11.0-11.9 | 12.0-12.9 | 13.0-13.9 | 14.0-14.9 | 15.0-15.9 | 16.0-16.9 | 17.0-17.9 | 18.0-18.9 |              |
| Scale units                 | Mm.            | Number                                  | Number  | Number  | Number  | Number  | Number  | Number  | Number  | Number  | Number    | Number    | Number    | Number    | Number    | Number    | Number    | Number    | Number    | Number       |
| 8                           | 0.1144         |   | 31      | 11      | 1       |         |         |         |         |         |           |           |           |           |           |           |           |           |           | 46           |
| 9                           | .1287          | 1                                       | 20      | 18      | 1       |         |         |         |         |         |           |           |           |           |           |           |           |           |           | 49           |
| 10                          | .1430          |   | 4       | 1       |         |         |         |         |         |         |           |           |           |           |           |           |           |           |           | 5            |
| 11-19                       | .1573 to .2717 |   |         |         |         |         |         |         |         |         |           |           |           |           |           |           |           |           |           | 0            |
| 20                          | .2860          |   |         | 1       | 4       | 2       | 1       | 1       | 1       |         |           |           |           |           |           |           |           |           |           | 10           |
| 21                          | .3003          |   |         | 7       | 6       | 7       | 5       | 6       | 1       |         |           |           |           |           |           |           |           |           |           | 32           |
| 22                          | .3146          |   |         | 7       | 19      | 19      | 17      | 6       | 8       |         |           |           |           |           |           |           |           |           |           | 76           |
| 23                          | .3289          |   |         | 11      | 18      | 21      | 27      | 10      | 10      |         |           |           |           |           |           |           |           |           |           | 97           |
| 24                          | .3432          |   |         | 2       | 18      | 17      | 12      | 4       | 9       |         |           |           |           |           |           |           |           |           |           | 62           |
| 25                          | .3575          |   |         |         | 8       | 6       | 5       | 1       | 9       |         |           |           |           |           |           |           |           |           |           | 32           |
| 26                          | .3718          |   |         |         | 2       | 6       | 5       | 6       | 8       |         |           |           |           |           |           |           |           |           |           | 27           |
| 27                          | .3861          |   |         |         |         |         | 1       |         | 1       |         |           |           |           |           |           |           |           |           |           | 2            |
| 28-52                       | .4004 to .7436 |   |         |         |         |         |         |         |         |         |           |           |           |           |           |           |           |           |           | 0            |
| 53                          | .7579          |   |         |         |         |         |         |         | 6       | 3       |           |           |           |           |           |           | 1         | 1         |           | 11           |
| 54                          | .7722          |   |         |         |         |         |         |         | 3       | 2       | 1         |           |           | 1         | 1         |           |           | 1         |           | 10           |
| 55                          | .7865          |   |         |         |         |         |         |         | 3       |         |           | 1         | 1         |           | 1         | 1         | 2         |           |           | 8            |
| 56                          | .8008          |   |         |         |         |         |         |         | 4       | 1       |           |           | 1         |           | 3         | 1         |           | 1         |           | 12           |
| 57                          | .8151          |   |         |         |         |         |         |         | 1       | 4       | 1         |           | 3         | 1         | 2         |           | 1         |           |           | 13           |
| 58                          | .8294          |   |         |         |         |         |         |         | 3       | 3       | 1         | 1         | 5         |           |           | 2         | 2         |           | 1         | 16           |
| 59                          | .8437          |   |         |         |         |         |         |         | 3       |         | 1         |           |           |           | 1         | 2         | 2         |           |           | 9            |
| 60                          | .8580          |   |         |         |         |         |         |         | 2       | 2       | 1         |           | 2         |           | 2         | 5         | 2         | 1         |           | 17           |
| 61                          | .8723          |   |         |         |         |         |         |         | 1       | 1       | 1         | 2         | 1         | 1         | 2         | 2         | 2         | 1         | 1         | 12           |
| 62                          | .8866          |   |         |         |         |         |         |         |         | 2       |           | 2         |           | 1         | 2         | 2         | 2         |           | 1         | 12           |
| 63                          | .9009          |   |         |         |         |         |         |         | 1       |         | 1         |           |           |           |           | 1         | 1         | 1         |           | 5            |
| 64                          | .9152          |   |         |         |         |         |         |         |         |         |           |           |           |           | 1         |           |           |           |           | 1            |
| 65                          | .9295          |   |         |         |         |         |         |         |         |         |           |           |           |           |           |           | 1         |           |           | 1            |
| Total larvae                |                | 1                                       | 64      | 61      | 77      | 78      | 73      | 37      | 73      | 18      | 7         | 7         | 14        | 4         | 14        | 12        | 16        | 6         | 3         | 565          |

<sup>1</sup> Leader lines in the columns are in all cases equivalent to zeros.

In addition to these, several larvae had been collected at various times in the process of molting, and these were preserved individually with their associated exuvia. These larvae were measured as were those of the main series, and also the widths of the spiracular processes on the exuvia were measured (table 2). The widths of the newly formed spiracular processes of larvae that are from 3.5 to 4.0 mm. long are practically identical with the widths of the processes on the exuvia, which are shed when the larvae are from 8.5 to 9.0 mm. long, and are also the same as those of the middle group of the series presented in table 1.

TABLE 2.—Widths of the posterior spiracular processes of freshly molted larvae of *Merodon equestris* and of the associated exuvia

| First larval molt                |                              |                    | Second larval molt               |                              |                    |
|----------------------------------|------------------------------|--------------------|----------------------------------|------------------------------|--------------------|
| Length of larva<br>(millimeters) | Width of spiracular process— |                    | Length of larva<br>(millimeters) | Width of spiracular process— |                    |
|                                  | On larva                     | On exuvium         |                                  | On larva                     | On exuvium         |
|                                  | <i>Scale units</i>           | <i>Scale units</i> |                                  | <i>Scale units</i>           | <i>Scale units</i> |
| 3.0                              | 21                           | 10                 | 8.3 <sup>2</sup>                 | 54                           | 24                 |
| 3.3                              | 22                           | 8                  | 8.4                              | 53                           | 23                 |
| 3.3                              | 22                           | 8                  | 8.5 <sup>2</sup>                 | 53                           | 23                 |
| 3.4                              | 25                           | 10                 | 8.5 <sup>2</sup>                 | 53                           | 24                 |
| 3.7                              | 23                           | 9                  | 8.5                              | 56                           | 22                 |
| 3.8                              | 22                           | 9                  | 8.5 <sup>2</sup>                 | 58                           | 24                 |
| 3.8                              | 22                           | 9                  | 8.5 <sup>2</sup>                 | 58                           | 25                 |
| 3.9                              | 24                           | 9                  | 8.5                              | 63                           | 26                 |
| 4.4                              | 26                           | 9                  | 8.6                              | 55                           | 22                 |
|                                  |                              |                    | 8.6                              | 59                           | 23                 |
|                                  |                              |                    | 8.7                              | 53                           | 25                 |
| 3.1                              | 21                           | (1)                | 8.7                              | 55                           | 22                 |
| 3.1                              | 21                           | (1)                | 8.7                              | 57                           | 23                 |
| 3.2                              | 22                           | (1)                | 8.8 <sup>2</sup>                 | 53                           | 21                 |
| 3.3                              | 21                           | (1)                | 8.8 <sup>2</sup>                 | 54                           | 22                 |
| 3.5                              | 22                           | (1)                | 8.8                              | 56                           | 24                 |
| 3.6                              | 21                           | (1)                | 8.9                              | 60                           | 25                 |
| 3.6                              | 23                           | (1)                | 9.0 <sup>2</sup>                 | 53                           | 24                 |
| 3.6                              | 23                           | (1)                | 9.0 <sup>2</sup>                 | 56                           | 23                 |
| 3.7                              | 23                           | (1)                | 9.0                              | 57                           | 22                 |
| 3.9                              | 21                           | (1)                | 9.1                              | 57                           | 21                 |
| 4.0                              | 22                           | (1)                | 9.1                              | 58                           | 24                 |
|                                  |                              |                    | 9.1                              | 60                           | 22                 |
|                                  |                              |                    | 9.2                              | 53                           | 25                 |
|                                  |                              |                    | 9.2 <sup>2</sup>                 | 62                           | 24                 |
|                                  |                              |                    | 9.4                              | 58                           | 23                 |
|                                  |                              |                    | 9.4                              | 62                           | 22                 |

<sup>1</sup> Freshly molted larva without associated exuvium.

<sup>2</sup> Larva distorted, length estimated.

This study leads rather positively to the conclusion that larvae of *Merodon equestris* pass through three instars in their development.

The smaller larvae are very light straw-colored, sometimes appearing almost white, but the larger larvae are slightly darker. The larvae generally appear to be of various shades of brown because of staining from the moist decomposed tissue in which they live. The posterior spiracular process is very heavily sclerotized and therefore remains practically unchanged in size throughout each instar. At the beginning of each instar, including newly hatched larvae, this process is light in shade. It darkens, however, in a few days, and then appears almost black. The mouth parts are arranged as a pair of ventrally directed, sharply pointed hooks uniting basally in a hoodlike formation covering the mouth opening. These mouth hooks are heavily sclerotized, very dark, and remain unchanged in size throughout the development of each instar. The transverse wrinkles of the body obscure the

segmentation, but each segment bears a transverse row of setae by which it may be recognized. The larvae skin is covered with very minute cuticular spines. The larva is somewhat subcylindrical, with the ventral surface flattened. The head is somewhat pointed and the posterior end truncated. On each side of the posterior spiracular process is a spine-covered tubercle from which protrudes a prominent seta. The newly hatched larva is 1.5 mm. long and the mature larva may attain a length of 18 mm. Length is a rather indefinite character because of the ability of the larva to contract and extend its body. This renders difficult the selection of a definite degree of extension for comparative purposes. An extended mature larva might have a length of 20 or 21 mm.

The three larval instars may be distinguished readily by the width of the posterior spiracular process. In the earlier phases of each instar the body is considerably wrinkled, but the skin becomes somewhat distended by the time the larva is ready to molt. In addition to the posterior spiracular process there are other characters which distinguish the three instars.

#### FIRST INSTAR

The first instars range from 1.5 to 3.8 mm. in length (fig. 2). The setae are relatively long in proportion to the body diameter, much more so than in the later instars. The posterior respiratory process is somewhat flattened, and the distal end is rather smoothly rounded,

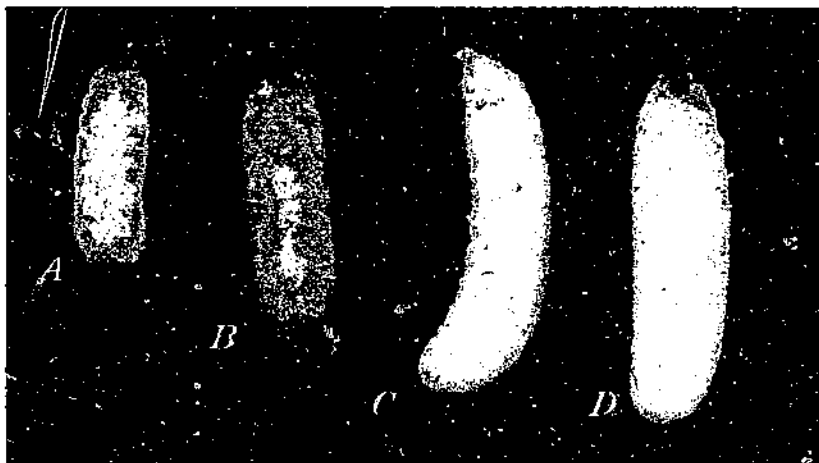


FIGURE 2.—First instars of the narcissus bulb fly, 2, 3, 3.5 and 3.5 mm. long, A to D, respectively,  $\times 10$ .

with a small conical projection in the center (fig. 3). This central projection is distinctive of the first instar. The average width of the process is 0.13 mm., ranging from 0.114 to 0.143 mm. On each side and slightly below the posterior spiracular process is a fleshy clublike protuberance about as long as the spiracular process. Each protuberance is covered with small short spines, somewhat larger than those on the body integument, and bears at its end a long bristlelike seta.

three times as long as the width of the spiracular process. Another pair of setae of about the same length is located at the lateral ends of the lobelike fold on the terminal body segment. Although many of the setae on the rest of the body appear rather long, the longest are only about half the length of the four bristlelike setae at the posterior end. The relatively long setae give the young larva a hairy appearance.

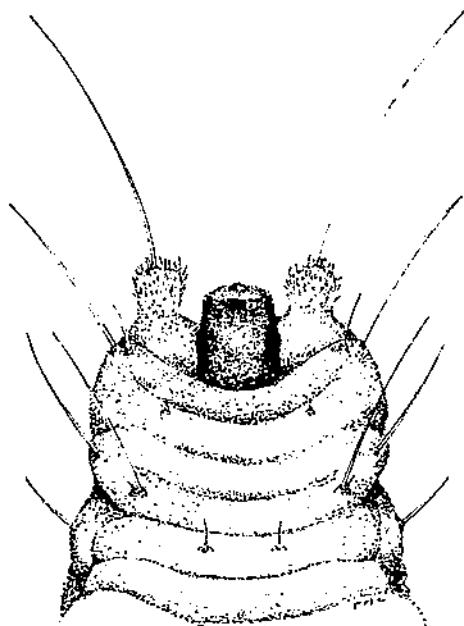


FIGURE 3.—The posterior spiracular process of a first instar of the narcissus bulb fly, with the adjacent tubercles with long setae,  $\times 8$ .

Ventrally, six pairs of protuberances like prolegs are easily seen in the first instar. Each of these bears two bristles, the ends of which are curved slightly, pointing backward. These are characteristic of the first instar.

#### SECOND INSTAR

The lengths of second instars (fig. 4) range from 3.5 to 8.7 mm. The segmental setae are relatively short and spinelike. Those of the posterior segments are a little longer than those of the anterior segments. There are no protuberances suggestive of prolegs. The posterior spiracular process is almost round, and is distinctly truncated. Its average width is 0.33 mm., with a range from 0.286 to 0.386 mm. The tubercles on each side of the posterior spiracular process are short, and their setae are spinelike and rather short. The total length of tubercle and seta is only slightly more than that of the spiracular process.

#### THIRD INSTAR

The lengths of third instars (fig. 5) range from 8.1 to 18.4 mm. The segmental setae are relatively very short and distinctly spinelike.

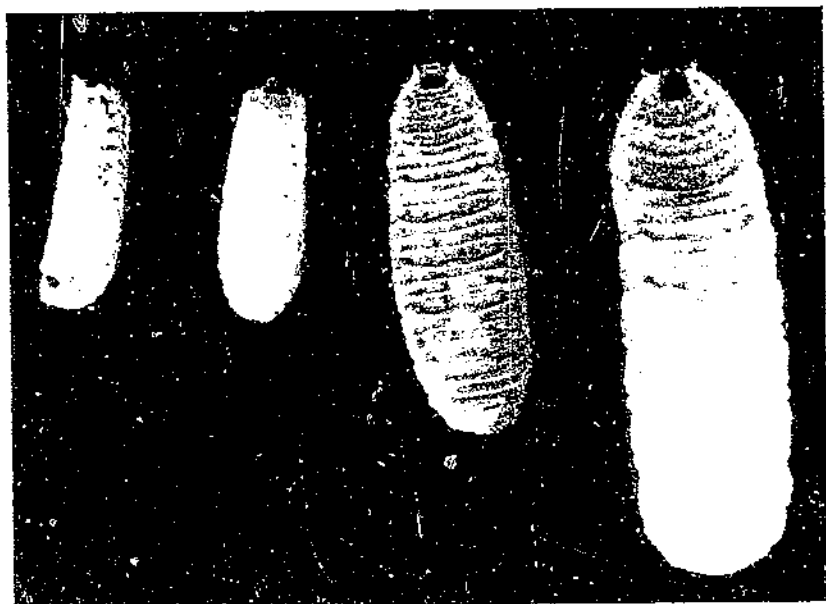


FIGURE 4. Second instars of the narcissus bulb fly, 4, 4, 6, and 8 mm. long, A to D, respectively,  $\times 8$ .

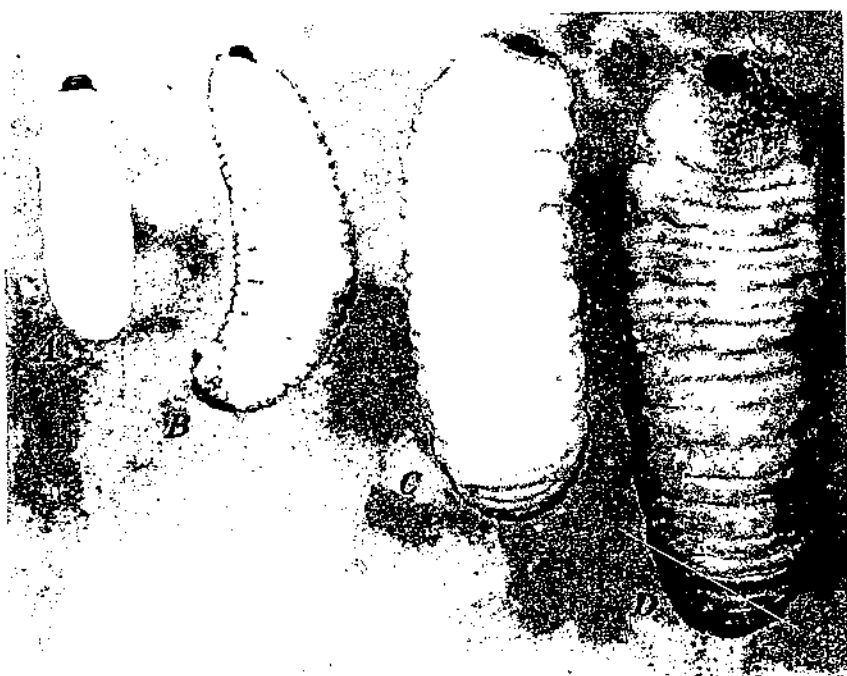


FIGURE 5. Third instars of the narcissus bulb fly, 9, 12, 15, and 18 mm. long, A to D, respectively,  $\times 4$ .

Those of the posterior segments are a little stouter and longer than those of the main part of the body. There are no protuberances resembling prolegs. The posterior spiracular process is distinctly truncated. Its average width is 0.84 mm., with a range from 0.758 to 0.93 mm. The posterior tubercles are short, with short, spinelike setae. The total length of the tubercle and seta is about half that of the spiracular process. The cuticular spines are larger than in the earlier instars.

#### THE PUPA

Since the skin of the mature larva becomes the case or shell within which pupation occurs, the external larval characters are evident on the puparium (fig. 6). Both ends become shortened and more rounded



A



B

FIGURE 6.—A, Puparium before emergence of the narcissus bulb fly,  $\times 7$ ; B, puparium after emergence of the narcissus bulb fly,  $\times 7$ .

than in the larval stage, and the ventral side is flattened. The posterior spiracular process of the larva is quite distinct in the puparium, and the wrinkles and folds of the larva remain in evidence. The skin becomes distinctly hard and unyielding to pressure, and becomes dark brownish gray. Several days after the puparium forms, a pair of respiratory cornua protrude from the upper part of the anterior end. The puparium is from 12 to 15 mm. long and from 7 to 8 mm. wide.

#### THE ADULT

The adult *Merodon equestris* is a robust two-winged fly with dense pubescence (fig. 7). A conspicuous toothlike projection on the under side of the femora of the hind legs is characteristic of the genus, and

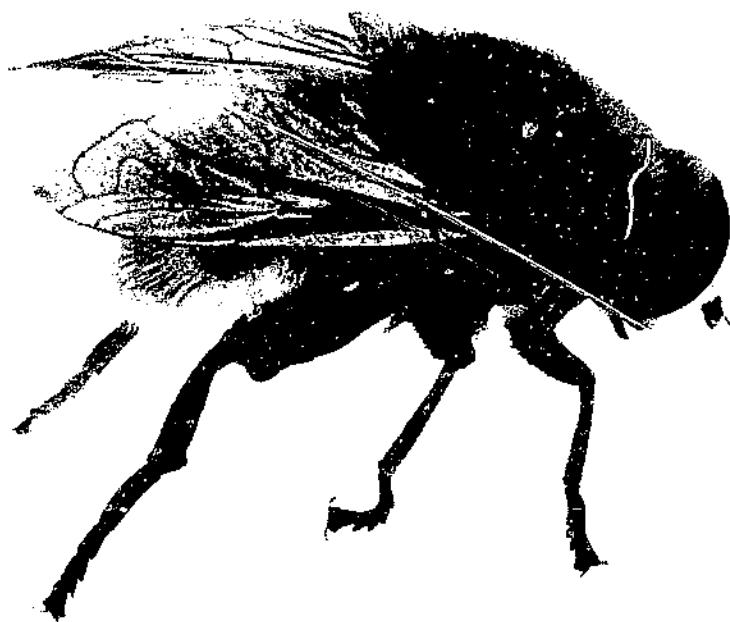


FIGURE 7.—Adult narcissus bulb fly (*Merodon equestris*),  $\times 7$ .

a stout spur at the distal end of the tibia of the hind leg in the male is distinctive for the species. The eyes are large, those of the males joined in the front, those of the females separated. The thorax is approximately as broad as it is long, and the dorsal part is arched to a slight extent. It, of course, bears the legs and wings. The wings are transparent, with prominent brown veins, and very little color except a brownish shading near the base. Viewed dorsally, the fore part of the abdomen is about as broad as the thorax, and the latter half tapers to the posterior end, which is rounded in the male and bluntly pointed in the female. The length ranges from 12 to 16 mm.—approximately  $\frac{1}{2}$  inch.

Coloration of the flies is striking because of the extensive variation. The pubescent body, with its varied colors, produces a strong resem-

blance to a bumblebee. The basic body color is black, and this is the apparent color of those portions of the body that are not covered with dense pubescence, namely, the eyes, the antennae, the ventral portion of the thorax and abdomen, and the legs. Near each edge of the dorsal part of the second abdominal segment is an irregularly round area of the exoskeleton which is brownish orange. The pubescence on the dorsal area of the thorax and abdomen is long and thick, and varied in color, so that it masks the basic black of the exoskeleton. This is the principal coloration visible in nature to other forms of life, and it might be considered a mimicry of bees as a protective measure against birds or other potential enemies.

Analysis of the color patterns reveals three transverse zones, or bands, on the thorax and three on the abdomen. The division between the anterior and middle bands of the thorax follows the suture separating the prescutum from the scutum, and the suture between the scutum and postscutellum is the line of demarcation between the middle band and the posterior band. On the abdomen the first band covers the first two apparent segments, the middle band corresponds with the third segment, and the third zone extends to the tip. The colors of the pubescence are black, brownish orange, and a pale yellowish gray. These colors may be found in many combinations on the six primary zones, and this allows an extensive variation. Different writers have used the terms fulvous, tawny, and ferrugineous to describe the brownish-orange shade. There are occasionally slight variations in the shade, a bit lighter or darker, but characteristically it may be considered as brownish orange with a moderate brilliancy.

The colors of the pubescence are most accurately observed by viewing the fly laterally to eliminate the influence of the underlying black body. The color variation may extend from an almost all black to a complete brownish orange. No black specimen has been observed with the abdominal tip black. When the remainder of the color is black the tip area is gray. Every observed specimen having the thorax all black was a female, and a black front thoracic zone has been noted only in those forms in which all three thoracic zones were black. Flies with the orange shade of pubescence in all zones have not been numerous, but all those observed have been males, and it may be that this combination is a sex-linked color variation, as is the all-black thorax. Very early students of the group established some of the color-variation forms as separate species, but later workers who reared adults have considered that only one species had been involved. Several forms have been considered as varieties, but these can hardly be termed varieties in the strictest interpretation of the term, since the evidence indicates that the several forms mate irrespective of color, and that the progeny of any mating, whether of similar or different colorings, may be a heterogenous mixture of color variations. Assuming that the term variety applies only to forms which reproduce themselves in the same form, it is not proper to apply the term to the adults of *Merodon equestris* on the basis of color.

