4-1960

Insect Pollinators of Carrots in Utah

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pollinators of carrots in utah

by GEORGE E. BOHART and WILLIAM P. NYE
ACKNOWLEDGMENTS are due M. D. Levin and L. R. Hawthorn, both of the Agricultural Research Service, who helped plan and carry of the experiments of which these observations are a part. S. F. McClellan, Takeshi Miura, and W. A. Trost, graduate students at Utah State University, made most of the many observations. Determinations of the carrot pollinators were made by taxonomic specialists of the Entomology Research Division and by W. D. Field, H. A. Scullen, R. M. Bohart, H. E. Evans, M. T. James, and the senior author.

The authors are both entomologists with the Entomology Research Division, Agricultural Research Service, U. S. Department of Agriculture. They are stationed on the Utah State University Campus and work cooperatively with the Agricultural Experiment Station.

Title on cover picture should read: Left, a drone fly (Tubifera tenax), one of the most abundant and efficient carrot pollinators on the experimental plots at Logan. Upper right, pollen-collecting honey bee. Note intimate contact of body and flower cluster. Lower right, nectar-collecting honey bee. There is only slight contact between body and flower cluster.
IN THE course of observation at Logan, Utah, on the occurrence and pollinating activities of insects on carrots grown for seed, 334 species representing 71 families, were collected. Most numerous in species were the hymenopterous families and superfamilies Sphecidae, Apoidea, Psammocharidae, Vespidae, and Ichneumonidae, and the dipterous families Syrphidae, Tachinidae, Bombyliidae, Stratiomyidae, and Sarcophagidae. Most numerous in individuals were the dipterous families Syrphidae, Ceratopogonidae, Chloropidae, and Piophilidae and the coleopterous family Coccinellidae. Families and superfamilies represented by the most efficient pollinators were Apoidea, Sphecidae, Syrphidae, and Stratiomyidae. Abundance times efficiency was used as a pollination index for each species. On this basis the most important genera of Apoidea were *Apis*, *Andrena*, *Halictus*, *Chloralictus*, and *Colletes*; of Sphecidae, *Cerceris*, *Lindenius*, *Philanthus*, *Nysson*, and *Sceliphron*; of Syrphidae, *Syritta* and *Tubifera*; of Stratiomyidae, *Eulalia* and *Stratiomys*.

Honey bees (*Apis mellifera* L.) were efficient pollinators, but they were only minor factors in the Logan area because of their scarcity on carrot flowers. In most areas a combination of honey bee colonies adjacent to carrot seed fields and elimination of competing bloom may be the most practical method of increasing carrot pollination.
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<td>Coleoptera</td>
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<tr>
<td>Lepidoptera</td>
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<td>Hemiptera</td>
<td>15</td>
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<td>Homoptera</td>
<td>15</td>
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<td>Neuroptera</td>
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<tr>
<td>Dermaptera</td>
<td>16</td>
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<tr>
<td>Thysanoptera</td>
<td>16</td>
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</tbody>
</table>
INSECT POLLINATORS OF CARROTS IN UTAH

by

George E. Bohart and William P. Nye

From 1954 to 1957 aspects of carrot pollination were studied at Logan, Utah. The results of the work in 1954 were reported by Hawthorn et al.¹ The present paper discusses the occurrence and pollinating efficiency of the many species of insects that visited flowers on the open plots each year.

That insect pollination is necessary for satisfactory yields of carrot seed was clearly demonstrated by the work in 1954. It was also shown that tiny Diptera, which are usually abundant on carrot flowers, can set a substantial amount of seed, although not nearly as much as the larger Diptera and Hymenoptera. Seed yields were satisfactory in the open plots, but slightly better in plots caged with colonies of honey bees. In subsequent years results of the first year were generally substantiated. However, in 1957, when insect populations in the open plots were much lower than previously, there was a large gap between the yields in the open plots and those caged with honey bees.