#### POSSIBLE CONFUSION WITH OTHER FORMS

In the United States and Canada no other species of the genus *Merodon* has been authoritatively recorded, although a considerable number of species are known to occur in Europe. The form most



likely to be confused with the narcissus bulb fly is the larval stage of a lesser bulb fly (*Eumerus* spp.). The mature larvae of the lesser bulb flies are similar in size to large second instars of *M. equestris*, hence any confusion would concern the smaller sizes of the latter. The larva of *M. equestris* may be distinguished from *Eumerus* spp. by the dark-colored, very short and stubby posterior respiratory process. In the lesser bulb fly larva this structure is distinctly more elongate and slender, and is a brick red. Also, a larva of the narcissus bulb fly is found by itself in a bulb, and in its younger stages is located in a distinct tunnel or burrow, whereas larvae of the lesser bulb flies work in groups, and the bulb tissue in which they feed is reduced to a homogenous, usually wet mass.

### LIFE HISTORY AND HABITS

Life-history studies of the narcissus bulb fly have been conducted in the Pacific Northwest for several seasons. This work represents conditions as they occur in the lower Puget Sound region—in a general way the region between Seattle and Olympia, Wash. Although accurate studies have not been made for all the Pacific Northwest, occasional observations indicate that in the narcissus-producing areas in northern Washington (Skagit and Whatcom Counties) growth conditions in the spring are about 1 to 2 weeks later than in the lower Puget Sound region, while in southwestern Washington and in Oregon the spring is more or less in advance of the lower Puget Sound area. The coastal section of southwestern Oregon is different from the Willamette Valley and Puget Sound regions, as the climate there approaches the conditions of central coastal California. The information obtained concerning the seasonal history of the narcissus bulb fly in the lower Puget Sound region would not therefore apply in detail to southwestern Oregon. It does approach the conditions of the Willamette Valley, lower Columbia Valley, and northern coastal areas of Oregon, with due regard to advancement of season, and of the northern counties of western Washington allowing for the slight retardation of season there.

#### THE EGG

The eggs of the narcissus bulb fly are deposited singly, often on the narcissus foliage approximately at or slightly below the ground level (fig. 8). Frequently eggs are placed in the soil close to the narcissus plant. Sometimes the soil around the plant may have a wide crack or be open otherwise, in which event the female fly backs downward as far as possible before depositing the egg. Hence eggs may be found one-quarter or one-half of an inch below the soil surface.

Information on the incubation period has been obtained under ordinary room temperatures. In these studies eggs were removed from potted narcissus plants over which adults were caged. The eggs were kept in stacked Syracuse watch glasses and water drops were placed on the bottom of each glass to help maintain humidity. A series of observations made at Santa Cruz, Calif., in 1926 is compared in table 3 with data obtained at Puyallup, Wash., in 1927 and at Sumner, Wash., in 1932 and 1933.



FIGURE 8. Egg placed by narcissus bulb fly on leaf at soil surface.

TABLE 3. Frequency distributions for incubation periods of eggs of *Merodon equestris* as observed in different localities

| Duration<br>days | Eggs observed at                  |                                 |                                |                                | Duration<br>days | Eggs observed at                  |                                 |                                |                                |
|------------------|-----------------------------------|---------------------------------|--------------------------------|--------------------------------|------------------|-----------------------------------|---------------------------------|--------------------------------|--------------------------------|
|                  | Santa<br>Cruz,<br>Calif.,<br>1926 | Puyal-<br>up,<br>Wash.,<br>1927 | Sum-<br>ner,<br>Wash.,<br>1932 | Sum-<br>ber,<br>Wash.,<br>1933 |                  | Santa<br>Cruz,<br>Calif.,<br>1926 | Puyal-<br>up,<br>Wash.,<br>1927 | Sum-<br>ner,<br>Wash.,<br>1932 | Sum-<br>ner,<br>Wash.,<br>1933 |
|                  | Num-<br>ber                       | Num-<br>ber                     | Num-<br>ber                    | Num-<br>ber                    |                  | Num-<br>ber                       | Num-<br>ber                     | Num-<br>ber                    | Num-<br>ber                    |
| 1                | 5                                 | 1                               |                                |                                | 12               |                                   |                                 |                                |                                |
| 2                | 10                                | 2                               |                                |                                | 13               |                                   | 1                               | 83                             | 1                              |
| 3                | 21                                | 1                               | 18                             |                                | 14               |                                   |                                 | 12                             | 2                              |
| 4                |                                   |                                 |                                |                                | 15               |                                   |                                 | 19                             | 1                              |
| 5                | 332                               | 11                              | 34                             | 1                              | 16               |                                   |                                 | 10                             |                                |
| 6                | 121                               | 85                              | 21                             | 0                              |                  |                                   |                                 | 17                             |                                |
| 7                | 76                                | 99                              | 11                             | 15                             |                  |                                   |                                 |                                |                                |
| 8                | 2                                 | 39                              | 136                            | 151                            | Mean             | 7.30                              | 8.71                            | 10.7                           | 10.54                          |
| 9                |                                   | 11                              | 50                             | 206                            |                  |                                   |                                 |                                |                                |
| 10               |                                   |                                 |                                |                                |                  |                                   |                                 |                                |                                |
| 11               |                                   |                                 |                                |                                |                  |                                   |                                 |                                |                                |

The duration of the egg stage in the Netherlands is stated to be 1 to 5 days (3). In England Hodson (19) found the egg period to range from 10 to 15 days, basing this on over 5 years' records. In the United States various periods are reported. Howard (20, p. 18), apparently referring to observations made at Washington, D. C., records that the eggs hatch in 3 or 4 days. Weigel (37), definitely reporting on observations at Washington, D. C., states that the

incubation period under greenhouse conditions is from 2 to 9 days, the average being about 6 days. Broadbent (9), as a result of 2 years of observations at Washington, D. C., states that a range of 10 to 14 days was noted at temperatures from 17.1° to 20.5° C. (62.8°-68.9° F.), with an average of 12.15 days. In Oregon Wilcox and Mote (39) found that the majority of the eggs hatched in from 8 to 10 days, with a range of 6 to 15 days. It is of course practically impossible to duplicate the field environmental conditions that eggs experience. Soil-surface temperatures may rise high in bright sunlight, and of course the location of the eggs gives them varied amounts of shade, causing varied temperature conditions. Some of the shortest periods observed by the writers probably represent unintentional errors, and the same is likely with some of the shortest periods reported in literature. In general, it appears that a 10- to 12-day period is required for embryological development in the eggs, and this is the approximate range indicated by the studies of Hodson and Broadbent, which were apparently sufficiently extensive to be considered accurate.

### THE LARVA

The newly hatched larva of the narcissus bulb fly migrates immediately from the egg to the narcissus bulb, which it enters and in which its entire developmental period is passed. When ready to pupate, the mature larva leaves the bulb and moves upward to the soil surface, where it changes to the pupa. To maintain larvae under observation in conditions even approaching normal would be extremely difficult. Even if kept in bulbs and examined from time to time, a serious disturbance of the environment is involved as well as disturbance of the larvae, for the bulbs must be cut open to reach the grubs. To avoid this disturbance factor, larval development has been studied by collecting numbers of infested bulbs at intervals and classifying the larvae from each sample on the basis of size as expressed by length. A study of the changes in the sizes from interval to interval has furnished a distinct picture of the development of the larvae. By this method actual development in natural conditions is determined, and, particularly, the method eliminates the influence of disturbance of the insect and environment which would be involved if observations were made at intervals on the same individuals.

Population samples were collected at intervals each season from 1934 to 1938, inclusive. Because the numbers of larvae in the various samples varied, the proportion of each sample for each length has been calculated, to make all the samples comparable. These data are presented in table 4. In all these studies the 2- and 3-mm. larvae represent the first instar, 4- to 8-mm. larvae represent the second instar, and 9- to 18-mm. larvae represent the third instar. Typical population samples are illustrated in figure 9.

Infestation of the bulbs first becomes evident late in May or early in June, and the number of new larvae increases through June. The individual rates of development vary considerably, and the range of sizes becomes very wide as the season progresses. Second instars were first observed on June 22, 1934, June 20, 1935, June 25, 1936, July 8, 1937, and June 23, 1938. The first third instars were noted on July 25, 1935, July 30, 1936, August 12, 1937, and August 5, 1938.

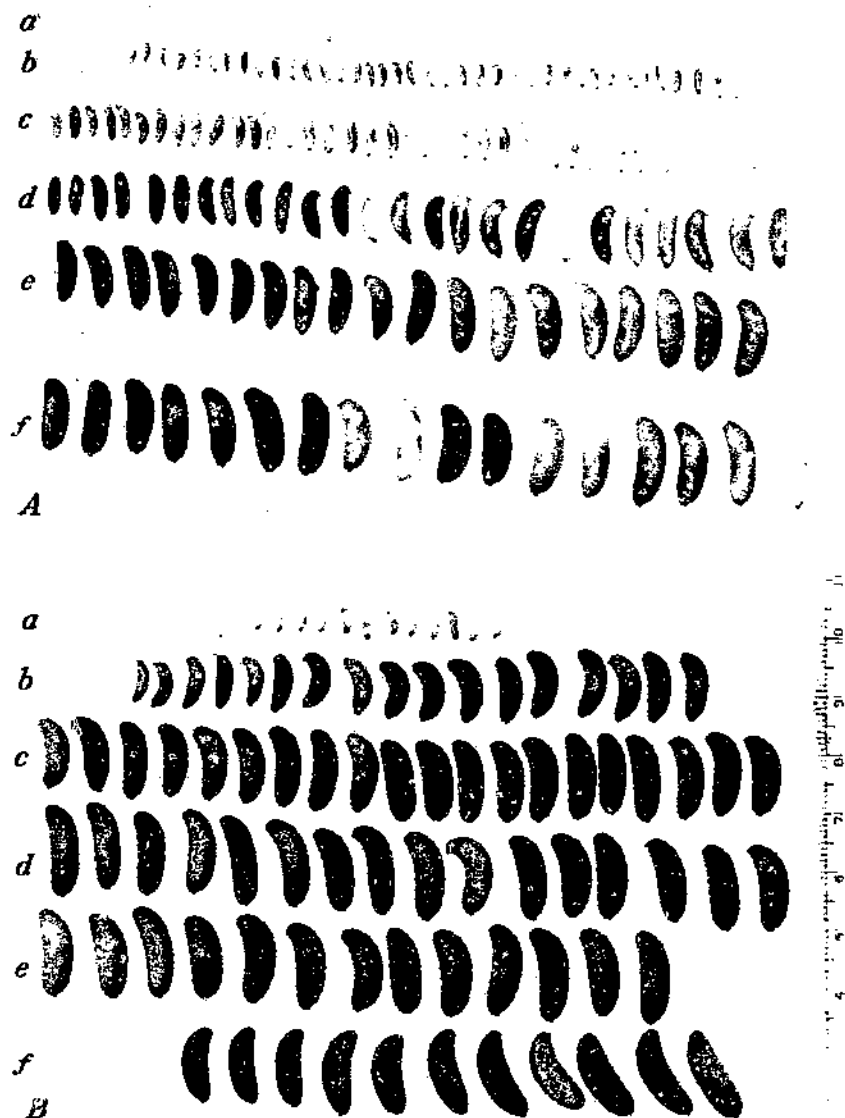


FIGURE 9.—A, *Narcissus* bulb fly larvae obtained in population sample collected Sept. 4, 1936: *a*, First instars; *b* and *c*, second instars; *d*, *e*, and *f*, third instars. B, larvae obtained in population sample collected February 12, 1937: *a*, Second instars; *b* to *f*, third instars.

TABLE 4.—Proportions of sizes, based on larval length of *Merodon equestris* larvae in natural population samples acquired at intervals

FROM EGGS DEPOSITED IN 1934

| Date of sampling | Total larvae in sample | Proportion of total sample of larvae for each length in millimeters |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
|------------------|------------------------|---|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|                  |                        | 2   | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 11   | 12   | 13   | 14   | 15   | 16   | 17   | 18   |
| 1934             | No.                    | Pct.  | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |
| May 31           | 25                     | 100   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| June 22          | 95                     | 56  | 37   | 7    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| July 27          | 103                    | 7   | 33   | 30   | 12   | 11   | 6    | 1    |      |      |      |      |      |      |      |      |      |      |
| Aug. 29          | 92                     |   | 4    | 9    | 12   | 12   | 6    | 7    | 10   | 14   | 11   | 10   | 5    |      |      |      |      |      |
| Sept. 28         | 80                     |   |      | 1    | 4    | 4    | 1    | 5    | 8    | 5    | 6    | 13   | 13   | 16   | 11   | 13   |      |      |
| Oct. 30          | 85                     |   |      | 5    | 5    | 2    | 1    |      | 1    | 5    | 6    | 8    | 8    | 13   | 17   | 13   |      |      |
| Nov. 30          | 91                     |   |      | 2    | 6    | 2    |      |      |      | 1    | 4    | 6    | 4    | 13   | 13   | 23   | 20   | 4    |
| Dec. 31          | 145                    |   |      | 5    | 8    | 1    |      |      | 1    | 1    | 1    | 2    | 5    | 12   | 18   | 19   | 20   | 7    |
| 1935             |                        |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Feb. 4           | 83                     |   |      | 2    | 5    | 1    |      |      | 1    |      | 1    | 3    | 3    | 16   | 19   | 25   | 17   | 7    |
| Mar. 21          | 54                     |   |      | 2    | 2    | 4    |      |      | 2    | 2    | 5    | 2    | 2    | 4    | 11   | 20   | 20   | 9    |
| Apr. 25          | 56                     |   |      | 4    | 12   | 23   | 4    |      | 2    | 2    | 2    | 2    | 2    | 5    | 0    | 9    | 10   | 4    |
| May 2            | 56                     |   |      | 4    | 14   | 17   | 14   |      | 2    | 2    | 4    | 4    | 7    | 4    | 5    | 9    | 5    | 2    |
| May 9            | 66                     |   |      | 1    | 12   | 17   | 11   |      | 4    | 2    | 4    | 6    | 5    | 3    | 5    | 15   | 9    |      |
| May 16           | 93                     |   |      | 1    | 24   | 20   | 14   |      | 4    | 2    | 2    | 8    | 8    | 5    | 3    | 3    | 4    | 1    |
| May 23           | 56                     |   |      | 2    | 23   | 29   | 16   |      | 7    | 7    | 5    | 5    | 5    |      |      |      |      |      |
| May 31           | 30                     |   |      | 5    | 18   | 18   | 21   |      | 8    | 3    | 5    | 8    | 10   | 2    |      | 2    |      |      |
| June 6           | 31                     |   |      |      | 6    | 6    | 23   |      | 23   | 10   | 10   | 6    | 13   | 3    |      |      |      |      |
| June 13          | 42                     |   |      |      | 10   | 17   | 16   |      | 13   | 3    | 10   | 17   | 17   | 3    |      |      |      |      |
| June 20          | 19                     |   |      |      | 5    |      | 14   |      | 22   | 14   | 5    | 9    | 17   | 5    |      |      |      |      |
| June 27          | 30                     |   |      |      | 5    | 5    | 11   |      | 25   | 5    | 11   | 5    | 11   | 11   | 5    |      |      |      |
| July 5           | 20                     |   |      |      | 5    | 10   | 25   |      | 10   | 10   | 6    | 10   | 15   | 5    | 5    |      |      |      |
| July 11          | 28                     |   |      |      |      | 5    | 10   |      | 17   | 11   | 14   | 25   | 17   | 4    |      |      |      |      |
| July 18          | 23                     |   |      |      |      | 4    | 4    |      | 13   | 13   | 13   | 13   | 13   | 13   |      |      |      |      |
| July 25          | 19                     |   |      |      |      |      |      |      | 5    | 5    | 11   | 26   | 27   | 16   | 5    |      |      |      |
| Aug. 10          | 17                     |   |      |      |      |      |      |      |      | 6    | 12   | 17   | 18   | 20   | 12   | 6    |      |      |
| Aug. 16          | 13                     |   |      |      |      |      |      |      |      |      |      | 23   | 31   | 30   | 30   | 8    |      |      |
| Aug. 24          | 13                     |   |      |      |      |      |      |      |      |      |      | 15   | 23   | 31   | 15   | 8    | 8    |      |
| Aug. 29          | 11                     |   |      |      |      |      |      |      |      |      |      |      | 0    | 18   | 18   | 28   | 27   |      |
| Sept. 5          | 16                     |   |      |      |      |      |      |      |      |      |      | 6    | 25   | 19   | 25   | 10   | 6    |      |
| Sept. 12         | 7                      |   |      |      |      |      |      |      |      |      |      |      | 14   | 14   | 15   | 28   | 15   | 14   |
| Sept. 19         | 21                     |   |      |      |      |      |      |      |      |      |      | 5    | 5    | 10   | 19   | 28   | 23   | 10   |
| Sept. 26         | 12                     |   |      |      |      |      |      |      |      |      |      |      |      | 8    | 17   | 25   | 33   | 17   |
| Oct. 11          | 20                     |   |      |      |      |      |      |      |      |      |      |      |      | 5    | 30   | 30   | 25   | 10   |
| Oct. 25          | 14                     |   |      |      |      |      |      |      |      |      |      |      |      | 14   | 14   | 29   | 43   |      |
| Nov. 8           | 13                     |   |      |      |      |      |      |      |      |      |      |      |      | 8    | 15   | 15   | 47   | 15   |
| Nov. 21          | 8                      |   |      |      |      |      |      |      |      |      |      |      |      |      | 25   | 38   | 25   | 12   |
| Dec. 6           | 9                      |   |      |      |      |      |      |      |      |      |      |      |      | 11   | 22   | 45   | 22   |      |
| Dec. 20          | 15                     |   |      |      |      |      |      |      |      |      |      |      |      |      | 20   | 33   | 33   | 14   |
| 1936             |                        |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Jan. 27          | 10                     |   |      |      |      |      |      |      |      |      |      |      |      |      | 10   | 60   | 30   |      |
| Feb. 28          | 7                      |   |      |      |      |      |      |      |      |      |      |      |      |      | 43   | 43   | 14   |      |

FROM EGGS DEPOSITED IN 1935

|          |     |     |    |    |    |    |    |    |   |   |    |   |    |    |    |    |    |  |
|----------|-----|-----|----|----|----|----|----|----|---|---|----|---|----|----|----|----|----|--|
| 1935     |     |     |    |    |    |    |    |    |   |   |    |   |    |    |    |    |    |  |
| May 31   | 3   | 100 |    |    |    |    |    |    |   |   |    |   |    |    |    |    |    |  |
| June 6   | 17  | 100 |    |    |    |    |    |    |   |   |    |   |    |    |    |    |    |  |
| June 13  | 75  | 79  | 21 |    |    |    |    |    |   |   |    |   |    |    |    |    |    |  |
| June 20  | 125 | 41  | 57 | 2  |    |    |    |    |   |   |    |   |    |    |    |    |    |  |
| June 27  | 206 | 19  | 77 | 3  | 1  |    |    |    |   |   |    |   |    |    |    |    |    |  |
| July 5   | 272 | 15  | 72 | 11 | 2  |    |    |    |   |   |    |   |    |    |    |    |    |  |
| July 11  | 284 | 13  | 65 | 19 | 2  | 1  |    |    |   |   |    |   |    |    |    |    |    |  |
| July 18  | 203 | 4   | 53 | 31 | 10 | 2  |    |    |   |   |    |   |    |    |    |    |    |  |
| July 25  | 230 | 2   | 37 | 35 | 10 | 5  | 4  | 4  | 2 | 1 |    |   |    |    |    |    |    |  |
| Aug. 3   | 238 | 3   | 19 | 28 | 12 | 10 | 2  | 10 | 9 | 4 | 2  |   |    |    |    |    |    |  |
| Aug. 10  | 184 | 11  | 20 | 17 | 13 | 10 | 14 | 4  | 3 | 3 | 2  |   |    |    |    |    |    |  |
| Aug. 16  | 194 | 3   | 15 | 18 | 10 | 13 | 12 | 7  | 5 | 4 | 1  | 1 | 1  | 1  | 1  | 1  | 1  |  |
| Aug. 24  | 188 | 4   | 16 | 11 | 13 | 11 | 9  | 8  | 6 | 6 | 6  | 4 | 3  | 2  | 1  | 1  | 1  |  |
| Aug. 29  | 187 | 3   | 12 | 12 | 6  | 5  | 8  | 7  | 6 | 6 | 11 | 8 | 7  | 4  | 4  | 1  | 1  |  |
| Sept. 5  | 198 | 1   | 8  | 9  | 8  | 6  | 4  | 6  | 6 | 8 | 11 | 9 | 9  | 8  | 5  | 3  | 1  |  |
| Sept. 12 | 137 |     | 7  | 5  | 9  | 6  | 4  | 8  | 8 | 6 | 6  | 7 | 8  | 9  | 8  | 6  | 2  |  |
| Sept. 19 | 170 |     | 5  | 7  | 4  | 3  | 2  | 8  | 7 | 7 | 11 | 8 | 9  | 10 | 11 | 6  | 2  |  |
| Sept. 26 | 119 |     | 2  | 7  | 7  | 3  | 3  | 2  | 3 | 5 | 8  | 8 | 9  | 10 | 17 | 13 | 3  |  |
| Oct. 11  | 137 |     | 4  | 4  | 1  | 2  | 1  | 5  | 3 | 3 | 4  | 3 | 6  | 9  | 28 | 21 | 6  |  |
| Oct. 25  | 151 |     | 2  | 6  | 3  | 2  |    | 1  | 2 | 3 | 4  | 5 | 9  | 10 | 14 | 27 | 12 |  |
| Nov. 8   | 133 |     | 3  | 5  | 2  |    |    | 3  | 4 | 4 | 4  | 5 | 9  | 13 | 19 | 23 | 6  |  |
| Nov. 21  | 87  |     | 2  | 7  | 4  |    |    | 1  | 3 | 2 | 4  | 6 | 7  | 9  | 32 | 18 | 5  |  |
| Dec. 6   | 151 |     | 3  | 5  | 4  |    |    | 2  | 3 | 2 | 4  | 5 | 11 | 15 | 26 | 15 | 5  |  |
| Dec. 20  | 154 |     | 3  | 4  | 2  |    |    | 2  | 1 | 1 | 2  | 3 | 8  | 12 | 44 | 16 | 2  |  |

TABLE 4.—Proportions of sizes, based on larval length, of *Merodon equestris* larvae in natural population samples acquired at intervals—Continued

FROM EGGS DEPOSITED IN 1935—Continued

| Date of sampling | Total larvae in sample | Proportion of total sample of larvae for each length in millimeters |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
|------------------|------------------------|---|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
|                  |                        | 2   | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 11   | 12   | 13   | 14   | 15   | 16   | 17   | 18   |  |
| 1936             |                        |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Jan. 27          | No. 120                | Pct.  | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |  |
| Feb. 28          | 116                    |   |      | 3    | 2    | 1    |      |      | 4    | 2    | 2    | 2    | 3    | 4    | 11   | 16   | 33   | 16   |  |
| May 26           | 23                     |   |      | 2    | 8    | 4    |      |      | 1    | 2    | 2    | 3    | 3    |      | 6    | 7    | 37   | 4    |  |
| June 4           | 14                     |   |      |      |      | 29   | 14   |      | 9    | 4    | 18   | 13   | 17   | 13   | 7    | 4    |      |      |  |
| June 11          | 23                     |   |      |      | 7    | 22   | 4    |      | 7    |      | 7    | 7    | 22   | 7    | 9    |      |      |      |  |
| June 18          | 18                     |   |      |      | 4    | 11   | 11   |      | 4    | 4    | 13   | 18   | 18   | 9    |      | 4    |      |      |  |
| June 23          | 17                     |   |      |      | 6    | 12   | 12   |      | 6    | 6    | 11   | 16   | 16   | 11   | 6    |      |      |      |  |
| July 2           | 21                     |   |      |      |      | 14   | 14   | 9    | 5    | 5    | 9    | 7    | 15   | 21   | 15   | 6    |      |      |  |
| July 9           | 14                     |   |      |      |      |      |      |      | 6    | 6    | 6    | 9    | 7    | 10   | 10   | 5    |      |      |  |
| July 16          | 10                     |   |      |      |      |      |      |      | 5    |      | 5    | 9    | 9    | 9    | 24   | 24   |      |      |  |
| July 23          | 21                     |   |      |      |      |      |      |      |      |      | 12   | 13   | 25   | 25   | 13   | 12   |      |      |  |
| July 30          | 8                      |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Aug. 6           | 15                     |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Aug. 14          | 10                     |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Aug. 21          | 11                     |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Aug. 28          | 9                      |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Sept. 3          | 17                     |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Sept. 11         | 11                     |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Sept. 18         | 20                     |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Sept. 24         | 6                      |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Oct. 1           | 12                     |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Oct. 8           | 11                     |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Oct. 15          | 18                     |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Oct. 22          | 11                     |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Nov. 5           | 13                     |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Nov. 19          | 16                     |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Dec. 3           | 10                     |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Dec. 17          | 7                      |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Dec. 31          | 12                     |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| 1937             |                        |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Feb. 11          | 11                     |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Feb. 25          | 4                      |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Mar. 11          | 1                      |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
| Mar. 25          | 1                      |   |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |

FROM EGGS DEPOSITED IN 1936

|             |     |     |    |    |    |    |    |    |   |   |   |   |   |   |   |    |    |  |
|-------------|-----|-----|----|----|----|----|----|----|---|---|---|---|---|---|---|----|----|--|
| <i>1936</i> |     |     |    |    |    |    |    |    |   |   |   |   |   |   |   |    |    |  |
| May 28      | 4   | 100 |    |    |    |    |    |    |   |   |   |   |   |   |   |    |    |  |
| June 4      | 17  | 100 |    |    |    |    |    |    |   |   |   |   |   |   |   |    |    |  |
| June 11     | 46  | 100 |    |    |    |    |    |    |   |   |   |   |   |   |   |    |    |  |
| June 18     | 85  | 100 |    |    |    |    |    |    |   |   |   |   |   |   |   |    |    |  |
| June 25     | 101 | 71  | 27 | 2  |    |    |    |    |   |   |   |   |   |   |   |    |    |  |
| July 2      | 129 | 32  | 59 | 9  |    |    |    |    |   |   |   |   |   |   |   |    |    |  |
| July 9      | 133 | 33  | 43 | 20 | 4  |    |    |    |   |   |   |   |   |   |   |    |    |  |
| July 16     | 133 | 12  | 51 | 23 | 8  | 4  | 1  | 1  |   |   |   |   |   |   |   |    |    |  |
| July 23     | 156 | 3   | 43 | 22 | 22 | 7  | 2  | 1  |   |   |   |   |   |   |   |    |    |  |
| July 30     | 168 | 6   | 37 | 21 | 17 | 11 | 4  | 1  | 1 |   |   |   |   |   |   |    |    |  |
| Aug. 6      | 138 | 3   | 33 | 16 | 17 | 14 | 10 | 2  | 4 |   |   |   |   |   |   |    |    |  |
| Aug. 14     | 157 |     | 28 | 19 | 16 | 9  | 7  | 7  | 4 | 3 | 3 | 2 |   |   |   |    |    |  |
| Aug. 21     | 112 | 3   | 12 | 13 | 14 | 13 | 9  | 9  | 4 | 3 | 6 | 4 | 4 | 4 | 1 |    |    |  |
| Aug. 28     | 143 |     | 5  | 9  | 13 | 13 | 12 | 11 | 6 | 5 | 4 | 4 | 5 | 5 | 2 | 2  | 1  |  |
| Sept. 3     | 127 |     | 3  | 9  | 15 | 13 | 14 | 12 | 6 | 5 | 4 | 4 | 6 | 6 | 4 | 1  | 1  |  |
| Sept. 11    | 113 |     | 2  | 7  | 12 | 14 | 10 | 15 | 9 | 3 | 2 | 2 | 3 | 3 | 3 | 4  | 7  |  |
| Sept. 18    | 140 |     |    | 7  | 7  | 4  | 5  | 8  | 7 | 4 | 8 | 5 | 7 | 7 | 7 | 8  |    |  |
| Sept. 24    | 118 |     |    | 2  | 8  | 9  | 9  | 8  | 7 | 7 | 4 | 6 | 7 | 7 | 6 | 9  | 10 |  |
| Oct. 1      | 133 |     | 1  |    | 5  | 7  | 5  | 6  | 4 | 4 | 4 | 5 | 7 | 7 | 7 | 15 | 4  |  |
| Oct. 8      | 88  |     |    | 1  | 7  | 5  | 3  | 1  | 3 | 3 | 3 | 3 | 6 | 6 | 7 | 22 | 20 |  |
| Oct. 15     | 129 |     |    |    | 5  | 5  | 2  | 2  | 3 | 3 | 5 | 3 | 2 | 7 | 7 | 17 | 30 |  |
| Oct. 22     | 109 |     |    | 2  | 5  | 4  | 1  |    | 1 | 1 | 1 | 5 | 5 | 7 | 7 | 9  | 31 |  |
| Nov. 5      | 150 |     |    | 2  | 7  | 4  |    |    |   | 2 | 1 | 4 | 4 | 4 | 8 | 16 | 35 |  |
| Nov. 19     | 136 |     |    | 2  | 7  | 8  |    |    |   | 2 | 2 | 4 | 4 | 4 | 9 | 13 | 15 |  |
| Dec. 3      | 115 |     |    | 3  | 5  | 6  | 1  |    | 2 | 1 | 2 | 3 | 4 | 8 | 9 | 17 | 33 |  |
| Dec. 17     | 85  |     |    | 1  | 2  | 8  |    |    | 1 | 2 | 5 | 4 | 7 | 6 | 6 | 13 | 38 |  |
| Dec. 31     | 76  |     |    | 2  | 9  | 11 |    |    | 1 | 3 | 1 | 3 | 2 | 5 | 5 | 20 | 30 |  |

TABLE 4.—Proportions of sizes, based on larval length, of *Merodon equestris* larvae in natural population samples acquired at intervals—Continued

FROM EGGS DEPOSITED IN 1936—Continued

[illegible]

## FROM EGGS DEPOSITED IN 1937

| 1937     |     |     |    |    |    |    |    |    |    |    |    |    |
|----------|-----|-----|----|----|----|----|----|----|----|----|----|----|
| June 10  | 7   | 100 |    |    |    |    |    |    |    |    |    |    |
| June 17  | 23  | 100 |    |    |    |    |    |    |    |    |    |    |
| June 24  | 50  | 100 |    |    |    |    |    |    |    |    |    |    |
| July 1   | 85  | 98  | 2  |    |    |    |    |    |    |    |    |    |
| July 8   | 114 | 86  | 9  | 5  |    |    |    |    |    |    |    |    |
| July 15  | 103 | 51  | 29 | 18 | 30 |    |    |    |    |    |    |    |
| July 22  | 175 | 33  | 23 | 30 | 13 | 4  | 1  |    |    |    |    |    |
| July 29  | 173 | 20  | 22 | 31 | 20 | 1  | 3  |    |    |    |    |    |
| Aug. 12  | 154 | 1   | 8  | 20 | 20 | 2  | 6  | 5  | 4  |    |    |    |
| Sept. 9  | 107 |     | 1  | 5  | 10 | 10 | 5  | 5  | 4  |    |    |    |
| Sept. 24 | 85  |     |    | 10 | 4  | 1  | 8  | 6  | 1  |    |    |    |
| Oct. 6   | 121 | 1   | 2  | 4  | 5  | 6  | 5  | 2  | 2  |    |    |    |
| Oct. 21  | 81  |     |    | 3  | 1  | 1  | 1  | 3  | 1  |    |    |    |
| Nov. 5   | 154 |     |    | 8  | 4  | 4  | 3  | 1  |    |    |    |    |
| Nov. 19  | 149 |     |    | 9  | 3  | 7  | 1  |    |    |    |    |    |
| Dec. 2   | 162 |     |    | 3  | 6  | 6  | 1  |    |    |    |    |    |
| Dec. 16  | 92  |     |    | 11 | 7  | 7  | 3  | 1  |    |    |    |    |
| Dec. 30  | 91  |     |    | 6  | 7  | 6  | 1  |    |    |    |    |    |
| 1938     |     |     |    |    |    |    |    |    |    |    |    |    |
| Jan. 13  | 132 |     | 1  | 10 | 7  |    | 2  | 2  | 1  | 3  | 4  | 10 |
| Feb. 3   | 88  |     | 1  | 13 | 10 |    | 1  | 3  | 3  | 3  | 4  | 10 |
| Feb. 17  | 69  |     |    | 12 | 7  |    | 2  | 6  | 0  | 0  | 2  | 10 |
| Mar. 3   | 94  |     |    | 16 | 11 | 1  | 2  | 6  | 2  | 1  | 2  | 10 |
| Mar. 17  | 74  |     |    | 20 | 12 |    | 5  | 5  | 2  | 0  | 4  | 10 |
| Mar. 30  | 45  |     |    | 15 | 20 |    | 4  | 5  | 2  | 7  | 7  | 10 |
| Apr. 14  | 47  |     |    | 15 | 20 |    | 5  | 4  | 4  | 6  | 0  | 10 |
| Apr. 28  | 55  |     |    | 20 | 25 | 16 | 2  | 6  | 7  | 4  | 2  | 10 |
| May 11   | 58  |     |    | 19 | 16 | 16 | 10 | 3  | 9  | 5  | 3  | 10 |
| May 20   | 50  |     |    | 14 | 14 | 14 | 6  | 4  | 6  | 6  | 2  | 10 |
| June 9   | 43  |     |    | 5  | 5  | 7  | 2  | 0  | 12 | 12 | 9  | 10 |
| June 23  | 24  |     |    | 17 | 4  | 4  | 17 | 8  | 14 | 23 | 12 | 10 |
| July 8   | 30  |     |    | 13 | 13 | 13 | 3  | 10 | 10 | 24 | 10 | 10 |
| July 22  | 25  |     |    |    |    |    | 4  | 16 | 28 | 21 | 12 | 10 |
| Aug. 5   | 19  |     |    |    |    |    |    |    |    | 42 | 26 | 10 |

A separation of the larvae into two distinct groups becomes evident in the fall months. Most of the larvae reach their full development by fall, which is represented by a size range of 14 to 18 mm. The principal group is composed of these mature larvae. There is a grouping of immature second instars which seemingly is held back in development and which shows little change in size through the winter. As the development of these smaller larvae is followed in successive population samples it is clear that they continue development through the second year and do not emerge as adults until the second spring after egg deposition. There is another grouping which is not so distinctly separated as the second instars. This is composed of third instars in the smaller sizes, and in this condition they pass the winter. A considerable number of these also apparently remain in the larval stage through the ensuing summer and pupate and emerge the second spring after oviposition. There is a definite retardation factor in the developmental history of the larvae, and this will be further discussed in detail. Normal development, representing approximately 80 per cent of the larval populations studied, is through a 1-year cycle.

In the normal course of development the first instars enter the bulbs late in May and throughout June, and the peak of this instar occurs approximately the first of July. Transformation to the second instar begins late in June, and the peak of this instar occurs early in August. Third instars appear early in August and these develop to a practically mature condition by the last of October, remain more or less inactive through the winter months, and leave the bulbs early in the spring to pupate.

Since the data for larvae originating in 1936 are the most complete and are practically free from abnormal phases, the developmental history of these larvae was selected for graphic presentation. The average size of the larvae collected on each date was calculated, and these means have been plotted on a semilogarithmic scale in figure 10 to demonstrate the developmental trend. In figure 11 the development of the larvae in each instar is similarly calculated and plotted in comparison with the developmental curve for the larvae of all

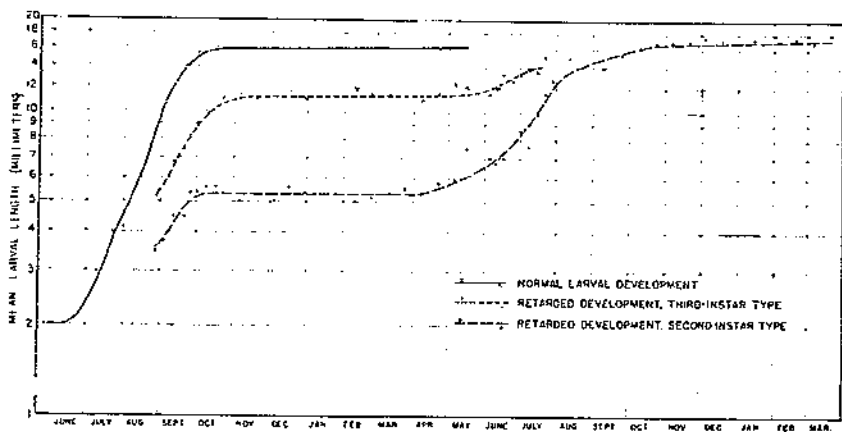


FIGURE 10.—Development of narcissus bulb fly larvae of 1936 origin, comparing the normal 1-year cycle with retarded second-instar and retarded third-instar groups.



instars. Because the curves represent rates of development the logarithmic scale is used to properly present the trend.

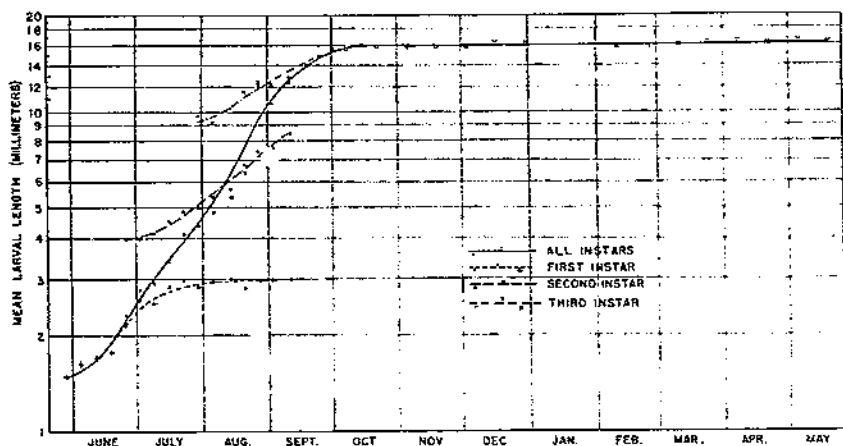


FIGURE 11.—Normal trend in development of narcissus bulb fly larvae, completed in 1 year, as exhibited by larvae of 1936 origin. The developmental trends of the three separate instars are included for comparison.

#### RETARDED LARVAL DEVELOPMENT

Although the normal development of the bulb fly larva requires only 1 year, it has been observed that the development of some larvae is retarded to such an extent that these do not pupate and transform to adults until the second spring after the beginning of their life cycle. Most published accounts of the life history indicate that the cycle from egg to adult requires 1 year. Referring to conditions in England, Stocks (32, p. 50) in 1914 said:

The life-cycle of *Merodon equestris* is of two years' duration, the larva carrying on its destructive work from July one year to February in the second following year, the grub and pupa remaining in the *bulb* approximately 19 months.

While no data are presented in support of this statement, and it can hardly be accepted as completely true, it is possible that this observer may have noted certain individuals whose development did require 2 years.

Bliss (4), also in England, reported in 1926 that certain individuals required 2 years for the completion of their cycles and offered evidence to support his statement. Poos and Weigel (29), in 1927, reported that "all data upon the biology of the *Narcissus* fly in the United States indicate that there is only one generation annually." Broadbent (9), in 1928, said:

In studies of this bulb fly continuing over a period of three years from 1925 to 1927, we have found no evidence indicating that some larvae of this species may require two years to complete their development.

In his account of 8 years' studies of this insect in England, Hodson (19), in 1932, said:

It can be accepted that there is not more than one generation each year, but certain writers have put forward the suggestion that larvae sometimes feed for

two seasons before reaching maturity. \* \* \* In the writer's experience all larvae, without exception, mature in one year \* \* \*

He considers that the confusion in this respect was caused by the great variation in sizes of larvae definitely of the same age. Hodson reports his observations on several larvae which were of small size during the winter months. None of these required a second year for the completion of its development. The description of his technique in one series of larval studies is as follows:

The larvae were periodically removed from their bulbs, measured, and returned to fresh bulbs, each thus being afforded equal opportunity of feeding and growth.

Whether similar methods were used throughout the studies is not known, nor is it stated whether the bulbs containing the larvae were placed in soil or kept as dry bulbs. It is evident that the environmental conditions surrounding these larvae were far from natural, particularly if they were replaced in fresh bulbs after each observation.

Hodson (19) stated further that it was an "established fact that quite small larvae are sometimes found in bulbs during the late winter and early spring months." This is definitely demonstrated in the larval developmental studies carried out in the Puget Sound region by means of interval population samples. Whereas Hodson failed to observe that the small larvae did continue their development through a second season, the interval-population-sample technique demonstrates distinctly that these small larvae, passing the winter period in the early phases of second-instar development, proceed in their feeding and growth through the ensuing season. This is evident in the population-sample data presented in table 4 and in the growth trend for those larvae of 1936 origin as shown in figure 10.

The observations of development during the winter periods as given in table 4 are further summarized in table 5 to demonstrate the proportions of overwintering larvae in the various developmental groups. The proportion of larvae passing through the first winter as second instars ranged from 11.2 to 16.1 percent of the populations. Resumption of developmental activity of the second instars becomes evident the second spring during April and early in May, transformation to third instars begins late in May or early in June, and the larvae become of a size considered mature in August or later. They pass through their second winter as mature larvae.

TABLE 5.—Proportion of larvae of *Merodon equestris* overwintering as second instars, immature third instars, and mature third instars during the years 1934 to 1938, inclusive, at Olympia, Wash.

| Season                          | Proportion of overwintering larvae in - |              |         |
|---------------------------------|---|--------------|---------|
|                                 | Second instar                           | Third instar |         |
|                                 |   | Immature     | Mature  |
|                                 | Percent                                 | Percent      | Percent |
| Oct. 30, 1934, to Feb. 4, 1935  | 11.25                                   | 10.25        | 78.50   |
| Oct. 25, 1935, to Dec. 20, 1935 | 11.40                                   | 10.40        | 78.20   |
| Oct. 22, 1936, to Feb. 11, 1937 | 15.60                                   | 9.14         | 75.86   |
| Oct. 21, 1937, to Feb. 3, 1938  | 16.12                                   | 9.00         | 74.88   |

Throughout the studies of larval development a somewhat indistinct grouping of larvae was evident in the overwintering populations. These were larvae in the early stages of the third instar. The grouping is indistinct because it merges into the mature-larvae group. An analysis of the data has revealed, however, that many of these immature third instars do not pupate until the second spring, and this group may also be considered as affected by retardation factors. During April these immature third instars resume activities and growth becomes evident. The group becomes merged with the retarded second-instar larval group late in July and in August, but apparently they reach maturity a little in advance of the latter group. As with the latter, the second winter is passed as mature larvae. Mature larvae from both types of retarded development seem to be among the first to leave the bulbs in the spring to pupate.

In addition to the population-sample studies, larvae of known size have been confined so that emergence of the adults could be recorded. Larvae of the smaller sizes, selected during examination of infested bulbs, were replaced in narcissus bulbs which were buried in soil in clay flowerpots. Each pot was individually covered with a small wire-screen cage, and all were plunged in soil under a large cage. The bulbs were not disturbed further. During the period when adult emergence was expected the cages were examined at frequent intervals and those adults present were removed. The record of adult emergence is given in table 6.

The cages installed in the winter of 1932-33 were continued into 1935 without disturbance of the bulbs or soil. From the larvae that were confined at that time, and which were of 1932 origin, three adults emerged in 1935. One of these that had been caged March 28, 1933, when 4 mm. long, and one caged May 20, 1933, when 10-12 mm. long, emerged June 6, 1935; and the other, caged May 23, 1933, when 10 mm. long, emerged May 31, 1935. All three had hibernated during three winters.

These instances show that the retardation of development may extend over 3 years in some cases. It is evident that such retardation is not due to failure of the larvae, as judged by the size, to mature earlier, for in two instances they were in the third instar when caged in 1933.

It has not been possible to determine what factors are responsible for the retardation in development. Observations indicate that the condition is more prevalent where the bulbs have been left in the ground for 2 or more years. Also there appears to be a general relationship between the drying of the basal plate and retardation. Hodson (19) considered the occasional occurrence of small second-instars late in the winter and early in the spring as due to desiccation or storage under excessively dry conditions. It is thought by the writers that the retarded larvae may be those that hatched from eggs laid during the later part of the oviposition season and that consequently at an early stage encountered drying conditions in the bulb tissue associated with the maturing of the bulbs. It is also believed that the condition is associated with cool climates with consequent late development of adults, and it may not occur in warmer climates.

TABLE 6.—Emergence of adults of *Merodon equestris* from caged larvae

| Larvae             |                   | Adults       |                     |        |
|--------------------|-------------------|--------------|---------------------|--------|
| Date caged and lot | Length when caged | Date emerged | Individuals emerged |        |
|                    |                   |              | Male                | Female |
|                    |                   |              | Number              | Number |
| Dec. 15, 1931      | 4                 | June 4, 1933 | 1                   |        |
| Nov. 15, 1932      | 4                 | May 14, 1934 | 1                   |        |
| Jan. 12, 1933      | 4                 | May 14       | 1                   |        |
| Jan. 24            | 4-5               | May 21       |                     | 1      |
| Do.                | 5-6               | May 14       | 2                   | 1      |
| Do.                | 6                 | May 26       | 1                   |        |
| Jan. 27            | 4-5               | May 11       |                     | 1      |
| Jan.               | 4                 | May 21       | 1                   |        |
| Mar. 28            | 4                 | May 14       | 1                   |        |
| Mar.               | 12-13             | May 21       | 1                   |        |
| Apr. 1             | 5                 | May 11       |                     | 1      |
| Apr. 4             | 4                 | May 26       | 1                   |        |
| Apr. 20            | 4-5               | May 21       |                     | 1      |
| Do.                | 4-6               | May 11       | 1                   |        |
| Do.                | 7                 | May 20       | 1                   |        |
| Do.                | 10                | May 14       | 1                   |        |
| Do.                | 12-13             | May 21       |                     | 1      |
| Do.                | 15                | June 6       |                     | 1      |
| Apr. 21            | 4-5               | May 14       | 3                   |        |
|                    |                   | May 14       | 1                   |        |
| Jan. 10, A, 1934   | 4-5               | May 31, 1935 | 1                   |        |
| Jan. 10, B         | 4-5               | June 6       |                     | 2      |
| Jan. 10, C         | 4-5               | May 31       | 1                   |        |
| Jan. 28            | 4-6               | June 6       | 2                   |        |
| Jan. 28, A         | 5                 | June 25      | 1                   | 1      |
| Jan. 28, B         | 5                 | May 22       | 1                   |        |
| Mar. 23, A         | 4-6               | May 31       | 2                   |        |
| Mar. 23, B         | 4-6               | May 31       | 3                   |        |
| Mar. 23, C         | 4-6               | June 6       | 1                   | 1      |
| Mar. 23, D         | 4-6               | June 11      |                     | 1      |
| Mar. 23, E         | 4-6               | May 31       |                     | 1      |
| Mar. 25            | 10-14             | June 6       | 2                   |        |
|                    |                   | June 6       | 1                   |        |

## THE PUPA

Very early in the spring the mature larva leaves the bulb in which it has developed and moves upward through the soil until its head barely protrudes through the soil surface (fig. 12). The larval skin hardens and becomes the pupal case in which the transformation to the adult fly occurs. Broadbent (9) states that at Washington, D. C., in 1926, the pupal period ranged from 33 to 50 days with mean temperatures (corrected for soil readings) of 53.6° to 60.3° F. (12.0°–15.7° C.) and that in 1927 it ranged from 48 to 61 days with mean temperatures of 53.2° to 55.8° F. (11.8°–13.2° C.). Hodson (19) states that in his experience in England the length of this stage showed marked constancy, ranging only between 35 and 40 days. He con-

sidered it highly probable, however, that it might be prolonged for an additional 10 to 20 days. Broadbent states that a large temperature characteristic is indicated in connection with the pupal period. In an experiment at Sumner, Wash., the relation of temperature to the duration of the pupal period was studied in 1933. The influence of temperature is strong, as indicated in the data summarization presented in figure 13.



FIGURE 12. Soil around narcissus bulbs partly removed to reveal narcissus bulb fly puparia in situ.

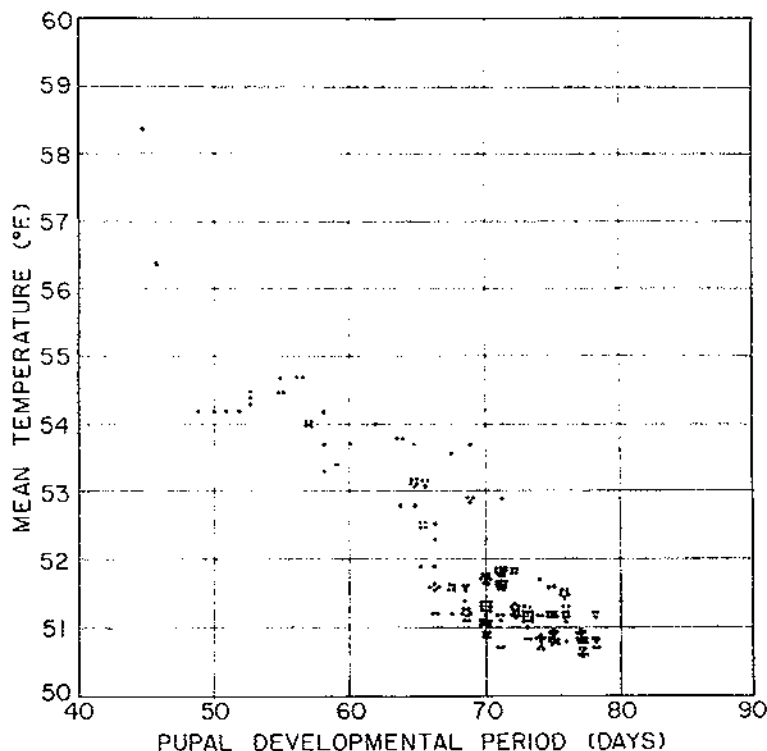


FIGURE 13. Relationship of mean temperature to length of pupal period of the narcissus bulb fly. The dots represent period means of individuals.

In this experiment the range of the period was 33 to 80 days and the mean temperature ranged from 50.5° to 63.5° F. These pupal periods appear to be slightly greater than those observed by Broadbent (9) for comparable temperatures.

General field studies were made at Olympia, Wash., in 1936, 1937, and 1938 to determine the season of pupation and emergence. In these studies infested bulbs were dug at regular intervals and the proportions noted of those from which the larvae had migrated. Only mature larvae were considered. As the time for expected adult emergence arrived, samples of puparia were collected at regular intervals by

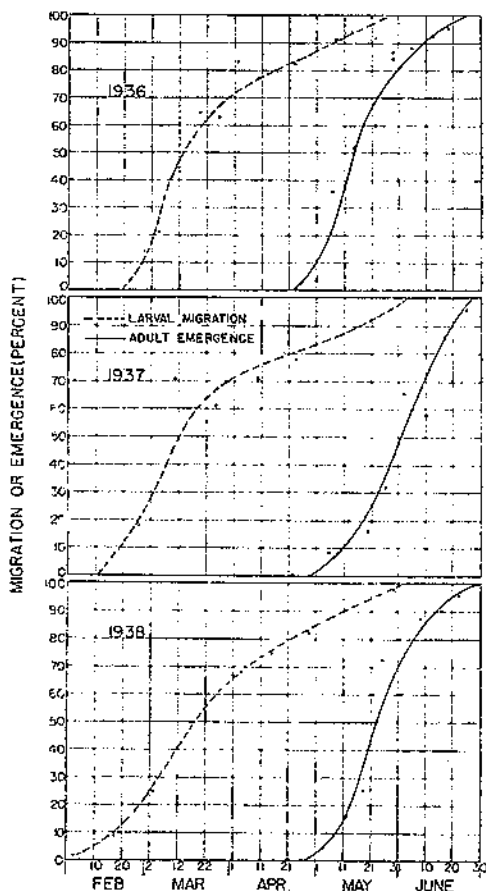


FIGURE 14.—Season of larval migration and adult emergence based on samples of larvae and pupae of the narcissus bulb fly collected at intervals during 1936, 1937, and 1938.

screening the surface soil over the bulb rows. The proportion of puparia from which adults had emerged was noted. The data are presented in tables 7 and 8. The increase in migration from the bulbs and in adult emergence is plotted graphically in figure 14. In these graphs a horizontal distance between the two curves at any point would represent the theoretical duration for that season. It

is evident that the duration is markedly lessened as the season advances, and it is assumed that seasonal rise in temperature is the most important factor involved in the shortening of the period.

TABLE 7.—Departure of mature larvae of *Merodon equestris* from bulbs for the purpose of pupation, Olympia, Wash., 1936, 1937, and 1938

| Date examined | Infested bulbs examined | Larvae missing |         | Date examined | Infested bulbs examined | Larvae missing |         |
|---------------|-------------------------|----------------|---------|---------------|-------------------------|----------------|---------|
|               |                         | Number         | Percent |               |                         | Number         | Percent |
| 1936          |                         |                |         | 1937          |                         |                |         |
| Feb. 29       | 100                     | 24             | 14      | Apr. 8        | 102                     | 73             | 72      |
| Mar. 5        | 100                     | 21             | 21      | Apr. 22       | 114                     | 89             | 78      |
| 12            | 100                     | 45             | 45      | May 20        | 80                      | 74             | 93      |
| 19            | 100                     | 65             | 65      | June 3        | 82                      | 82             | 100     |
| 27            | 100                     | 64             | 64      | 1938          |                         |                |         |
| Apr. 2        | 100                     | 83             | 83      | Jan. 13       | 99                      | 0              | 0       |
| 9             | 100                     | 78             | 78      | Feb. 3        | 65                      | 1              | 2       |
| 16            | 100                     | 80             | 80      | Feb. 17       | 44                      | 4              | 9       |
| 23            | 100                     | 82             | 82      | Mar. 3        | 80                      | 19             | 24      |
| 30            | 100                     | 88             | 88      | Mar. 17       | 74                      | 37             | 50      |
| May 7         | 103                     | 91             | 91      | Apr. 3        | 73                      | 49             | 67      |
| 14            | 109                     | 94             | 94      | Apr. 14       | 82                      | 61             | 74      |
| 21            | 100                     | 92             | 92      | May 11        | 82                      | 68             | 83      |
| 28            | 100                     | 86             | 86      | May 26        | 134                     | 123            | 92      |
| 1937          |                         |                |         | June 9        | 104                     | 102            | 98      |
| Feb. 11       | 59                      | 0              | 0       | June 23       | 60                      | 0              | 100     |
| 25            | 90                      | 11             | 12      |               | 70                      | 70             | 100     |
| Mar. 11       | 45                      | 32             | 71      |               |                         |                |         |
| 25            | 54                      | 33             | 61      |               |                         |                |         |

TABLE 8.—Emergence of adults from pupae of *Merodon equestris* collected in the field at intervals through the spring season, Olympia, Wash., 1936, 1937, and 1938

| Date examined | Pupae      |         | Proportion emerged | Date examined | Pupae      |         | Proportion emerged |
|---------------|------------|---------|--------------------|---------------|------------|---------|--------------------|
|               | Un-emerged | Emerged |                    |               | Un-emerged | Emerged |                    |
| 1936          |            |         |                    | 1937          |            |         |                    |
| Apr. 23       | 25         | 0       | 0                  | June 9        | 21         | 29      | 58                 |
| 30            | 24         | 1       | 4                  | 16            | 7          | 43      | 86                 |
| May 7         | 16         | 9       | 36                 | 23            | 1          | 43      | 98                 |
| 14            | 12         | 13      | 52                 | July 7        | 1          | 40      | 98                 |
| 21            | 10         | 15      | 60                 | 21            | 0          | 48      | 100                |
| 28            | 4          | 21      | 84                 | 1938          |            |         |                    |
| June 4        | 3          | 22      | 88                 | Apr. 20       | 25         | 0       | 0                  |
| 11            | 2          | 23      | 92                 | 26            | 25         | 0       | 0                  |
| 17            | 1          | 24      | 96                 | May 4         | 24         | 1       | 4                  |
| 25            | 0          | 25      | 100                | 11            | 21         | 4       | 16                 |
| 1937          |            |         |                    | 18            | 19         | 6       | 24                 |
| Apr. 21       | 25         | 0       | 0                  | 25            | 7          | 18      | 72                 |
| 28            | 50         | 0       | 0                  | June 1        | 10         | 15      | 60                 |
| May 5         | 46         | 4       | 8                  | 8             | 3          | 22      | 88                 |
| 12            | 20         | 5       | 20                 | 15            | 2          | 19      | 90                 |
| 19            | 84         | 10      | 16                 | 22            | 1          | 22      | 96                 |
| 25            | 34         | 16      | 32                 | 20            | 0          | 23      | 100                |
| June 2        | 17         | 33      | 66                 |               |            |         |                    |

Observations in February and early in March indicate that the migrating larvae may not assume the pupal condition for several days after leaving the bulbs; later this period is shorter as the activity is increased at higher temperatures. Approximately two-thirds of the mature larvae were found to have left the bulbs by the end of March. The remaining larvae entered the pupal stage over the whole month of April, and stragglers were still present well into May. This may also be observed in the data on larval-population samples in table 4. Many of the later individuals are thought to be larvae that passed the

winter in a more or less immature condition, resumed feeding and development early in the spring, and became sufficiently mature to pupate the same season. Apparently the inclination or urge to pupate is associated with the spring season, since mature larvae have been observed to continue as larvae through the summer, fall, and winter, seemingly waiting for the spring season before pupating.

## THE ADULT

### EMERGENCE

At time of emergence the adult pushes against the anterior end of the pupal case, causing it to break along a line close to the anterior respiratory cornua. The round cap thus broken off is pushed to one side and the fly works its way out of the case. Immediately after emergence the body of the fly is distended with fluid, the wings are unexpanded, and the body wall is soft. The fly seeks some object close by, such as grass or a leaf or other support, climbs up on this a few inches above the ground, and completes the transformation to the adult by expanding the wings. The body fluids are ejected, and the exoskeleton quickly hardens. After these final phases of transformation are accomplished the fly assumes regular adult activities. It has been observed that emergence always occurs during the morning hours. This corresponds to similar observations by Broadbent (8) and Hodson (19).

### ACTIVITIES

The adult narcissus bulb fly is definitely a sunshine-loving insect. Its activities in the open are negligible unless the temperature is above 60° F. It avoids exposed situations, preferring areas more or less sheltered from winds. The flies are seldom observed on cloudy days unless the temperature is rather high. Periods of cool, rainy weather extending over 4 or 5 days probably cause many of the flies to perish through inability to obtain food. Continuous periods of sunny, mild weather are favorable to activity, particularly mating and oviposition. Probably weather conditions during the adult period have a strong influence on the extent of bulb infestation because of their effect on ovipositional activity.

The males are more active fliers than the females. In a narcissus planting a fly when first disturbed flies a short distance ahead of the observer, settling down again on a leaf or clod. Sometimes a second approach will cause the same action, but usually the second or third disturbance causes the fly to rise vertically a short distance and depart rapidly and vigorously straight away in any direction, and it is very quickly lost to sight. Ordinary, undisturbed flight in a narcissus planting is usually at a low level, a few inches below the narcissus leaf tips, with a tendency to follow the rows, although the fly frequently passes through or between plants to adjacent rows. Very rarely individuals have been observed hovering—that type of flying habit associated with many of the Syrphidae. The few times that this has been observed the weather was warm, over 80° F. The flies maintained themselves in a relatively stationary position about 2 feet above the ground, and the period of hovering ranged between 10 and 25 seconds.

The adults are able to produce a strongly vibrant humming sound, but this noise is heard infrequently from flies in the open. If caught in



an insect net or spider web, or held between thumb and forefinger, a fly gets noisy, and it is possible that this noise is a protective sound associated with its beelike coloration, for it is similar to the buzz or hum of a bumblebee. It is supposedly made by vibration of the dorsal part of the thorax, for it is not associated with wing movement.

While mating the flies produce a much higher pitched hum that is quite characteristic. It has not been definitely determined whether this particular tone is produced by the male, the female, or both. The male is very active preceding mating. Its usual procedure is to dart rapidly from above a slowly flying female, grasping it in the thoracic region, the pair then coming to rest on the ground or on a horizontal leaf surface, where actual union is accomplished. Actively flying males have been observed on numerous occasions grasping honeybees just departing from flowers, which would seem to indicate that the female has no particular preliminary call or other means of attraction. This is further evidence of the close resemblance of the flies to bees.

The duration of life of individual flies under natural conditions is difficult to estimate. In cages, with food continuously available, the flies may live as long as 20 days. Outside, the climatic conditions are important factors determining the length of adult life. If conditions unfavorable to feeding, such as low temperatures, cloudiness, or precipitation, are prolonged, the flies may succumb quickly. In the Pacific Northwest such conditions, lasting a week or more, are not uncommon during May and infrequently occur during June. Hence the adult population may be significantly affected by unfavorable weather.

#### FEEDING HABITS

The adult flies have been reported as feeding on a number of flowers. In England, Stocks (32) reported them feeding on dandelion and in daffodil beds. He also stated that he had found them feeding on all kinds of flowers in masses and on fruit blossoms, particularly those of apple. Hodson (19) writes that the flies may often be taken at flowers and that some preference is shown for those of various members of the order Compositae, notably the common dandelion. He noted also that flowering shrubs are visited as well as the large pink flowers of *Mesembryanthemum*. Osburn (28) reported specimens of *Merodon equestris* being taken at the flowers of salmonberry (*Rubus spectabilis*) at Vancouver, B. C.

In the Pacific Northwest numerous observations have been made of the flies feeding at the flowers of various plants. In cages the flies fed readily on cane-sugar solutions and on dilute honey. The flies in the field were also noted feeding deep in flowers as though after nectar. On some occasions they were apparently feeding entirely on pollen. To check these observations on pollen feeding some of the flies were dissected and their digestive tracts mounted on microscope slides. It was found that many of the flies had ingested considerable quantities of pollen. The grains appeared to be practically unchanged, even in the rectum, so there is some doubt as to whether pollen really serves as food. Study of the ingested pollen has indicated that a fly feeds on several kinds of flowers, and that in different localities and at different times during the season flies would feed on available flowers. The pollen grains from the digestive tracts of flies have been used to some extent to check observations of feeding on certain plants.

The following is a list of the flowers on which adults of *Merodon equestris* have been observed feeding in the Pacific Northwest:

| Scientific name:                               | Common name             |
|--|-------------------------|
| <i>Agoseris lactinea</i> (Nutt.) Greene        | Field chickweed.        |
| <i>Cerastium arvense</i> L.                    | Candy flower.           |
| <i>Claytonia (Montia) sibirica</i> (L.) Howell | Woolly sunflower.       |
| <i>Crepis capillaris</i> Walls                 | Wild strawberry.        |
| <i>Eriophyllum lanatum</i> (Prush.) Forbes     | St. Johnswort.          |
| <i>Fragaria cuneifolia</i> Nutt.               | False dandelion.        |
| <i>Hypericum perforatum</i> L.                 | White double narcissus. |
| <i>Hypochaeris radicata</i> L.                 | Potentilla.             |
| <i>Narcissus albaplena odorata</i>             | Field buttercup.        |
| <i>Potentilla gracilis</i> Dougl.              | Wild radish.            |
| <i>Ranunculus occidentalis</i> Nutt.           | Thimbleberry.           |
| <i>Raphanus sativus</i> L. (caged flies)       | Blue-eyed-grass.        |
| <i>Rubus parviflorus</i> Nutt.                 | Dandelion.              |
| <i>Sisyrinchium idahoense</i> Bicknell         | Thyme.                  |
| <i>Taraxacum taraxacum</i> (L.) Karst.         |                         |
| <i>Thymus</i> sp.                              |                         |

In only one instance was an unconfined fly found feeding on anything other than flowers. In this instance one was noted apparently feeding on a ripe blackberry fruit, *Rubus* sp.

#### OVIPOSITION

The neck area of the narcissus plant is the focal point for the act of oviposition. Usually the movements of the leaves in the wind cause the soil to be more or less open around the neck. As a rule the female approaches this region by walking down a leaf to the soil, then moves here and there, occasionally extending her ovipositor, apparently considering and seeking the most favorable location for placing an egg. She generally backs down the opening around the plant, and places the egg either on the plant itself or in the soil close to the plant. The eggs are seldom more than one-fourth inch below the soil surface. After depositing an egg the fly may walk along the soil surface to an adjoining bulb, but more commonly she ascends a leaf a few inches and from there flies slowly to another plant within 2 or 3 feet to deposit another egg. In the field no fly has been noted to deposit more than a single egg at any one bulb, but the presence of an egg at a bulb does not deter another female from depositing there. Multiple larval infestation of bulbs, therefore, usually represents progeny of different females.

Females probably deposit a considerable number of eggs each day when weather conditions are favorable. It is extremely difficult to keep a single individual under continuous observation in the open to determine the extent of this operation, and when the flies are caged the unnatural conditions often retard egg deposition to some extent until shortly before a fly dies, when she may deposit a considerable number of eggs in a short time. The average number of eggs deposited by caged females receiving suitable food was approximately 80. The maximum number of eggs laid by a single female in these cage tests was 174, and the largest number deposited by 1 fly in a single day was 102.

#### SEASONAL DEVELOPMENTAL HISTORY

##### PUBLISHED RECORDS

Information on various phases of the life history of *Merodon equestris* has been presented by a number of writers who have stud-

ied the insect in several regions. As far as can be determined by descriptions of technique employed, these studies were based on confined or caged individuals. The comparative seasonal occurrence of the several stages in the localities where comprehensive studies have been made is indicated in table 9.

TABLE 9.—Comparative seasonal occurrence of the stages of *Merodon equestris* as reported from different localities

| Locality                          | Adult          | Egg                  | Larva                    | Pupa                    |
|-----------------------------------|----------------|----------------------|--------------------------|-------------------------|
| Netherlands (5).....              | (?)            | May                  | May to March-April       | March-April.            |
| England (19).....                 | Apr. 26-July 9 | May into June        | May-June to March-April. | April.                  |
| District of Columbia (8, 37)..... | Apr. 24-June 4 | do                   | do                       | March-May.              |
| Oregon (39).....                  | Mar. 27-May    | Late April into May. | May to March.            | Early March into April. |

The season of appearance of the different stages in these localities is much the same. Wilcox and Mote (39) indicated that the spring of 1926, when they studied the biology of this insect in Oregon, was exceptionally advanced, and hence the normal period when the stages would be expected to occur would be a little later than the times presented in their account.

#### SEASONAL DEVELOPMENT IN THE PACIFIC NORTHWEST

In the lower Puget Sound region the adult flies first appear late in April or early in May, depending on climatic conditions. In 1935 a schedule of daily (except Sunday) observations, regardless of weather conditions, was followed in the Puyallup Valley throughout the period of adult activity, May 7 to June 27. Six narcissus fields, variety King Alfred, were visited each morning between 10 a. m. and noon by three of the laboratory staff, two fields being covered each day by each observer. The visitations were alternated so that each field was visited twice a week by each observer. Exactly one-half hour was spent in a field, and the number of adults observed during that period was recorded. The summarized data of these studies are presented in table 10. Two fields were noticeably more heavily infested than the other four, and the data of these two fields have been compared with temperature means and precipitation records in figure 15. It is very noticeable that the increases in adult appearances are associated with temperature peaks.

Further information on the seasonal occurrence of adults was obtained from records made of the emergence of adults within a large screen cage covering infested bulbs placed in the soil the preceding fall. The data obtained are presented graphically in figure 16.

The cage-emergence data correspond in a general way with the field observations except that flies were observed in the field several days in advance of cage emergence. The peak of emergence occurred during the period from May 20 to 27. During this period the peak of activity in the field was also observed. A secondary peak of emergence in the cage was noted at the end of May and the first few days of June, and

this compares with a field activity peak from June 3 to 6. Stragglers emerged throughout the month of June and reduced numbers of adults were noted in the fields during the same period.

TABLE 10.—Number of adults of *Merodon equestris* observed in six fields of King Alfred narcissus during the period of adult activity, Puyallup River Valley, 1935

| Date of<br>obser-<br>vation | Weather conditions at time<br>of observations                                 | Temp.<br>10 a. m.<br>to 12 m. | Adults observed in field— |             |             |             |             |             | Total       |
|-----------------------------|---|-------------------------------|---------------------------|-------------|-------------|-------------|-------------|-------------|-------------|
|                             |   |                               | A                         | B           | C           | D           | E           | F           |             |
|                             |   | F.                            | Num-<br>ber               | Num-<br>ber | Num-<br>ber | Num-<br>ber | Num-<br>ber | Num-<br>ber | Num-<br>ber |
| May 6                       | 75 percent cloudy   | 56-69                         | 0                         | 0           | 0           | 0           | 0           | 0           | 0           |
| 7                           | Clear, light breeze   | 60-65                         | 8                         | 0           | 2           | 0           | 0           | 0           | 10          |
| 8                           | do  | 64-69                         | 2                         | 3           | 0           | 0           | 0           | 0           | 5           |
| 9                           | Clear, moderate wind  | 62-64                         | 5                         | 2           | 3           | 2           | 1           | 0           | 13          |
| 10                          | Cloudy, brief sunshine  | 52-56                         | 1                         | 1           | 0           | 0           | 0           | 0           | 2           |
| 11                          | 75 percent cloudy, light wind   | 51-54                         | 0                         | 1           | 0           | 0           | 0           | 2           | 3           |
| 12                          | Clear, light breeze   | 66-73                         | 2                         | 2           | 5           | 9           | 0           | 7           | 25          |
| 13                          | Hazy, light breeze  | 61-66                         | 9                         | 14          | 1           | 1           | 0           | 19          | 44          |
| 14                          | Rain previous night, 50 percent<br>cloudy, light wind                         | 56-60                         | 0                         | 0           | 1           | 1           | 0           | 0           | 2           |
| 15                          | Moderately hazy, light breeze   | 57-61                         | 0                         | 1           | 4           | 0           | 0           | 0           | 5           |
| 16                          | Cool, cloudy, light wind  | 53-57                         | 0                         | 0           | 0           | 0           | 0           | 0           | 0           |
| 17                          | Cleared at 10 a. m., light breeze   | 56-61                         | 6                         | 3           | 1           | 2           | 0           | 7           | 19          |
| 18                          | Clear and hot all day except 10:15 a. m.,<br>12 m., 75 percent cloudy, breeze | 72-77                         | 55                        | 43          | 3           | 19          | 3           | 5           | 128         |
| 19                          | Partly cloudy, warm   | 67-70                         | 49                        | 25          | 5           | 16          | 7           | 4           | 106         |
| 20                          | Cool, 75 percent cloudy, wind   | 61-63                         | 0                         | 0           | 0           | 0           | 1           | 0           | 1           |
| 21                          | Cool, 80 percent cloudy, light breeze   | 61-63                         | 3                         | 2           | 0           | 0           | 0           | 2           | 7           |
| 22                          | Clear, moderate wind  | 60-66                         | 15                        | 5           | 2           | 5           | 5           | 2           | 35          |
| 23                          | Thin clouds, light breeze   | 63-69                         | 10                        | 7           | 1           | 8           | 5           | 5           | 46          |
| 24                          | Clear, light breeze   | 64-71                         | 59                        | 50          | 8           | 12          | 19          | 5           | 144         |
| 25                          | High fog breaking at 11 a. m., light<br>breeze                                | 55-65                         | 0                         | 2           | 9           | 0           | 1           | 2           | 14          |
| 26                          | Cloudy, cool, quiet   | 59-60                         | 0                         | 0           | 0           | 0           | 0           | 0           | 0           |
| 27                          | Cloudy, cool, drizzle 9:30 to 10 a. m.  | 55-59                         | 0                         | 0           | 0           | 0           | 0           | 0           | 0           |
| 28                          | Cloudy, cool, threatening   | 55-60                         | 0                         | 0           | 0           | 0           | 0           | 0           | 0           |
| 29                          | do  | 61-65                         | 0                         | 0           | 0           | 0           | 0           | 0           | 0           |
| June 1                      | Clear, moderate wind  | 66-72                         | 37                        | 13          | 0           | 2           | 2           | 3           | 57          |
| 2                           | Clear, quiet  | 72-78                         | 23                        | 19          | 3           | 4           | 4           | 5           | 58          |
| 3                           | Clear, light breeze, 10 a. m., moderate<br>wind, 12 m.                        | 77-81                         | 33                        | 17          | 5           | 6           | 7           | 7           | 75          |
| 4                           | Clear, light breeze   | 80-87                         | 66                        | 27          | 0           | 3           | 5           | 11          | 112         |
| 5                           | Cloudy, cool, moderate wind   | 65-66                         | 0                         | 0           | 0           | 0           | 0           | 0           | 0           |
| 6                           | Shower 10 a. m., cloudy 11:30, clear<br>10:30, moderate wind                  | 66-70                         | 33                        | 1           | 6           | 2           | 2           | 1           | 45          |
| 7                           | Cloudy, light breeze  | 66-70                         | 0                         | 0           | 0           | 0           | 0           | 0           | 0           |
| 8                           | do  | 64-68                         | 3                         | 5           | 1           | 0           | 0           | 0           | 9           |
| 9                           | Cloudy, shower 9:30 a. m.   | 63-69                         | 0                         | 0           | 0           | 0           | 0           | 0           | 0           |
| 10                          | 80 percent cloudy, light breeze   | 66-70                         | 13                        | 6           | 0           | 2           | 5           | 1           | 27          |
| 11                          | Showers   | 57-59                         | 0                         | 0           | 9           | 0           | 0           | 0           | 9           |
| 12                          | Cloudy, cool, moderate wind   | 59-64                         | 0                         | 0           | 0           | 0           | 0           | 0           | 0           |
| 13                          | Cloudy early, cleared at 10:30 a. m., light<br>wind                           | 63-69                         | 1                         | 6           | (1)         | (1)         | (1)         | (1)         | 7           |
| 14                          | Cloudy, showers   | 62-66                         | 0                         | 0           | 0           | 0           | 0           | 0           | 0           |
| 15                          | Partly cloudy, clear 10:30 a. m., wind  | 62-66                         | 1                         | 0           | 0           | 0           | 0           | 0           | 1           |
| 16                          | Clear, light breeze   | 68-74                         | 16                        | 5           | 0           | 0           | 0           | 0           | 21          |
| 17                          | do  | 70-74                         | 13                        | 8           | 0           | 0           | 0           | 0           | 21          |
| 18                          | Shower  | 60-63                         | 0                         | 0           | 0           | 0           | 0           | 0           | 0           |
| 19                          | Cloudy  | 64-67                         | 0                         | 0           | 0           | 0           | 0           | 0           | 0           |
| 20                          | Clear, moderate breeze  | 68-71                         | 10                        | 3           | 0           | 0           | 0           | 0           | 13          |
| 21                          | Clear, light breeze   | 71-75                         | 9                         | 3           | 0           | 0           | 0           | 0           | 12          |
| 22                          | Partly cloudy, breeze   | 76-84                         | 1                         | 7           | 0           | 0           | 0           | 0           | 8           |
| 23                          | Cloudy  | 69-67                         | 0                         | 0           | 0           | 0           | 0           | 0           | 0           |
| Total                       |   |                               | 492                       | 282         | 60          | 94          | 68          | 88          | 1,074       |

\* Observations discontinued.

The principal period of egg deposition would naturally correspond closely to the peak of adult activity. Entrance of larvae into the bulbs would follow the peak of adult activity by about 10 to 14 days, the time required for incubation. In 1935, narcissus bulbs were examined at weekly intervals after April 25. Not until May 31, when three were

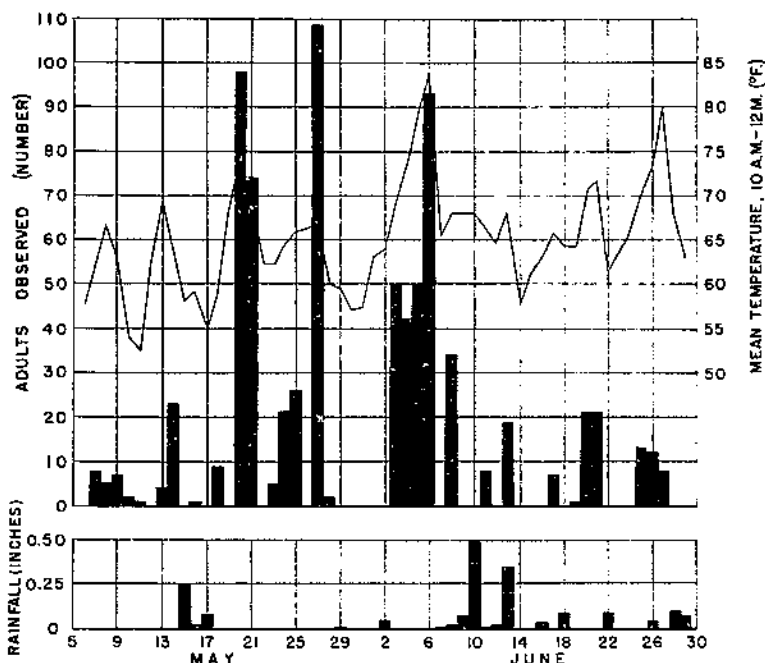


FIGURE 15.—Occurrence of adult narcissus bulb flies in two narcissus plantings near Sumner, Wash., during the season of 1935, compared with records of temperature means and of precipitation.

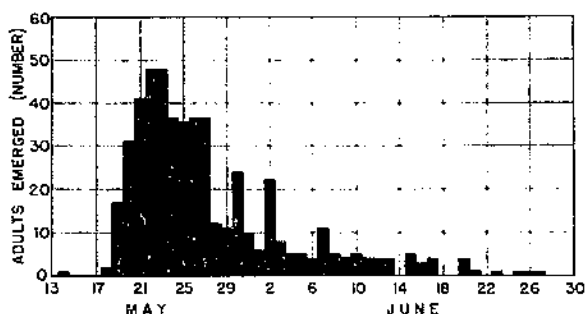


FIGURE 16.—Emergence of adult narcissus bulb flies from pupae at Sumner, Wash., 1935.

found, were young larvae detected in the bulbs. Approximately equal numbers of bulbs were examined each week and the numbers of new larvae found were as follows:

| Date:   | Number of new larvae |
|---------|----------------------|
| May 31  | 3                    |
| June 6  | 17                   |
| June 13 | 75                   |
| June 20 | 125                  |
| June 27 | 206                  |
| July 5  | 272                  |
| July 11 | 284                  |

In the usual developmental procedure the larvae grow to mature size by the late part of September or early in October. These larvae remain more or less inactive in the bulbs throughout the winter. Early in spring they leave the bulbs and move close to the soil surface, where they pupate. After the changes which occur within the pupal cases have been completed the adult flies emerge.

Those larvae whose development is retarded during the first season overwinter either as early second instars or early third instars and resume development in the following spring. These reach mature size during the second summer and spend the second winter as mature larvae within the bulbs, which they leave early the next spring to pupate. Figure 17 presents a diagrammatic comparison of the normal development of the narcissus bulb fly with two types of retarded development represented by the overwintering second and third instars.

### FOOD PLANTS

Published accounts dealing with the narcissus bulb fly record a number of bulbous plants as hosts. Compilations of published host records were presented by MacDougall (24) in 1913 and Fryer (17) in 1914. Hodson (19) in his report on the insect refers to Fryer's list of hosts and adds *Eurycles* and *Galanthus*. Poos and Weigel (29) list several host plants compiled from various references in American and European literature, the only ones not included by Hodson being *Iris* and lilies.

The lists of insects intercepted by the plant quarantine units of the United States Department of Agriculture furnish additional host-plant records. According to these records (from 1915 to 1939) larvae of *Merodon* sp. have been intercepted in various hosts as follows:

| Host plant:                         | Number of interceptions |
|-------------------------------------|-------------------------|
| <i>Allium cepa</i>                  | 1                       |
| <i>Amaryllis belladonna rosea</i>   | 1                       |
| <i>Galanthus</i> sp.                | 5                       |
| <i>Gladiolus</i> sp.                | 1                       |
| <i>Hyacinthus</i> sp.               | 6                       |
| <i>Lachenalia</i> sp.               | 1                       |
| <i>Leucojum</i> sp.                 | 6                       |
| <i>Lycoris</i> sp. . .              | 1                       |
| <i>Muscari comosum</i> (tripollini) | 268                     |
| <i>Narcissus</i> sp. . .            | 951                     |
| <i>Ornithogalum</i> sp.             | 1                       |
| <i>Scilla</i> sp.                   | 2                       |
| <i>Sternbergia lutea</i>            | 1                       |
| <i>Tulipa</i> sp. . .               | 1                       |

Assumedly, practically all these records refer to larval attack. Almost none of the published accounts of plants attacked indicate that positive determination of species was obtained by rearing of adults. Hence complete assurance cannot be had that *Merodon equestris* was always the species involved.

Most accounts indicate that narcissus is the only host of general importance, infestation in the others being more or less incidental. No reference to *Muscari comosum* as a host has been noted other than the interception records listed, but the large number of interceptions indicates that this bulb must be considered as an important host. These infested bulbs came from Italy and Morocco. It is possible that the species involved in this host may not be *equestris*.

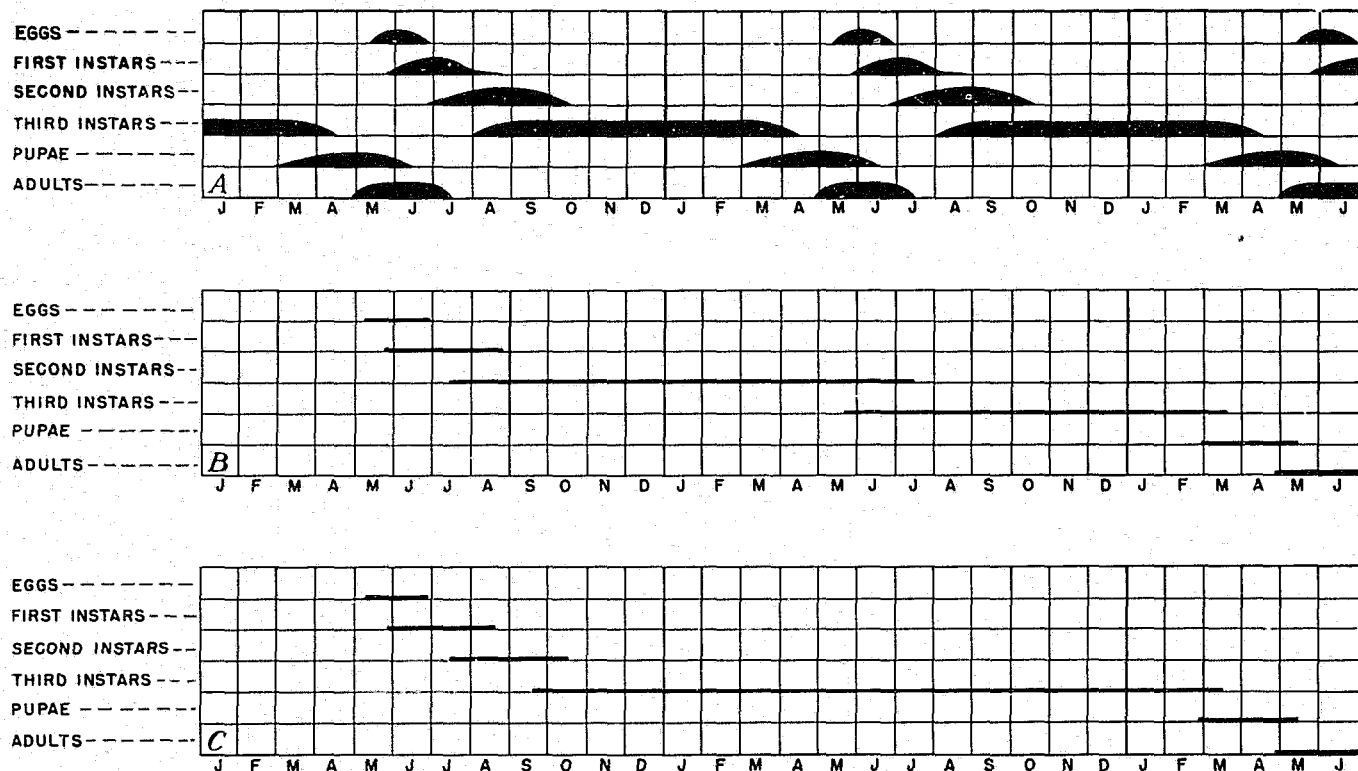


FIGURE 17.—Comparison of the normal development of the narcissus bulb fly at Sumner, Wash., with development of retarded forms overwintering as second instars and as third instars: A, Normal development; B, retarded second instars; C, retarded third instars.

Extensive larval infestation was observed by the writers in a stock of potted *Hyacinthus* hybrids in western Washington which were moved from a greenhouse early in May and plunged in soil outside. The extensiveness of the infestation indicated that these plants were very acceptable to the narcissus bulb fly. A grower in the same region reported that approximately 10 percent of a planting of 2,000 *Lycoris squamigera* bulbs were destroyed by bulb fly larvae. From a home garden in the Puget Sound area infested iris bulbs and bulbs of *Vallota purpurea* were brought to the laboratory one fall.

General experience indicates that narcissus is the most important host, but it is probable that if *Hyacinthus* bulbs were grown in a region where the fly is present serious infestation might be expected. Further information regarding the status of *Muscari comosum* would be desirable. While serious infestation may be experienced in some of the other hosts it is probable that the infestation reported for most of these was more or less accidental, and they need not be considered as generally subject to infestation.

The several host plants recorded belong to three plant families, as follows:

- Iridaceae (Iris family)
  - Gladiolus*
  - Iris* (bulbous types)
- Amaryllidaceae (Amaryllis family)
  - Amaryllis*
  - Eurycotis* (Brisbane lily)
  - Hyacinthus* (includes *Habranthus*)
  - Leucojum*
  - Lycoris*
  - Narcissus*
  - Sternbergia lutea*
  - Vallota purpurea* (Scarborough lily)
- Liliaceae (Lily family)
  - Allium cepa*
  - Gallionia* (summer hyacinth)
  - Hyacinthus*
  - Lachenalia*
  - Lilium*
  - Muscari comosum*
  - Ornithogalum*
  - Scilla*
  - Tulipa*

## NATURE OF INJURY

### LARVAL ATTACK

Injury to its host is done by the larva of the narcissus bulb fly, which attacks the bulb immediately after it has hatched and feeds on the bulb tissue until mature and ready to pupate. The egg is deposited on or close to the bulb foliage approximately at the soil surface, which may be 2 to 6 inches above the bulb proper. The newly hatched larva is actively geotropic and moves downward through the soil, following the foliage to the bulb and then moving around the bulb to the basal plate. It has been recognized that the basal plate is the customary region of initial larval attack. Observations of many recently attacked bulbs have been classified according to the location of the entrance, and these data are presented in table 11.



TABLE 11.—*Region of entry into narcissus bulbs by newly hatched larvae of Merodon equestris, Olympia, Wash., 1935*

| Date        | Larvae entering bulb— |                         |                 |
|-------------|-----------------------|-------------------------|-----------------|
|             | In root ring          | Between slab and center | In other places |
|             | Number                | Number                  | Number          |
| May 31..... | 3                     | 0                       | 0               |
| June 6..... | 17                    | 0                       | 0               |
| 13.....     | 71                    | 4                       | 0               |
| 20.....     | 121                   | 3                       | 11              |
| 27.....     | 202                   | 4                       | 11              |
| Total.....  | 414                   | 11                      | 2               |

<sup>1</sup> Larva entered center of basal plate, 1 mm. from a decayed area.

<sup>2</sup> Larva entered bulb through rotted portion previously infested with *M. equestris*, and was in scale adjacent to this mass near center of bulb.

These observations demonstrate that the root ring around the periphery of the basal plate is the usual region of entry. Figure 18

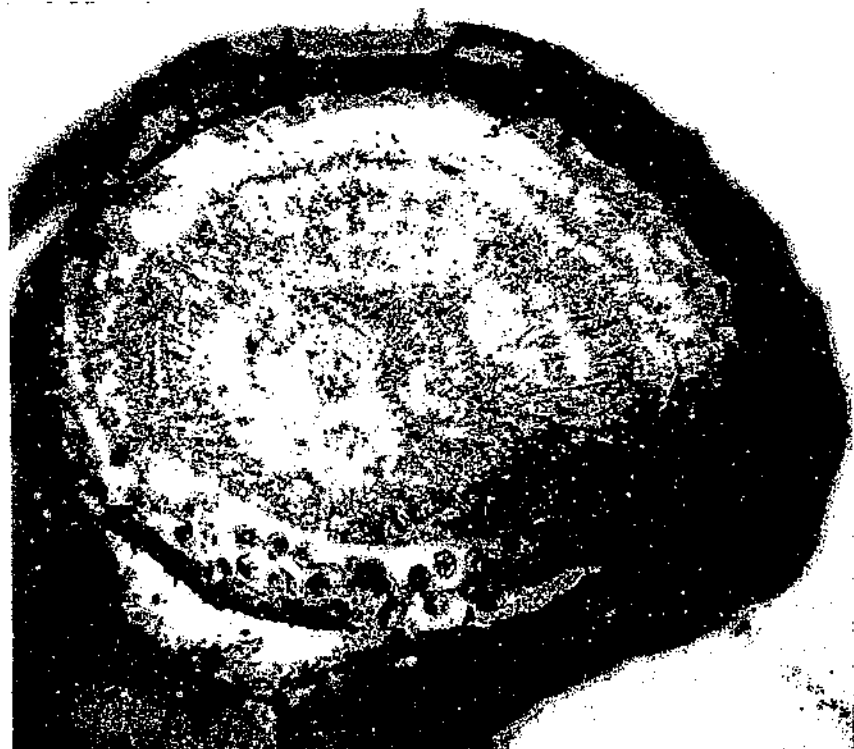


FIGURE 18.—Cross section of base of narcissus bulb revealing place of entry of a larva of the narcissus bulb fly in root ring,  $\times 3$ .

illustrates a typical entrance hole recently made in the root area of the basal plate of a bulb. Entrance between a slab and the center of a bulb is sometimes observed. This occurs in the mother-bulb type where the slabs are somewhat separated from the central portion,

and the larvae in their downward migration apparently get between these parts of the bulb. This type of entrance is shown in figure 19. In the course of these observations a few bulbs were encountered in which larval entrance was just being effected. When examined under magnification it was noted that the larva had apparently started its feeding in a root tissue before moving upward into the bulb. In figure 20 the root torn by an entering larva may be seen. Whether or not the larvae actually start in a root could not be observed in most cases, but the locations of most of the entrance holes in the root-ring area coincided with roots, and it is considered probable that the typical method of entrance is to start on a root and follow it inward. The nature of the tissue of the basal plate also would strengthen this supposition, for the root tissue would be of somewhat softer consistency than the surrounding basal plate tissue.



FIGURE 19. Entrance of a small larva of the narcissus bulb fly into the basal plate of a mother bulb between central portion and slab. The slab has been pulled off to reveal the nature of the entry,  $\times 5$ .

Occasionally a bulb is encountered in which a larva had fed on the outer scales. This type of feeding is seldom noticed in the earlier part of the season, but later, as the outer scales dry during the storage season, the injury is rather noticeable. The larva feeds within a single scale for some time, tunneling back and forth (fig. 21), and the larval path appears very similar to mines made in leaves by leaf-mining insects.

In the more usual manner of tunneling, after a larva has entered the basal plate through a root it changes the direction of its path to a more horizontal plane and begins a tunnel which tends to follow the root ring for a while but eventually may lead anywhere in the



FIGURE 20. Small larva of the narcissus bulb fly entering the basal plate of a narcissus bulb through a root, which the larva has torn for a short distance below the bulb,  $\times 6$ .

basal tissue (fig. 22). The tissue surrounding the tunnel becomes discolored for a radius of two or three times the tunnel's diameter. In almost all cases the larva remains in the basal plate until after its first molt. Soon after the second instar period begins the larva proceeds upward into the scale portion of the bulb (fig. 23) and there continues its feeding, enlarging the burrow, and destroying a very considerable amount of bulb tissue by the time it becomes mature (fig. 24).

The injury to the basal plate is serious, for this region is morphologically the stem of the plant and the destruction of it, or portions of it, interferes seriously with the transfer of nutriment from the roots or storage of reserves in the scales. Smaller bulbs are usually completely destroyed by the larval attack, but in larger bulbs, par-



FIGURE 21.—Mining by young larvae of the narcissus bulb fly in the outer scales of narcissus bulbs.

ticularly mother-bulb types, the injury is often concentrated in a slab or one side of the bulb, and the remainder of the bulb remains sound. Often portions of the basal plate may remain sound, and from these areas small bulbs may develop from adventitious growth points. Such bulbs require several years to reach normal size, and in commercial handling are usually discarded as substandard.

Infestation of a narcissus bulb is indicated externally by a depressed portion of the root ring around the basal plate. The tissue surrounding the point of attack becomes dark brown, and this discoloration extends over an irregular area of scale tissue adjacent to the sunken part of the periphery of the basal plate. The necrosis of the tissue associated with the larval feeding is responsible for the sunken and discolored condition. It is evident as soon as the bulbs are mature and at any time throughout the storage season. Shortly after a larva enters a bulb the roots in the area of entrance die and become shriveled and brown. After the bulbs are dug practical examination is facilitated by cleaning the bulb bases with a brush or by a light scraping with a knife blade.

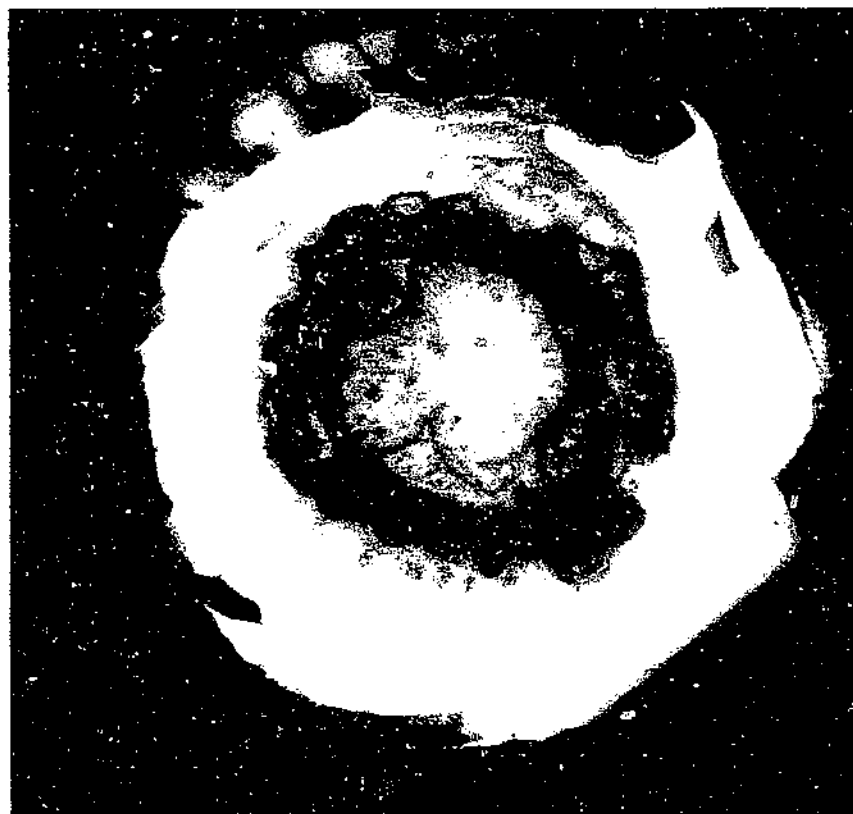


FIGURE 22. Cross section of basal plate of narcissus bulb revealing extensive tunneling by a larva of the narcissus bulb fly which has practically encircled the basal plate,  $\times 2$ .

#### MULTIPLE LARVAL INFESTATION

Only 1 larva is commonly found in an infested narcissus bulb. Occasionally, however, bulbs are noted with 2 or more larvae. In the course of life-history observations, control experiments, and infestation surveys a considerable number of infested bulbs have been examined. In these studies the presence of more than 1 larva in a bulb has always been recorded. The highest number of larvae found in a single bulb was 8. In this single occurrence the larvae were in a mother bulb of the variety *Twink*, with 2 large slabs and a large central section, 5 larvae being in the central portion, 2 in one slab, 1 in the other. One bulb was observed with 6 larvae, and 1 bulb has been noted with 5. The total number of infested bulbs considered in this study was 24,042. These contained larvae as follows:

| Number of larvae per bulb: | Number of bulbs |
|----------------------------|-----------------|
| 1                          | 22,491          |
| 2                          | 1,389           |
| 3                          | 141             |
| 4                          | 18              |
| 5                          | 1               |
| 6                          | 1               |
| 8                          | 1               |



FIGURE 23.—Vertical section of narcissus bulb indicating the movement of the young bulb fly larva into the scale tissue above the basal plate,  $\times 2$ .



FIGURE 24.--Vertical section of narcissus bulb revealing extensive injury resulting by the time the bulb fly larva has reached maturity,  $\times 2$ .

## ECONOMIC IMPORTANCE

Losses of narcissus bulbs have been reported at various times in major narcissus-growing regions. Bos (5) states that already in 1847, narcissus were suffering so much from the larvae of *Merodon*, near Haarlem, that the new malady of these bulbs was the subject of discussions at the meetings of the Netherlands Society for the development of the industry.

In England it was reported (2) in 1896 that a Cornwall grower had to destroy several thousand bulbs of *Narcissus stella*, *N. gloriosa*, and other varieties. MacDougall (24, p. 595), referring to Great Britain, says:

In different parts of the country great destruction of *Narcissus* bulbs has been reported, and the adult flies have now and again been caught in large numbers.

Verrall (36) adds:

many other records have been given in recent years of similar damage done near London and in other districts where bulbs are extensively cultivated.

Hewitt (18) in 1911 says:

In British Columbia, it is now a serious pest of bulbs, and Mr. A. E. Wallace reported it as attacking narcissus and daffodil bulbs near Victoria, B. C., about 50,000 bulbs having been destroyed in the year.

Treherne (34), referring to British Columbia, reported in 1915:

During the past spring I observed an extraordinary bad attack from this insect just outside the city limits of Vancouver. \* \* \* Furthermore, Mr. Tom Wilson, Dominion Inspector of Indian Orchards, informs me that less than 1 per cent of a large bed of daffodils \* \* \* at Yale, 150 miles inland, matured.

In 1932 Hodson (19) reported:

At the present time commercial growers in Britain are faced with yearly losses of many thousands of pounds worth of valuable bulbs as a direct outcome of fly infestations \* \* \*.

These reports, while not very specific, reflect the general impressions of the growers. Detailed data of the actual amount of infestation is generally lacking. In the Pacific Northwest sampling of commercial stocks for infestation has been followed for a number of years by the Summer, Wash., laboratory staff. In the earlier years the sampling was on a somewhat haphazard basis, but beginning in 1933 a definite plan of sampling was adopted whereby the results obtained would be on a comparable basis, both for locality and for year. Out of this developed a definite infestation survey which covered the major production areas in western Washington and western Oregon. Sampling was restricted to the variety King Alfred, as it is the principal variety grown and can be found in practically every commercial planting. In this variety examination was restricted to the double-nosed bulbs, which constitute the principal commercial grade selected for marketing purposes. Thus the influence of varietal and bulb-size factors was eliminated in the survey.

The usual practice in bulb handling is to grade the bulbs roughly when they have dried 2 weeks or more after the digging. This grading separates the commercial sizes from the planting stock. The commercial sizes may be separated to some extent in this first grading, or may be grouped together and graded more exactly a second time. Usually the bulbs being graded are carried by a slowly moving belt in front of several workers on the sides of a grading table. The dumping of miscellaneous crates of bulbs onto the belt mixes the stock





TABLE 12.—Infestation by *Merodon equestris* of narcissus bulbs, variety King Alfred, in commercial stocks grown in Washington and Oregon, 1931 to 1940

| Locality (State and county) | Stock No. | Year    |         |         |         |         |         |         |         |         |         |
|-----------------------------|-----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
|                             |           | 1931    | 1932    | 1933    | 1934    | 1935    | 1936    | 1937    | 1938    | 1939    | 1940    |
| Washington:                 |           |         |         |         |         |         |         |         |         |         |         |
|                             |           | Percent | Percent | Percent | Percent | Percent | Percent | Percent | Percent | Percent | Percent |
| Whatcom County              | 1         |         |         |         | 5.4     | 3.3     |         |         | 5.5     | 2.2     | 3.3     |
|                             | 2         |         |         |         |         |         |         |         | .8      |         |         |
|                             | 3         |         |         |         |         | 7.2     | 4.7     |         |         |         |         |
|                             | 4         |         |         |         | 10.0    | 6.8     |         |         |         |         |         |
|                             | 5         |         |         |         |         |         |         | .2      | 0       | 1.7     | .5      |
| Skagit County               | 6         |         |         |         |         |         |         |         | .1      |         |         |
|                             | 7         |         |         |         |         |         |         |         | 3.9     | 3.1     | 1.4     |
|                             | 8         |         |         |         |         |         |         |         | .2      |         |         |
| Island County               | 9         |         |         |         |         |         |         | 8.7     |         |         |         |
| King County                 | 10        |         |         |         |         | 5.8     |         |         | 5.9     |         |         |
|                             | 11        | 2.5     |         |         | 3.4     | 0       |         |         |         |         |         |
|                             | 12        | 2.3     |         |         |         | 1.4     | 5.8     | 3.5     | 6.3     | 1.5     | 9.8     |
|                             | 13        | 1.5     |         |         |         | .4      |         | 3.4     | .5      |         |         |
|                             | 14        | 1.1     |         |         |         | 4.0     |         |         |         |         |         |
|                             | 15        | 2.7     | 2.8     |         |         | 1.8     |         |         |         |         |         |
|                             | 16        | 3.5     |         |         |         | 8.5     | 7.3     | 6.8     | 20.8    | 10.1    | 6.8     |
|                             | 17        | 4.7     | 3.1     | 6.3     | 20.7    | 19.2    | 8.7     | 20.6    | 12.5    | 16.4    | 32.8    |
|                             | 18        | 2.9     |         |         |         | 4.4     |         |         | 6.4     | 1.3     | 2.9     |
|                             | 19        |         | 2.8     |         |         | 6.3     |         |         | 2.9     | 7.7     | 10.6    |
|                             | 20        |         | 23.9    |         | 18.8    |         |         |         |         |         |         |
|                             | 21        |         |         | .2      | 15.9    | 1.2     | 7.3     | 4.5     | 2.3     | 9.7     | 4.5     |
|                             | 22        |         |         |         |         | .7      |         | 6.3     |         |         |         |
| Pierce County               | 23        |         |         |         |         | 3.2     |         |         |         |         |         |
|                             | 24        |         |         |         |         | 13.0    |         |         |         |         |         |
|                             | 25        |         |         | 3.2     | 11.2    | 8.7     | 4.0     | 8.4     | 2.9     | 8.5     | 6.2     |
|                             | 26        |         |         | 2.0     |         |         |         |         |         |         |         |
|                             | 27        |         |         |         | 3.3     | 2.6     | 4.2     | 2.1     | 2.1     | 2.8     | 1.0     |
|                             | 28        |         |         |         |         |         |         | 1.8     | 2.1     |         |         |
|                             | 29        |         |         |         | 21.2    | 22.6    | 5.2     | 7.3     | 6.0     | 7.5     | 8.8     |
|                             | 30        |         |         |         |         | 1.4     | 1.4     | 1.2     | 1.3     | 2.5     | 3.1     |
|                             | 31        |         |         |         |         |         |         | 2.4     |         | 3.9     | 4.6     |
|                             | 32        |         |         |         |         | 5.3     |         |         |         |         |         |
|                             | 33        |         |         |         |         | 16.0    |         |         |         |         |         |
|                             | 34        |         |         |         |         | 34.5    |         |         |         |         |         |
|                             | 35        |         |         |         |         |         |         |         | 18.4    |         |         |
|                             | 36        |         |         |         |         |         |         |         | 1.2     | 2.8     | 3.7     |
|                             | 37        | 5.5     |         |         |         |         |         |         |         | 13.1    | 5.1     |
| Thurston County             | 38        |         |         | 1.8     | 8.2     | 5.8     |         |         |         |         |         |
|                             | 39        |         |         |         |         | 6.4     |         |         |         |         |         |
|                             | 40        |         |         |         |         |         |         | 15.3    |         |         |         |
| Grays Harbor County         | 41        |         |         |         |         | 0       |         |         |         |         |         |
| Cowlitz County              | 42        |         |         |         |         | 5.2     |         |         | .3      | .1      | .3      |
| Clark County                | 43        |         |         |         |         | 2.9     | 6.0     | 3.0     | .3      | .9      | 2.5     |
| Oregon:                     | 44        |         |         |         |         |         |         |         | 8.1     | 5.3     | 8.4     |
|                             | 45        |         |         | 1.0     | 3.8     | 2.5     | 4.7     | 5.4     | 4.8     | 7.0     | 7.5     |
|                             | 46        |         |         |         | 4.2     | 5.7     |         |         |         |         |         |
|                             | 47        |         |         |         | 4.0     | 2.1     | 2.6     | 2.6     | 3.2     | 4.7     | 17.6    |
| Multnomah County            | 48        |         |         |         | 3.5     | 4.0     |         |         |         |         |         |
|                             | 49        |         |         |         |         | 4.1     |         |         |         |         |         |
|                             | 50        |         |         |         |         |         | 4.8     | 2.4     |         |         |         |
|                             | 51        |         |         |         |         | .5      | 8.6     | 3.3     | 2.0     | 1.0     | 4.2     |
|                             | 52        |         |         |         |         | 2.3     |         |         |         | 4.3     | 3.8     |
| Clackamas County            | 53        |         |         |         |         | 3.6     |         |         |         |         |         |
| Washington County           | 54        |         |         |         |         | 3.2     | 4.6     |         |         | .6      | 5.2     |
| Marion County               | 55        |         |         |         |         | .5      |         |         |         |         |         |
|                             | 56        |         |         |         |         |         | 2.5     | .8      | .4      | .2      | 6.1     |
| Linn County                 | 57        |         |         |         | 5.8     |         | 12.9    |         | 9.8     | 6.2     | 21.4    |
| Benton County               | 58        |         |         |         |         | 0       |         |         |         |         |         |
| Douglas County              | 59        |         |         |         |         |         |         |         | 9.2     |         |         |
| Josephine County            | 60        |         |         |         |         | .3      |         |         |         |         |         |
| Clatsop County              | 61        |         | 3       |         |         |         |         |         |         |         |         |
|                             | 62        |         |         |         |         | 2.1     | 3.8     | 2.8     | 10.1    | 8.4     | 10.4    |
|                             | 63        |         |         |         | 1.6     | 3.2     |         |         | 16.4    |         |         |
| Tillamook County            | 64        |         |         |         |         |         |         |         | 20.5    |         |         |
|                             | 65        |         |         |         |         |         |         |         | 15.3    | 20.7    |         |
|                             | 66        |         |         |         |         |         |         |         | 21.3    |         |         |
| Lincoln County              | 67        |         |         |         |         |         | 0       | 0       | 0       | 1.1     | 24.2    |
|                             | 68        |         |         |         |         | 6.2     |         |         |         | .2      | .0      |
| Curry County                | 69        |         |         |         |         |         |         |         | 6.9     |         |         |
|                             | 70        |         |         |         |         |         |         |         | 3.4     |         |         |
|                             | 71        |         |         |         |         |         |         | 2.2     |         |         |         |

Previous to 1934 the examinations were somewhat scattered and insufficient to be used as a basis for general representation. The infestation data for 1934 and the following years have been weighted according to the sizes of the plantings represented, and general averages calculated for Washington and Oregon and for the combined areas. Thus the figures for 1939 represent stocks of King Alfred totaling 19,660,000 bulbs in Washington, of which 669,634 were infested, assuming that the infestation found in the samples was representative of the entire stock. This amounts to a general average infestation of 3.41 percent for the State. Likewise, in Oregon, in 1939, the samples represented stocks totaling 12,255,000 bulbs, of which 472,670, or 3.86 percent, were calculated as infested.

The weighted mean infestation in percentages for Washington and Oregon for the years 1934 to 1940 are shown in table 13. The figures for 1934 are somewhat biased because of a preponderance of examinations in the Puyallup Valley district, where infestation was somewhat high that year. There is a general range between approximately 2.5 percent and 4.5 percent from year to year.

TABLE 13.—Weighted mean infestation of narcissus bulbs in Washington and Oregon, 1934-40

| State                          | Average infestation of narcissus bulbs during year— |         |         |         |         |         |         |
|--------------------------------|---|---------|---------|---------|---------|---------|---------|
|                                | 1934  | 1935    | 1936    | 1937    | 1938    | 1939    | 1940    |
|                                | Percent   | Percent | Percent | Percent | Percent | Percent | Percent |
| Washington                     | 3.02  | 3.21    | 4.14    | 2.68    | 3.70    | 3.41    | 4.89    |
| Oregon                         | 3.03  | 2.03    | 4.61    | 3.01    | 5.42    | 3.86    | 7.71    |
| Washington and Oregon combined | 3.74  | 2.81    | 4.33    | 2.82    | 4.15    | 3.58    | 5.88    |

The total number of bulbs in commercial plantings in the two States is estimated as 90,000,000 in 1939. The number of infested bulbs in 1939 is calculated as 3,222,000. The value of this quantity of bulbs would be between \$75,000 and \$85,000 on a tonnage basis. It is further estimated that there are approximately 25,000,000 narcissus bulbs in noncommercial plantings, principally of an ornamental nature, either in home gardens or parks. The infestation in this type of plantings is decidedly higher than in commercial fields, and a minimum of 10 percent of these bulbs may be considered infested, or a total of 2,500,000. The replacement value of these infested bulbs would be approximately \$50,000. Thus, the total value would be over \$125,000. A conservative estimate of the yearly damage in the two States would be \$80,000 to \$100,000.

## FACTORS INFLUENCING DEGREE OF INFESTATION

### PREFERENCE FOR NARCISSUS VARIETIES

The number of narcissus varieties is so large that it precludes any practical efforts to evaluate their relative susceptibilities to infestation by *Merodon equestris*. In various articles concerning the insect, statements are frequently encountered that the flies apparently favored certain varieties. Hodson (19) states that he was unable to find confirmation of a suggestion that certain varieties or types were more susceptible and believed that the critical factor was almost certainly the ease or difficulty with which the flies could approach the bulbs for oviposition.

In the laboratory planting at Sumner a number of varieties have been under cultivation each year and in most seasons these have been examined to determine the amount of infestation present. In the data for the years 1930 to 1939, presented in table 14, the varieties are arranged each year according to decrease in infestation. The infestation in any variety varies considerably from year to year. One variety, Twink, seemed to be heavily infested year after year, except the first year it was included (1933), when only a small lot was grown. In the 1934 vapor-heat series 40 percent of the block of Twink became infested. Golden Sceptre on one side of Twink was only 7 percent infested and Majestic, on the other side, only 4 percent. In 1939 the infestation of 13 lots (50 bulbs each) of Twink planted more or less at random throughout the laboratory planting ranged from 38 to 72 percent as follows: 38, 44, 44, 46, 52, 52, 52, 54, 56, 56, 60, 66, 72. The mean infestation of these lots was 53.2 percent.

TABLE 14.—Infestation by larvae of *Merodon equestris* of various narcissus varieties in laboratory plot, Sumner, Wash., 1930-39

| Year and variety               | Classification type | Bulbs infested | Year and variety     | Classification type | Bulbs infested |
|--------------------------------|---------------------|----------------|----------------------|---------------------|----------------|
| 1930                           |                     |                | 1931                 |                     |                |
| Princess                       | 1c                  | 10.3           | Martha               | 1c                  | 26.5           |
| Golden Spur                    | 1a                  | 9.6            | Twink                | 10                  | 12.7           |
| Narcissus "Tetramorus plenus"  | 10                  | 7.7            | King Alfred          | 1a                  | 8.0            |
| Victoria                       | 1c                  | 7.6            |                      |                     |                |
| Emperor                        | 1a                  | 1.5            |                      |                     |                |
| Sir Watkin                     | 2a                  | 3.3            |                      |                     |                |
| Laurens Koster                 | 8                   | .6             |                      |                     |                |
| 1931                           |                     |                | 1932                 |                     |                |
| Martha                         | 1c                  | 21.4           | Twink                | 10                  | 40.0           |
| Golden Beauty                  | 1c                  | 14.9           | Emperor              | 1a                  | 23.0           |
| Sir Watkin                     | 2a                  | 12.4           | Aeroline             | 1a                  | 20.0           |
| Narcissus "Tetramorus plenus"  | 10                  | 11.7           | Sir Francis Drake    | 1a                  | 18.0           |
| Sulphur Phoenix                | 10                  | 10.8           | Laurens              | 9                   | 17.0           |
| Golden Spur                    | 1a                  | 8.5            | Orange Cup           | 8                   | 17.0           |
| Cervantes                      | 1a                  | 7.7            | Minister Tahnua      | 1a                  | 16.0           |
| Emperor                        | 1a                  | 7.4            | Livingston           | 1b                  | 15.0           |
| King Alfred                    | 1a                  | 7.5            | Sir Watkin           | 2a                  | 15.0           |
| Spring Glory                   | 1c                  | 6.4            | The First            | 1a                  | 15.0           |
| Princess                       | 1c                  | 6.0            | Tresserve            | 1a                  | 11.0           |
| Tresserve                      | 1a                  | 5.8            | Achilles             | 8                   | 10.0           |
| Laurens Koster                 | 8                   | 5.6            | Pacific Spur         | 1a                  | 10.0           |
| Minister Tahnua                | 1a                  | 5.2            | Victoria             | 1c                  | 10.0           |
| Victoria                       | 1c                  | 4.9            | Boppy                | 1c                  | 9.0            |
| 1932                           |                     |                | King Alfred          | 1a                  | 9.0            |
| Will Scarlett                  | 2b                  | 26.9           | Lucinus              | 2a                  | 9.0            |
| Golden Beauty                  | 1c                  | 25.6           | Grand Soleil d'Or    | 8                   | 8.0            |
| Sir Watkin                     | 2a                  | 19.7           | Golden Sceptre       | 7                   | 7.0            |
| Orange Cup                     | 8                   | 18.9           | Spring Glory         | 1c                  | 6.0            |
| Doris                          | 3b                  | 11.9           | Laurens Koster       | 8                   | 5.0            |
| King Alfred                    | 1b                  | 11.1           | Gloria of Sassenheim | 1c                  | 4.0            |
| Tresserve                      | 1a                  | 10.5           | Majestic             | 8                   | 4.0            |
| Emperor                        | 1a                  | 9.5            |                      |                     |                |
| Minister Tahnua                | 1a                  | 9.0            |                      |                     |                |
| Robert Sydenham                | 1a                  | 8.0            |                      |                     |                |
| Lord Kitchener                 | 4a                  | 7.7            |                      |                     |                |
| Victoria                       | 1c                  | 5.5            |                      |                     |                |
| Majestic                       | 8                   | 5.0            |                      |                     |                |
| Admiral (Hellas)               | 8                   | 1.1            |                      |                     |                |
| Golden Spur                    | 1a                  | 3.2            |                      |                     |                |
| Sir Francis Drake              | 1a                  | 3.2            |                      |                     |                |
| Narcissus poeticus flore pleno | 10                  | 3.1            |                      |                     |                |
| Narcissus odoratus varietal    | 7                   | 2.8            |                      |                     |                |
| Fraus Hals                     | 8                   | 2.6            |                      |                     |                |
| Gloria of Sassenheim           | 1c                  | 2.1            |                      |                     |                |
| Narcissus "Tetramorus plenus"  | 10                  | 2.0            |                      |                     |                |
| Silver Spur                    | 1c                  | 2.0            |                      |                     |                |
| Narcissus poeticus crandis     | 9                   | 1.4            |                      |                     |                |
| Spring Glory                   | 1c                  | 1.4            |                      |                     |                |
| Laurens Koster                 | 8                   | .9             |                      |                     |                |
| 1933                           |                     |                | 1934                 |                     |                |
| Twink                          | 10                  | 43.8           |                      |                     |                |
| King Alfred                    | 1a                  | 24.0           |                      |                     |                |

See footnotes at end of table.

TABLE 14.—*Infestation by larvae of Merodon equestris of various narcissus varieties in laboratory plot, Sumner, Wash., 1930-39—Continued*

| Year and variety    | Classification type | Bulbs infested | Year and variety      | Classification type | Bulbs infested |
|---------------------|---------------------|----------------|-----------------------|---------------------|----------------|
| <i>1936</i>         |                     |                | <i>1939</i>           |                     |                |
| Twink               | 10                  | Percent 46.4   | King Alfred           | 1a                  | 14.2           |
| King Alfred         | 1a                  | 0.4            | Juliet                | 9                   | 14.0           |
| Victoria            | 1c                  | 7.2            | Minister Talma        | 1a                  | 6.0            |
| Minister Talma      | 1a                  | 6.4            | <i>1939</i>           |                     |                |
| Glory of Sassenheim | 1c                  | 4.0            | Lady Moore            | 3b                  | 56.2           |
| Sir Watkin          | 2a                  | 1.2            | Juliet                | 9                   | 53.4           |
| <i>1937</i>         |                     |                | Twink                 | 10                  | 53.2           |
| Twink               | 10                  | 36.0           | Golden Sceptre        | 7                   | 52.5           |
| King Alfred         | 1a                  | 19.6           | Cheerfulness          | 10                  | 40.0           |
| <i>1938</i>         |                     |                | The First             | 1a                  | 46.0           |
| Twink               | 10                  | 29.5           | Victoria              | 1c                  | 45.7           |
| Sir Watkin          | 2a                  | 26.7           | Aerolite              | 1a                  | 42.6           |
| Sir Francis Drake   | 1a                  | 25.0           | Glory of Sassenheim   | 1c                  | 42.0           |
| Lady Moore          | 3b                  | 20.5           | Laureus               | 2a                  | 41.0           |
| The First           | 1a                  | 30.0           | Livingston            | 1b                  | 26.7           |
| Livingston          | 1b                  | 20.0           | Sir Watkin            | 2a                  | 26.0           |
| Victoria            | 1c                  | 18.0           | King Alfred           | 1a                  | 16.4           |
| Aerolite            | 1a                  | 16.0           | Minister Talma        | 1a                  | 14.0           |
|                     |                     |                | Mrs. Ernst H. Krelage | 1b                  | 3.0            |

<sup>1</sup> As grouped by The Royal Horticultural Society in Classified List of Daffodil Names.

In various plantings the infestation in several varieties has been noted, and these data are presented in table 15. The limited number of varieties involved in the examinations does not permit definite conclusions, but there are indications that possibly certain double varieties, including Twink, may be more susceptible to infestation than other varieties. Golden Phoenix (Butter and Eggs), a double type, was the most heavily infested variety in the Olympia planting in both years of sampling. The variety Cheerfulness, also a double, in the 1939 laboratory planting developed 49 percent infestation. Paralleling it in the next row the variety Mrs. Ernst H. Krelage developed only 3 percent infestation. Regarding infestation in double varieties Hodson (19) states that—

in the Tamar valley those growers who specialise in the colourless "Double white" frequently find this more seriously damaged than coloured cups such as "Ornatus" and "Horace."

TABLE 15.—*Infestation of narcissus bulbs by Merodon equestris in various plantings in western Washington*

PUYALLUP, 1928

| Name of variety                       | Classification type | Bulbs infested | Name of variety | Classification type | Bulbs infested |
|---------------------------------------|---------------------|----------------|-----------------|---------------------|----------------|
| <i>Percent</i>                        |                     |                | <i>Percent</i>  |                     |                |
| <i>Narcissus poeticus ornatus</i>     | 9                   | 20.1           | Victoria        | 1c                  | 5.2            |
| Sir Watkin                            | 2a                  | 13.9           | Emperor         | 1a                  | 4.5            |
| <i>Narcissus "Tetamonius plenius"</i> | 10                  | 7.7            | King Alfred     | 1a                  | 4.2            |
| Glory of Sassenheim                   | 1c                  | 6.8            | Laureus Koster  | 8                   | 4.0            |
| Golden Spur                           | 1a                  | 6.5            | Spring Glory    | 1c                  | 3.9            |

OLYMPIA, 1931

|                                       |    |      |                     |    |     |
|---------------------------------------|----|------|---------------------|----|-----|
| Golden Phoenix                        | 10 | 21.4 | King Alfred         | 1a | 5.5 |
| Emperor                               | 1a | 19.2 | Glory of Sassenheim | 1c | 5.0 |
| <i>Narcissus "Tetamonius plenius"</i> | 10 | 16.8 | Golden Beauty       | 1c | 5.0 |
| Princeps                              | 1c | 9.0  | Weardale Perfection | 1c | 3.5 |
| Olympia                               | 1a | 7.2  |                     |    |     |

TABLE 15.—*Infestation of narcissus bulbs by Merodon equestris in various plantings in western Washington—Continued*

## OLYMPIA, 1932

|                         |    |      |                                   |    |      |
|-------------------------|----|------|-----------------------------------|----|------|
| Golden Phoenix.....     | 10 | 39.0 | Golden Spur.....                  | 1a | 18.8 |
| Emperor.....            | 1a | 32.7 | Narcissus "Telamonius piens"..... | 10 | 18.1 |
| Victoria.....           | 1c | 32.5 | Stella.....                       | 2b | 16.3 |
| Laurens Koster.....     | 8  | 28.3 | Elvira.....                       | 5  | 13.0 |
| Pacific Spur.....       | 1a | 26.7 | Princes.....                      | 1c | 9.3  |
| Narcissus recurvus..... | 9  | 19.2 |                                   |    |      |

## TACOMA, 1932

|               |    |      |                  |    |      |
|---------------|----|------|------------------|----|------|
| Emperor.....  | 1a | 47.2 | King Alfred..... | 1a | 23.9 |
| Victoria..... | 1c | 44.4 | Golden Spur..... | 1a | 19.1 |

## SUMNER—HOME GARDEN, 1932

|                  |    |      |                    |    |      |
|------------------|----|------|--------------------|----|------|
| King Alfred..... | 1a | 23.1 | Juliet.....        | 9  | 10.0 |
| Emperor.....     | 1a | 22.3 | Martha.....        | 1c | 8.2  |
| Doris.....       | 3b | 16.6 | Spring Glory.....  | 1c | 5.0  |
| Tresserve.....   | 1a | 11.8 | Golden Beauty..... | 1c | 4.8  |
| Frans Hals.....  | 8  | 11.1 |                    |    |      |

## SUMNER—HOME GARDEN, 1934

|                                 |    |      |                   |    |      |
|---------------------------------|----|------|-------------------|----|------|
| King Alfred.....                | 1a | 72.8 | Emperor.....      | 1a | 47.4 |
| Narcissus porticus ornatus..... | 9  | 56.5 | Spring Glory..... | 1c | 37.9 |
| N. odoratus rugulosus.....      | 7  | 50.0 | Tresserve.....    | 1a | 33.3 |

<sup>1</sup> As grouped by The Royal Horticultural Society in Classified List of Daffodil Names.

In general it may be considered that the influence of the varietal factor on the degree of infestation is rather minor and is considerably overshadowed by environmental factors which influence the activities of the adult flies.

## BULB DEPTH

Several experiments were conducted to determine whether planting depth might have some influence on the infestation of the bulbs. Throughout this discussion the terms bulb depth, planting depth, and depth are used interchangeably to designate the distance of the base of the bulbs from the soil surface.

In the first series bulbs were planted in boxes at depths of 6, 8, and 10 inches, and by keeping the soil level with the top of the box the depths were maintained constant throughout the growing season. Larvae were allowed to hatch in the laboratory and then were either placed on the leaf slightly below the soil surface or allowed to drop down a crack near the leaves. Later the bulbs were dug and examined for infestation. A total of 525 larvae were placed in the soil over 369 bulbs. Infestation was found in 53 bulbs. The proportions of these in the several lots is presented in table 16.

TABLE 16.—*Infestation by larvae of Merodon equestris of narcissus bulbs planted at various depths, Sumner, Wash., 1933*

| Planting depth (inches) | Bulbs  | Larvae entering bulbs | Infestation |
|-------------------------|--------|-----------------------|-------------|
|                         | Number | Number                | Percent     |
| 6.....                  | 155    | 26                    | 17          |
| 8.....                  | 102    | 18                    | 18          |
| 10.....                 | 112    | 10                    | 9           |

In the second series comparison was made of the effect of depth in two types of soil, a peat and a silt, both of which are commonly used for narcissus growing. In this test eggs from caged adults were placed against the foliage of the bulbs at the soil surface, and after maturity of the bulbs they were examined for infestation. The results of this examination are given in table 17.

TABLE 17.—*Infestation by larvae of Merodon equestris of narcissus bulbs planted at various depths in peat and silt soils, western Washington, 1934-35*

| Bulb depth<br>(inches)                       | Bulbs         |          | Infestation | Larvae |         | Total<br>larval<br>mortality <sup>1</sup> |
|--|---------------|----------|-------------|--------|---------|---|
|  | Exam-<br>ined | Infested |             | Alive  | Missing |   |
| IN PEAT SOIL, 1934                           |               |          |             |        |         |   |
|  | Number        | Number   | Percent     | Number | Number  | Percent                                   |
| 4.....                                       | 92            | 25       | 27          | 17     | 8       | 32  |
| 6.....                                       | 88            | 21       | 24          | 20     | 1       | 5   |
| 8.....                                       | 93            | 20       | 22          | 16     | 4       | 20  |
| Total.....                                   | 273           | 66       | 24          | 53     | 13      | 20  |
| IN SILT, 1934                                |               |          |             |        |         |   |
|  | Number        | Number   | Percent     | Number | Number  | Percent                                   |
| 4.....                                       | 92            | 11       | 12          | 7      | 1       | 36  |
| 6.....                                       | 88            | 17       | 19          | 15     | 2       | 12  |
| 8.....                                       | 64            | 8        | 13          | 6      | 2       | 25  |
| Total.....                                   | 244           | 36       | 15          | 28     | 5       | 22  |
| Total at 4 inches                            | 184           | 36       | 20          | 24     | 12      | 33  |
| Total at 6 inches                            | 176           | 38       | 22          | 35     | 3       | 8   |
| Total at 8 inches                            | 157           | 28       | 18          | 22     | 6       | 21  |
| IN SILT, 1935                                |               |          |             |        |         |   |
|  | Number        | Number   | Percent     | Number | Number  | Percent                                   |
| 6.....                                       | 154           | 67       | 44          | 53     | 15      | 29  |
| 8.....                                       | 136           | 17       | 13          | 38     | 9       | 19  |
| 10.....                                      | 118           | 49       | 42          | 47     | 3       | 6   |
| Total.....                                   | 408           | 133      | 40          | 138    | 27      | 16  |
| IN FIELD WITH SURFACE LEVEL AND HILLED, 1935 |               |          |             |        |         |   |
|  | Number        | Number   | Percent     | Number | Number  | Percent                                   |
| 5 1/4 (soil level).....                      | 271           | 85       | 31          | 68     | 18      | 21  |
| 9 3/4 (soil hilled).....                     | 287           | 73       | 25          | 56     | 17      | 23  |

<sup>1</sup> Presumably dead and so recorded.

A third series of tests was made in 1935 comparing planting depths of 6, 8, and 10 inches in silt soil. In this series eggs obtained from caged adults were placed on the necks of bulbs. The data are also presented in table 17.

A somewhat different test was made with bulbs growing in the laboratory planting to determine the effect of keeping the soil hilled up around the necks of the bulbs. This in effect was a test of the influence of bulb depth. In six parallel rows three sections, each 10 feet long, were marked. Early in the spring as the leaf tips were breaking through the soil the winter hilling of alternate blocks was leveled. During the growing season the soil was carefully maintained on a hilled or level basis according to the plan. No artificial infestation was attempted, dependence being placed on natural infestation. In this series there were nine sections of bulb row in each of the two types of culture. At digging time the average depth of the bulbs in

each section was determined, and all the bulbs in each section were examined for infestation. The average depth of the bulbs with level culture was 5½ inches, and the bulbs where the soil was kept hilled up were at an average depth of 9½ inches. The infestation data obtained in this test are summarized in the lowest block of table 17.

Throughout these several experimental series the indications are that planting depths within practical limits (not more than 10 inches) do not affect the degree of infestation. In the one series in which a 4-inch depth was tested the natural larval mortality resulting at this shallow depth was much greater than in the bulbs at greater depths. This may have been associated with an earlier maturity of the bulbs and consequent earlier drying out of the basal tissue. Further tests would be desirable, however, to determine whether this was due to the shallow depth alone or whether other factors might have been involved.

### SOIL TYPE

In one of the experiments for bulb-planting depth two types of soil were used. One type, a peat soil, obtained from a bulb farm, is a true peat, with a rather low proportion of inorganic constituents. The other type was silty in nature, of river-deposit formation, rather high in sand. The infestation that developed in the bulbs in this experiment is tabulated in summarized form in the first two total lines of table 17.

These data indicate that greater infestations develop on peat soil than on silt. However, as there are numerous soil types this test is hardly more than a general indication that soil type may be a factor of some influence in the infestation of narcissus bulbs by larvae of *Merodon equestris*.

### LOCATION IN FIELD

Observations have indicated that bulbs in marginal areas of narcissus plantings appeared to be more heavily infested than the bulbs in the more central portions. Certain infestation data have been studied in connection with mapped plantings to determine the extent of the marginal influence.

The laboratory planting at Sumner, Wash., for the season of 1931-32 included a block of experimental tolerance tests. Most of a rectangular block 70 feet by 140 feet was planted with 253 lots of narcissus bulbs, which were all free of larval infestation at time of planting. The infestation of 246 of the 253 lots was determined and this information mapped. The block was arbitrarily zoned into 9 more or less concentric zones, approximately 5 feet wide. Zone 1 is the periphery of the area and zone 9 the central zone. The infestation percentages for each of the zones is presented in table 18.

TABLE 18.—Infestation by larvae of *Merodon equestris* in narcissus bulbs at Sumner, Wash., in 1932, tabulated according to position in planting

| Zone No. | Bulbs  |          |         | Infestation | Zone No. | Bulbs  |          |         | Infestation |
|----------|--------|----------|---------|-------------|----------|--------|----------|---------|-------------|
|          | Total  | Infested |         |             |          | Total  | Infested |         |             |
|          | Number | Number   | Percent |             |          | Number | Number   | Percent |             |
| 1        | 1,360  | 157      | 13.8    | 7           |          | 162    | 42       | 4.4     |             |
| 2        | 1,724  | 121      | 7.0     | 8           |          | 750    | 55       | 4.8     |             |
| 3        | 1,348  | 118      | 8.8     | 9           |          | 900    | 29       | 3.2     |             |
| 4        | 1,626  | 58       | 3.6     |             |          |        |          |         |             |
| 5        | 1,323  | 69       | 5.2     |             |          |        |          |         |             |
| 6        | 1,111  | 49       | 4.4     |             | Total    | 11,194 | 709      | 6.4     |             |



It is evident from the data that there is a distinct concentration of infestation in the outer zone (No. 1) and that the infestation becomes lower as the central areas are approached. An analysis of distribution of the infestation in zone No. 1 showed the northern edge to have an infestation of 28 percent and the southern edge 21 percent, whereas at the western edge of the planting the infestation was only 6 percent.

In a commercial planting containing several varieties, one variety, Seagull, was sampled for infestation in 1933 according to distance from the field edge. The rows ran all the way across the planting, and the three rows of this variety were in the central block. Each sample represented about 50 feet of row taken at the stated distances from the ends of the rows. The infestation observed was as follows:

| Location of sample:              | Infestation, percent |
|----------------------------------|----------------------|
| A. West edge of field.....       | 23.0                 |
| B. 120 yards from west edge..... | 4.7                  |
| C. 250 yards from west edge..... | .4                   |
| D. 400 yards from west edge..... | .8                   |

Sample D was at the approximate center of the entire planting. As in the previous case the infestation on the edge of the planting was much heavier than that in the more central portions.

Infestation in a moderate-sized planting was studied in 1932 by examination of samples of bulbs dug at various places throughout the area. The planting was laid out in the shape of a letter L. The long axis, extending north and south, was bordered on the east by a woods of moderately thick second-growth fir, sloping away from the bulb field and separated from the bulbs by a strip of grass and weeds ranging in width from 10 to 25 yards. An analysis of the infestation data has been made on the basis of position in relation to the eastern

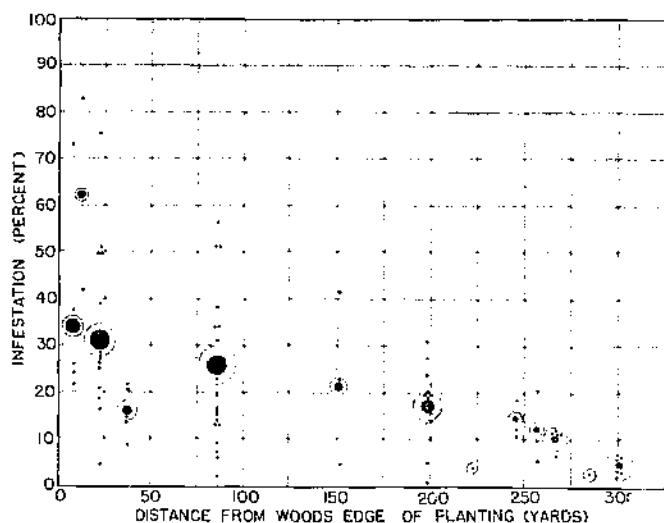


FIGURE 26. Relation between degree of infestation by *Merodon equestris* and distance from edge of planting adjacent to woods, Olympia, Wash., 1932. The circles represent the average infestation of the samples examined at the distances as indicated; the areas of the larger circles are proportional to the number of bulbs examined and the areas of the shaded inner circles are proportional to the number of larvae found.

edge, adjacent to the woods, and a very distinct influence of the woods on the distribution of the infestation is evident. The infestation is shown by varieties in table 19 and presented graphically in figure 26.

TABLE 19.—*Infestation by Merodon equestris in narcissus samples at various distances from woods at the eastern edge of a planting, Olympia, Wash., 1932*

| Variety                             | Infestation in samples selected at distances in yards from eastern, or woods, edge of planting |      |      |      |      |      |      |      |      |      |      |      |      |  |
|-------------------------------------|--|------|------|------|------|------|------|------|------|------|------|------|------|--|
|                                     | 7  | 12   | 25   | 35   | 85   | 150  | 200  | 220  | 245  | 255  | 270  | 285  | 300  |  |
|                                     | Pct.   | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |  |
| Golden Phoenix                      | 73   | 42   |      |      | 31   |      |      |      |      | 7    |      |      |      |  |
|                                     |  | 83   |      |      | 34   |      |      |      |      | 11   |      |      |      |  |
| <i>Narcissus recurvus</i>           | 38   |      |      | 20   | 15   |      |      |      | 11   | 6    |      |      |      |  |
|                                     | 22   |      |      |      | 19   |      |      |      | 12   | 9    |      |      |      |  |
|                                     |  |      |      |      |      |      |      |      | 18   | 20   |      |      |      |  |
| Golden Spur                         | 27   |      | 26   |      | 15   |      |      | 4    |      |      |      |      |      |  |
|                                     | 24   |      | 28   |      |      |      |      |      |      |      |      |      |      |  |
| Elvira                              |  |      |      |      | 9    | 5    | 14   |      |      |      |      |      |      |  |
|                                     |  |      |      |      | 7    | 7    | 19   |      |      |      |      |      |      |  |
|                                     |  |      |      |      | 6    |      |      |      |      |      |      |      |      |  |
|                                     |  |      |      |      | 16   |      |      |      |      |      |      |      |      |  |
| Stella                              |  |      | 19   |      | 12   |      |      |      |      |      |      |      | 4    |  |
|                                     |  |      | 4    |      |      |      |      |      |      |      |      |      | 5    |  |
|                                     |  |      | 77   |      |      |      |      |      |      |      |      |      | 1    |  |
| Princeps                            |  |      | 29   | 21   | 14   |      | 1    |      |      |      |      |      | 5    |  |
|                                     |  |      | 17   |      | 11   |      |      |      |      |      |      |      | 7    |  |
| <i>Narcissus "Telmoneus plenus"</i> |  |      | 22   |      | 38   |      | 27   |      |      |      | 11   |      | 3    |  |
|                                     |  |      | 27   |      |      |      | 19   |      |      |      | 11   |      |      |  |
|                                     |  |      |      |      |      |      |      |      |      |      | 12   |      |      |  |
|                                     |  |      | 40   |      | 16   |      | 23   |      |      |      |      |      |      |  |
| Victoria                            |  |      |      |      | 28   |      | 31   |      |      |      |      |      |      |  |
|                                     |  |      |      |      | 55   |      | 16   |      |      |      |      |      |      |  |
|                                     |  |      |      |      | 30   |      |      |      |      |      |      |      |      |  |
| Pacific Spur                        |  |      | 49   | 14   | 50   |      |      |      |      |      |      |      |      |  |
|                                     |  |      | 25   | 7    |      |      |      |      |      |      |      |      |      |  |
| Emperor                             |  |      | 50   | 14   | 34   |      |      |      |      |      |      |      |      |  |
|                                     |  |      | 49   |      |      |      |      |      |      |      |      |      |      |  |
| Laurens Koster                      |  |      |      |      | 50   | 41   | 19   |      |      |      |      |      |      |  |
|                                     |  |      |      |      |      | 22   | 14   |      |      |      |      |      |      |  |
|                                     |  |      |      |      |      |      | 20   |      |      |      |      |      |      |  |

All edges of a field do not necessarily exhibit increased infestation. The marginal influence is considered as being associated with two phases of adult bulb fly habits. The adults feed on pollen and nectar of various flowers and must search for these in areas outside the bulb planting. Also to a large extent, the adults' nocturnal habitat is in brushy or weedy growth, sometimes adjacent to the planting, occasionally at some distance. Consequently the adults are away from the narcissus plantings frequently, and it is quite natural for the females when approaching plantings to stop for ovipositional activities more frequently at the margins than in the inner areas.

A further factor of influence is the presence of windbreaks of any sort close to the edges of, or within, plantings. These cause conditions favorable to the adults, and the consequent concentration of the flies is reflected in an increased infestation in that immediate protected area.

#### BULB SIZE

In a number of instances bulbs of mixed sizes were examined for infestation. In these cases the bulbs were graded before examination and the data recorded separately according to the general grade size. Such data, which represent corresponding size groups from individual bulb lots, are presented in table 20. In this tabulation the sizes have

been grouped in two classes, termed large and small. The classification "large" includes the double-nosed grades and some mother bulbs. The term "small" refers almost entirely to round bulbs. The data compare the infestation of large and small sizes in 38 lots of narcissus bulbs examined during 7 seasons. The infestation of the large bulbs was 12.48 percent and of the small bulbs 7.10 percent. In 29 of the 38 lots the infestation of the large-sized bulbs was greater than that of the small-sized bulbs.

TABLE 20.—Comparative infestation of large and small sizes of narcissus bulbs by *Merodon equestris*, western Washington

| Year and variety               | Large bulbs   |               |                | Small bulbs   |               |                |
|--------------------------------|---------------|---------------|----------------|---------------|---------------|----------------|
|                                | Examined      | Infested      | Infestation    | Examined      | Infested      | Infestation    |
| <b>1931</b>                    | <i>Number</i> | <i>Number</i> | <i>Percent</i> | <i>Number</i> | <i>Number</i> | <i>Percent</i> |
| Emperor.....                   | 1,955         | 143           | 7.3            | 727           | 14            | 1.9            |
| Golden Beauty.....             | 138           | 8             | 5.8            | 95            | 3             | 3.2            |
| Golden Spur.....               | 674           | 59            | 8.8            | 1,747         | 98            | 5.6            |
| King Alfred.....               | 2,012         | 48            | 2.4            | 4,771         | 72            | 1.5            |
| Minister Talma.....            | 614           | 29            | 4.7            | 101           | 8             | 7.9            |
| Sir Watkin.....                | 795           | 85            | 11.1           | 118           | 1             | .8             |
| Spring Glory.....              | 214           | 13            | 6.1            | 86            | 2             | 2.3            |
| Tresserve.....                 | 148           | 5             | 3.4            | 169           | 8             | 4.7            |
| Victoria.....                  | 3,540         | 178           | 5.0            | 6,149         | 266           | 3.4            |
| <b>1932</b>                    |               |               |                |               |               |                |
| Emperor (M) <sup>1</sup> ..... | 750           | 43            | 5.7            | 485           | 26            | 5.4            |
| Emperor (R).....               | 255           | 169           | 66.3           | 100           | 62            | 62.0           |
| Golden Spur (G).....           | 2,000         | 69            | 3.5            | 3,090         | 82            | 2.1            |
| Golden Spur (R).....           | 340           | 58            | 17.1           | 475           | 90            | 18.9           |
| King Alfred (L).....           | 210           | 12            | 5.7            | 436           | 59            | 13.5           |
| Do.....                        | 338           | 23            | 6.8            | 1,080         | 74            | 6.9            |
| King Alfred (H).....           | 300           | 5             | 1.7            | 509           | 17            | 3.4            |
| Laurens Koster.....            | 531           | 3             | .6             | 564           | 2             | .4             |
| Pacific Spur.....              | 485           | 84            | 17.3           | 465           | 48            | 10.5           |
| Sir Watkin.....                | 81            | 32            | 39.5           | 199           | 39            | 19.1           |
| <b>1933</b>                    |               |               |                |               |               |                |
| King Alfred (L1).....          | 313           | 19            | 6.1            | 389           | 8             | 2.1            |
| King Alfred (L2).....          | 181           | 25            | 13.8           | 160           | 5             | 3.1            |
| King Alfred (L3).....          | 287           | 23            | 8.0            | 216           | 6             | 2.8            |
| King Alfred (L4).....          | 263           | 25            | 12.3           | 225           | 10            | 4.4            |
| Tresserve.....                 | 166           | 26            | 15.7           | 275           | 15            | 5.5            |
| <b>1934</b>                    |               |               |                |               |               |                |
| Glory of Sassenheim.....       | 515           | 33            | 6.4            | 361           | 16            | 4.4            |
| King Alfred.....               | 1,446         | 352           | 24.3           | 1,480         | 285           | 19.1           |
| Sir Watkin.....                | 487           | 232           | 47.6           | 70            | 22            | 27.8           |
| Spring Glory.....              | 231           | 101           | 43.7           | 179           | 53            | 29.4           |
| Tresserve.....                 | 139           | 80            | 57.6           | 199           | 58            | 29.1           |
| Victoria.....                  | 869           | 317           | 36.5           | 331           | 72            | 21.8           |
| <b>1935</b>                    |               |               |                |               |               |                |
| King Alfred (L).....           | 920           | 214           | 23.3           | 422           | 110           | 26.2           |
| King Alfred (W).....           | 343           | 37            | 7.9            | 220           | 6             | 2.7            |
| Twink.....                     | 128           | 74            | 57.8           | 527           | 211           | 40.0           |
| <b>1936</b>                    |               |               |                |               |               |                |
| King Alfred.....               | 1,040         | 82            | 8.1            | 238           | 27            | 11.3           |
| Minister Talma.....            | 165           | 11            | 6.7            | 163           | 10            | 6.1            |
| Twink.....                     | 174           | 90            | 56.0           | 175           | 63            | 36.0           |
| <b>1937</b>                    |               |               |                |               |               |                |
| King Alfred.....               | 318           | 32            | 10.1           | 37            | 4             | 10.8           |
| Twink.....                     | 185           | 85            | 45.9           | 340           | 101           | 30.6           |
| Total.....                     | 23,420        | 2,923         |                | 28,182        | 2,061         |                |
| Mean relative infestation..... |               |               | 12.48          |               |               | 7.10           |

<sup>1</sup> Letters in parentheses refer to the laboratory code differentiating stocks of the same variety.

An analysis of variance was made in order to show definitely whether these differences in infestation were due to chance variation or to a

real association between infestation and bulb size. This analysis determined that the mean difference of 5.8 had a standard error of 1.3, which made it evident that the bulb size had a highly significant effect on infestation.

It is very probable that the fact that the larger bulbs have more leaves and growth shoots than the smaller bulbs is responsible for the greater infestation. This larger number of leaves would be conducive to more egg deposition.

### NATURAL LARVAL MORTALITY

Larval mortality is discussed by Hodson (19) but his reference is to mortality of newly emerged larvae. Contrary to his observation that "premature death is very rare once a larva has entered a bulb and survived the first few weeks," it has been observed in the Pacific Northwest that a considerable number of larvae succumb after an apparently successful initiation of bulb attack. Bulbs in which such mortality occurs exhibit typical external basal symptoms of infestation. When the bulb is sectioned the course of the larva in the basal plate is quite distinct, and more or less of the basal-plate tissue and some scale tissue is found to have been killed (fig. 27). Usually the feeding and accompanying necrosis of bulb tissue are sufficiently ex-

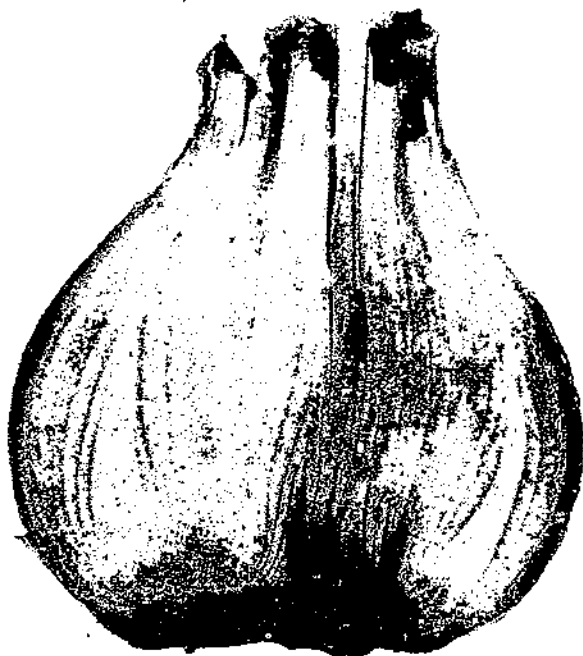


FIGURE 27.—Vertical section of a narcissus bulb, demonstrating extent of bulb injury caused by a larva of *Alerodon equestris* which was unsuccessful in maintaining itself for more than a few weeks.

tensive to destroy at least one growth region of the bulb. Adventitious buds may develop around the injured area, according to the amount of healthy basal-plate tissue remaining, but flower production is definitely impaired, and the bulb growth does not become normal until the second year of ensuing growth, or later. Observations indicate that environmental conditions are probably responsible for this phenomenon. In some instances larvae have been observed caught between the sides of their tunnels by an apparently rapid growth of a corky nature.

To determine the influence of commercial handling methods and certain environmental conditions a block of bulbs of the variety Golden Phoenix, known to be rather heavily infested, was dug and the bulbs placed in the conditions to be observed. Five different conditions were represented as follows:

- (1) Stored in a shed, protected from rain but with free air circulation.
- (2) Stored in a field stack of trays, subjected to some occasional light rains, but not exposed to direct sunlight.
- (3) Buried in a light sandy loam, containing enough moisture to be in good tilth but not particularly wet, and no attempt made to keep the soil damp.
- (4) Stored in moist peat moss in a box. The peat moss was maintained in a distinctly damp condition, and at the time of examination new roots several inches long were common.
- (5) Block of bulbs left undug until the end of the period of the test. The light, sandy soil was dry at the time this sample was dug.

The bulbs were dug (except lot 5) on July 10 and immediately placed in their test situations. They were examined for infestation during the first 10 days of September, and the results obtained from the examination are summarized in table 21.

TABLE 21.—Mortality of larvae of *Merodon equestris* occurring in bulbs subjected to various storage conditions

| Storage condition       | Larvae |        |        | Larval mortality<br>Percent |
|-------------------------|--------|--------|--------|-----------------------------|
|                         | Total  | Alive  | Dead   |                             |
|                         | Number | Number | Number |                             |
| (1) Shed storage        | 220    | 83     | 137    | 62.3                        |
| (2) Field stack         | 150    | 65     | 85     | 56.7                        |
| (3) Buried in silt loam | 180    | 107    | 73     | 40.6                        |
| (4) In moist peat       | 240    | 151    | 89     | 37.1                        |
| (5) Left in soil        | 340    | 245    | 95     | 27.9                        |

The difference in resulting mortality between storage in the shed and in a field stack is small, and there was little difference in the mortality in the two lots buried in silt soil and in moist peat. The difference between tray storage, (1) and (2), and soil "storage," (3) and (4), is marked. Also, the sample which was not dug until the end of the experimental period had the least mortality, quite a bit less than those bulbs dug earlier and replaced in soil. This indicates that a disturbance factor is associated with digging that causes a certain amount of larval mortality. The factor of drying in storage also seems to be important in causing mortality.

Further experimental work was conducted to determine the influence of the storage period and of the digging date. Samples of bulbs of *Narcissus recurvus* were dug at weekly intervals from an abandoned planting in which the bulbs had been in the ground at least 4 years. Each sample was stored at the laboratory for 1

month after it was dug and was then thoroughly mixed and divided into two portions. One half was examined for infestation and larval mortality and the other half replaced and held in storage until the end of the storage season (late in September). A summary of the data is presented in table 22.

TABLE 22.—*Natural mortality of larvae of Merodon equestris in samples of narcissus bulbs dug at weekly intervals and examined 1 month after digging and at the end of the storage season, Sumner, Wash., 1936*

| Date of digging | Mortality in storage for 1 month | Mortality in various storage periods from date of digging to end of storage |           |         | Date of digging | Mortality in storage for 1 month | Mortality in various storage periods from date of digging to end of storage |           |         | Increased mortality in storage to the end of the season |
|-----------------|----------------------------------|---|-----------|---------|-----------------|----------------------------------|---|-----------|---------|---|
|                 |                                  | Actual storage period   | Mortality | Percent |                 |                                  | Actual storage period   | Mortality | Percent |   |
|                 | Percent                          | Weeks   | Percent   | Percent |                 | Percent                          | Weeks   | Percent   | Percent |   |
| June 24         | 85                               | 14  | 90        | 14      | Aug. 12         | 83                               | 8   | 89        | 6       |   |
| July 1          | 91                               | 12  | 98        | 4       | 19              | 77                               | 7   | 89        |         |   |
| 8               | 83                               | 12  | 97        | 14      | 26              | 80                               | 7   | 83        | 12      |   |
| 15              | 77                               | 12  | 85        | 18      | Sept. 2         |                                  | 5   | 88        | 2       |   |
| 22              | 78                               | 11  | 94        | 16      | 9               |                                  | 4   | 85        |         |   |
| 29              | 79                               | 10  | 91        | 12      | 17              |                                  | 3   | 79        |         |   |
| Aug. 5          | 68                               | 9   | 87        | 19      | 23              |                                  | 2   | 76        |         |   |

In this experiment small darkly stained areas in the root-ring area of the basal plate were considered as having been caused by unsuccessful larval attack, and such spots were counted as cases of larval mortality. Also, the bulbs, having been in the ground for 4 or more years, were naturally small and dried quickly after the digging. These two factors were largely responsible for the very high mortality reported throughout this series of tests. The mortality after 1 month of storage following the digging varied irregularly, and there is no indication that the digging date in itself exerted any influence on mortality. The mortality at the end of the storage season is highest in those lots dug earliest, and a decreasing trend is indicated in this part of the data. Thus earlier digging dates exert a certain amount of influence because of the consequent increase in the storage period. The study indicates that the earlier part of the larval life is the more critical period.

Through several seasons of the larval-development studies, samples of infested bulbs were collected at intervals from an undisturbed narcissus planting. When these bulbs were examined for infestation notations were made of those bulbs in which larval attack had attained an apparently satisfactory start but in which no larvae could be located. Very slight symptoms indicating possible failure of larvae to become well established were not considered, as there were no intergrading degrees of injury, and such very slight injury would indicate that the larva had only partially entered the bulb tissue. The difficulty of interpreting such symptoms after a considerable lapse of time made it advisable to ignore this type. The type of injury considered sufficiently extensive to be included in the data of table 23 indicated a minimum feeding period of 2 or 3 weeks, and the larval burrow could easily be discerned. The data concerning the mortality observed in these interval larval samples are summarized in table 23.

TABLE 23.—Seasonal occurrence of natural mortality of larvae of *Merodon equestris* in narcissus bulbs dug at intervals during the season of principal larval activity in Olympia, Wash., 1935 to 1938

| LARVAE OF 1935 ORIGIN |              |                   |              |                  |         |              |                   |              |                  |
|-----------------------|--------------|-------------------|--------------|------------------|---------|--------------|-------------------|--------------|------------------|
| Date                  | Total larvae | Larvae considered |              | Larval mortality | Date    | Total larvae | Larvae considered |              | Larval mortality |
|                       |              | Successful        | Unsuccessful |                  |         |              | Successful        | Unsuccessful |                  |
| 1935                  | Number       | Number            | Number       | Percent          | 1935    | Number       | Number            | Number       | Percent          |
| May 31                | 3            | 3                 | 0            | .0               | Sept. 5 | 272          | 108               | 74           | 27.2             |
| June 6                | 17           | 17                | 0            | .0               | 12      | 109          | 137               | 62           | 31.2             |
| 13                    | 75           | 75                | 0            | .0               | 19      | 222          | 170               | 52           | 23.4             |
| 20                    | 125          | 125               | 0            | .0               | 26      | 175          | 119               | 56           | 32.0             |
| 27                    | 206          | 206               | 0            | .0               | Oct. 11 | 210          | 137               | 73           | 34.8             |
| July 5                | 272          | 272               | 0            | .0               | 25      | 221          | 146               | 75           | 33.9             |
| 11                    | 284          | 284               | 0            | .0               | Nov. 8  | 212          | 133               | 79           | 37.3             |
| 18                    | 217          | 203               | 14           | 6.5              | 21      | 148          | 87                | 61           | 41.2             |
| 25                    | 270          | 230               | 40           | 14.8             | Dec. 6  | 214          | 151               | 63           | 29.4             |
| Aug. 3                | 281          | 238               | 43           | 15.3             | 20      | 215          | 154               | 61           | 28.4             |
| 10                    | 237          | 184               | 53           | 22.4             | 1936    |              |                   |              |                  |
| 16                    | 238          | 194               | 44           | 18.5             | Jan. 27 | 210          | 120               | 90           | 42.9             |
| 24                    | 235          | 188               | 47           | 20.0             | Feb. 28 | 173          | 116               | 57           | 32.9             |
| 20                    | 221          | 187               | 34           | 15.4             |         |              |                   |              |                  |
| LARVAE OF 1936 ORIGIN |              |                   |              |                  |         |              |                   |              |                  |
| 1936                  |              |                   |              |                  | 1936    |              |                   |              |                  |
| May 28                | 4            | 4                 | 0            | .0               | Aug. 21 | 138          | 112               | 26           | 18.8             |
| June 4                | 17           | 17                | 0            | .0               | 28      | 181          | 143               | 38           | 21.0             |
| 11                    | 46           | 46                | 0            | .0               | Sept. 3 | 172          | 128               | 44           | 25.6             |
| 18                    | 95           | 95                | 0            | .0               | 11      | 158          | 113               | 45           | 28.5             |
| 25                    | 101          | 101               | 0            | .0               | 21      | 192          | 149               | 52           | 27.1             |
| July 2                | 130          | 120               | 1            | .8               | 24      | 149          | 118               | 31           | 20.8             |
| 9                     | 133          | 133               | 0            | .0               | Oct. 1  | 167          | 133               | 34           | 20.4             |
| 16                    | 139          | 133               | 6            | 4.3              | 8       | 120          | 88                | 32           | 26.7             |
| 23                    | 165          | 156               | 9            | 5.5              | 15      | 164          | 129               | 35           | 21.3             |
| 30                    | 179          | 168               | 11           | 6.1              | 22      | 180          | 109               | 71           | 39.4             |
| Aug. 6                | 155          | 138               | 17           | 11.0             | Nov. 5  | 195          | 150               | 45           | 23.1             |
| LARVAE OF 1937 ORIGIN |              |                   |              |                  |         |              |                   |              |                  |
| 1937                  |              |                   |              |                  | 1937    |              |                   |              |                  |
| June 10               | 7            | 7                 | 0            | .0               | Sept. 9 | 137          | 107               | 30           | 21.9             |
| 17                    | 23           | 23                | 0            | .0               | 24      | 105          | 85                | 20           | 19.0             |
| 24                    | 56           | 56                | 0            | .0               | Oct. 8  | 148          | 121               | 27           | 18.2             |
| July 1                | 85           | 85                | 0            | .0               | 21      | 99           | 81                | 18           | 18.2             |
| 8                     | 116          | 114               | 2            | 1.7              | Nov. 5  | 184          | 154               | 30           | 16.3             |
| 15                    | 121          | 103               | 18           | 14.9             | 19      | 205          | 149               | 56           | 27.3             |
| 22                    | 196          | 175               | 21           | 10.7             | Dec. 2  | 142          | 102               | 40           | 28.2             |
| 29                    | 190          | 173               | 17           | 8.9              | 16      | 127          | 92                | 35           | 27.6             |
| Aug. 12               | 178          | 154               | 24           | 13.5             |         |              |                   |              |                  |
| LARVAE OF 1938 ORIGIN |              |                   |              |                  |         |              |                   |              |                  |
| 1938                  |              |                   |              |                  | 1938    |              |                   |              |                  |
| July 8                | 178          | 162               | 16           | 9.0              | Aug. 5  | 220          | 151               | 69           | 31.4             |
| 22                    | 190          | 145               | 45           | 23.7             |         |              |                   |              |                  |

From these data it is seen that the larval mortality begins each season about the middle of July and increases at a fairly even rate until the middle of September, when it appears to reach an approximate level.

The extent of natural mortality has also been determined in many commercial stocks of narcissus bulbs in the principal bulb-producing areas in Washington and Oregon (fig. 25). This information has been obtained in connection with the infestation survey which has been carried out for several seasons. Bulbs exhibiting symptoms of infestation, obtained from the survey sampling of double-nosed King Alfred bulbs, were cut open to determine the larval status. The data are presented in table 24.

TABLE 24.—*Natural mortality of larvae of Merodon equestris in commercial stocks of narcissus bulbs, double-nosed size, variety King Alfred, grown in Washington and Oregon, 1934-39*

| Locality (State and county) | Stock number | Mortality of larvae observed in — |         |         |         |         |         |
|-----------------------------|--------------|-----------------------------------|---------|---------|---------|---------|---------|
|                             |              | 1934                              | 1935    | 1936    | 1937    | 1938    | 1939    |
| Washington:                 |              | Percent                           | Percent | Percent | Percent | Percent | Percent |
| Clark County                | 1            |                                   | 27      | 67      | 23      | 39      | 21      |
| Cowlitz County              | 1            |                                   | 73      |         |         | 67      | 78      |
| Grays Harbor County         | 2            |                                   |         |         |         | 67      | 100     |
| Island County               | 1            |                                   | 71      |         |         |         |         |
| King County                 | 1            |                                   |         |         |         | 51      |         |
|                             | 1            | 27                                |         | 17      |         | 52      | 87      |
|                             | 2            |                                   |         |         | 38      | 33      |         |
|                             | 3            |                                   |         |         | 27      |         |         |
|                             | 5            |                                   |         | 17      | 31      | 21      | 25      |
|                             | 7            | 20                                | 12      | 12      | 19      | 8       | 31      |
|                             | 8            |                                   | 52      |         |         |         | 15      |
|                             | 9            |                                   | 66      |         |         | 45      | 47      |
|                             | 10           | 21                                |         |         |         |         |         |
|                             | 11           | 24                                | 36      |         |         | 61      | 34      |
| Pierce County               | 12           |                                   |         | 13      | 23      |         |         |
|                             | 13           |                                   | 57      |         |         |         |         |
|                             | 14           |                                   |         |         | 19      |         |         |
|                             | 15           |                                   |         | 40      | 40      | 52      | 21      |
|                             | 17           | 24                                | 27      | 30      | 41      | 71      | 45      |
|                             | 18           |                                   |         |         | 21      | 76      |         |
|                             | 19           |                                   | 35      | 38      | 61      | 37      | 24      |
|                             | 20           |                                   | 36      | 21      | 56      | 31      | 36      |
|                             | 21           |                                   |         |         | 33      |         | 26      |
|                             | 22           |                                   | 57      |         |         |         |         |
|                             | 24           |                                   | 60      |         |         |         |         |
|                             | 25           |                                   |         |         |         | 38      |         |
|                             | 27           |                                   |         |         |         |         | 13      |
| Skagit County               | 1            |                                   |         |         | 50      |         |         |
|                             | 2            |                                   |         |         |         | 100     |         |
|                             | 3            |                                   |         |         |         | 55      | 58      |
|                             | 4            |                                   |         |         |         | 100     |         |
|                             | 5            |                                   |         |         | 28      |         |         |
| Thurston County             | 2            | 21                                | 49      |         |         |         |         |
|                             | 3            |                                   | 55      |         |         |         |         |
|                             | 4            |                                   |         |         |         | 52      |         |
| Whateam County              | 1            | 21                                | 32      |         |         | 48      | 27      |
|                             | 2            |                                   |         |         |         | 75      |         |
|                             | 3            |                                   | 41      | 16      |         |         |         |
|                             | 4            | 19                                | 36      |         |         |         |         |
| Oregon:                     |              |                                   |         |         |         |         |         |
| Benton County               | 1            |                                   |         |         |         | 41      |         |
| Clackamas County            | 1            |                                   | 43      |         |         |         | 56      |
|                             | 2            |                                   | 41      | 15      |         |         |         |
| Clatsop County              | 1            |                                   | 55      | 26      | 29      |         | 35      |
|                             | 1            |                                   | 31      |         |         |         |         |
| Curry County                | 2            |                                   |         |         |         | 61      |         |
|                             | 3            |                                   |         |         |         | 44      |         |
|                             | 4            |                                   |         |         | 17      |         |         |
| Douglas County              | 1            |                                   | 67      |         |         |         |         |
| Lincoln County              | 1            |                                   |         |         |         |         | 36      |
|                             | 2            |                                   |         |         |         |         | 50      |
| Marion County               | 1            |                                   |         | 36      |         |         | 87      |
|                             | 2            | 36                                |         |         |         |         |         |
|                             | 1            | 16                                | 30      | 19      | 15      |         | 14      |
|                             | 2            | 48                                | 36      |         |         |         |         |
|                             | 3            | 50                                | 24      | 19      | 42      | 33      | 35      |
|                             | 4            | 79                                | 14      |         |         |         |         |
| Multnomah County            | 5            |                                   | 39      |         |         |         |         |
|                             | 6            |                                   | 25      |         |         |         |         |
|                             | 7            |                                   |         | 29      | 42      |         | 27      |
|                             | 8            |                                   | 50      | 20      | 29      |         | 33      |
|                             | 9            |                                   | 22      |         |         |         |         |
|                             | 1            |                                   | 19      |         |         |         |         |
| Tillamook County            | 3            |                                   |         |         |         | 29      | 15      |
| Washington County           | 1            |                                   | 80      | 15      | 13      | 50      |         |

Although the data from the several stocks are hardly comparable because of the great variation in such conditions as digging date, type of storage, climate, date of examination, etc., arithmetical means



have been calculated for each year to furnish an indication of the approximate mortality occurring in the different years. These means are as follows:

| Year:   | Mean of natural mortality percentages |
|---------|---------------------------------------|
| 1934... | 32                                    |
| 1935... | 42                                    |
| 1936... | 25                                    |
| 1937... | 32                                    |
| 1938... | 51                                    |
| 1939... | 38                                    |

It is evident that in the Pacific Northwest a very appreciable proportion of the larvae that enter bulbs are not able to continue their development to maturity. The factors involved in this phenomenon have not been definitely determined, but they are principally conditions of environment. The moisture aspect of the environment is probably the most important. Possibly the factors involved in retardation of larval development may be the same as those involved in larval mortality, but with the retarded larvae being subjected to the conditions in lesser degree of intensity than those larvae that succumb.

#### NATURAL ENEMIES

Very few natural enemies of the narcissus bulb fly have been observed. Occasionally, in the course of collecting pupal samples, puparia have been found with the end broken off and pinched and the contents gone. In a few instances when birds have found entry into



FIGURE 28. —Parasite *Rhembobius abdominalis* emerging from puparium of the narcissus bulb fly,  $\times 5$ .

cages, pupae eaten by them have been left in this same condition, so it has been assumed that such puparia found in the field show the results of feeding by birds. These have been noted so infrequently that it does not appear to be a factor of any particular importance.

Only once has a parasite been found attacking the narcissus bulb fly. In 1927 at Sumner, Wash., a quantity of bulbs that had been forced in a greenhouse were dumped outside during the latter part of February. Larvae in the bulbs migrated to the surface of the pile of soil and bulbs, where they pupated. The soil surface was examined and 206 puparia were collected. These were kept inside to furnish a supply of adults. Eleven ichneumonid parasites emerged from these puparia (fig. 28) and these were determined by R. A. Cushman (11) as *Rhembobius* (*Phygadeuon*) *abdominalis* Prov. Examination of all the puparia from this lot that failed to produce adult bulb flies revealed that 16 others had been parasitized but the parasite adult had failed to emerge. Thus a total of 27 of the 206 pupae collected, or 13 percent, were parasitized. An adult ichneumonid which had emerged from a puparium of *Eumerus* sp. in Santa Cruz, Calif., in 1926 was also determined by Cushman as the same species. This parasite has not been encountered since, however, nor has any evidence of any other parasitic form been obtained in the course of the studies.

### SUMMARY

The narcissus bulb fly has become one of the major insect pests confronting the recently expanded narcissus bulb industry in the Pacific Northwest, and losses are experienced every season by practically every grower.

Three larval instars are indicated by the sizes of the individuals and the widths of the spiracular processes. The skin of the mature larva hardens to form the pupal case. The adult bears a strong resemblance to a bumblebee.

The eggs are laid at the base of the foliage or in a crack in the soil nearby. The incubation period is generally from 10 to 12 days.

Normally the narcissus fly requires 1 year for the development of a generation. Newly hatched larvae enter the bulbs late in May and in June and develop through three instars to mature size by late September or October, passing through the winter as larvae still within the bulbs. The mature larvae leave the bulbs early in spring and pupate close to the soil surface, and the adults emerge in May and June. For some individuals, larval development is retarded during the first summer, so they pass through the first winter as early second instars, or less frequently as early third instars. These immature larvae continue development during the second spring and summer, reaching mature size in the middle of or late in summer, remaining as larvae in the bulbs through the second winter and pupating the next spring.

Larvae attack bulbs immediately after they have hatched, usually entering through the root ring into the basal plate, where they feed for some time, tunneling through the tissue. Later they burrow upward into the scale region, eventually consuming a large part of the bulb. Usually only one larva is present in a bulb, but occasionally two may be present and rarely three or four. Single records of five, six, and eight larvae per bulb have been noted.

Narcissus is the principal host affected economically, but infestation has been recorded in a number of bulbous plants, and some of these may become hosts of general importance.

The general average infestation of narcissus in the Pacific Northwest has ranged between 2.5 and 4.5 percent during the seasons of 1934 to 1940 and the value of the infested bulbs in this region is estimated at \$80,000 to \$100,000 each year.

No positive preference for particular narcissus varieties has been observed, although indications have been noted that the fly may prefer certain varieties under certain conditions.

Depth of bulb planting and type of soil in which bulbs are grown influence to some extent the amount of infestation. Infestation has been observed to be more intense on the margins of plantings than in the central areas, and infestation has been observed to be distinctly greater in large than in bulbs of smaller size.

An important proportion of larvae succumb to certain influences, presumably environmental, in the earlier stages of development. In commercial stocks the proportion of this natural larval mortality has averaged between 25 and 51 percent of the larvae successfully entering the bulbs.

Only one instance of parasitization has been observed, involving an ichneumonid, *Rhombobius abdominalis*. Birds may possibly find and destroy a small number of pupae. Natural enemies have not yet become a factor of importance in the Pacific Northwest.

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