DESCRIPTION OF AREA

The work was carried on at three locations near Logan, each offering diverse habitats for insects. In 1954 and 1956 the plots were located a mile north of Logan, where the surrounding land is used principally for dairying; to the west there were several artesian springs and alkaline meadows and hummocks, and to the east foothills with sagebrush, small orchards, and scattered suburban development. In 1955 the plots were a mile farther east, more isolated from the alkaline areas, and surrounded by alfalfa, grain, small orchards, and sagebrush. In 1957 the plots were a few miles south of Logan, where the surrounding land is more intensely farmed and the foothills and orchard areas are farther away than in the previous locations.

CHARACTERISTICS OF CARROT FLOWERS

Carrot pollen is abundant and readily accessible to all visitors. Carrot nectar is not abundant but it is exposed on the petals and readily accessible to all insects except those with long, slender tongues. The individual florets are tiny and easily worked by minute insects. At the same time they are aggregated into flat, compact heads affording support to larger insects. It is not surprising, therefore, that a diverse assemblage of insects is attracted to the flowers.

VARIETY AND ABUNDANCE OF POLLINATORS

As indicated in the accompanying list, 334 species of insects representing 71 families were collected on the carrot blossoms in the open plots and on small adjacent plantings used for other types of studies. Most of the species were scarce or transient and individually contributed little pollination, although they accounted for a substantial percentage of the total pollination.

As might be expected, the different species varied greatly in abundance from location to location, from year to year, and from week to week at the same location and year. The 25 most abundant species in order of their abundance each year are shown in table 1. Except in 1957, the small syrphid fly, *Syritta pipiens* (L.), was by far the most numerous. The variable populations of the other species from year to year illustrate how futile it would be to count on consistent pollination by any one species. Many of the more abundant Diptera breed in wet and decaying vegetable matter. The availability of this material varied greatly from place to place and season to season, depending upon

Table 1. Populations of the 25 most abundant species of insects on carrot flowers of the open plots, Logan, Utah, (number per plot per observation)*

<table>
<thead>
<tr>
<th>Species</th>
<th>1954</th>
<th>1955</th>
<th>1956</th>
<th>1957</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Syritta pipiens</em></td>
<td>478</td>
<td>274.0</td>
<td>264.0</td>
<td>11</td>
<td>257</td>
</tr>
<tr>
<td><em>Piophila casei</em></td>
<td>304</td>
<td>3.2</td>
<td>62.0</td>
<td>0</td>
<td>92</td>
</tr>
<tr>
<td><em>Hippodamia spp.</em></td>
<td>14</td>
<td>1.8</td>
<td>0.5</td>
<td>283</td>
<td>75</td>
</tr>
<tr>
<td><em>Chrysomyza demandata</em></td>
<td>270</td>
<td>12.7</td>
<td>2.4</td>
<td>0</td>
<td>71</td>
</tr>
<tr>
<td><em>Madiza glabra</em></td>
<td>168</td>
<td>18.6</td>
<td>95.4</td>
<td>0</td>
<td>71</td>
</tr>
<tr>
<td><em>Dasyhelea spp.</em></td>
<td>168</td>
<td>0.0</td>
<td>87.2</td>
<td>0</td>
<td>64</td>
</tr>
<tr>
<td><em>Leptocoris trivittatus</em></td>
<td>30</td>
<td>0.0</td>
<td>86.4</td>
<td>0</td>
<td>29</td>
</tr>
<tr>
<td><em>Lindesius columbianus</em></td>
<td>4</td>
<td>0.6</td>
<td>66.8</td>
<td>32</td>
<td>26</td>
</tr>
<tr>
<td><em>Phaenicia sericata</em></td>
<td>90</td>
<td>6.8</td>
<td>2.8</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td><em>Senotainia trilineata</em></td>
<td>90</td>
<td>0.4</td>
<td>4.5</td>
<td>0</td>
<td>24</td>
</tr>
<tr>
<td><em>Cerceris nigrescens</em></td>
<td>64</td>
<td>1.0</td>
<td>9.8</td>
<td>8</td>
<td>21</td>
</tr>
<tr>
<td><em>Sepsis punctum</em></td>
<td>54</td>
<td>6.0</td>
<td>3.7</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td><em>Andrena prunorum</em></td>
<td>50</td>
<td>10.1</td>
<td>2.8</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td><em>Lygus spp.</em></td>
<td>5</td>
<td>0.2</td>
<td>26.0</td>
<td>29</td>
<td>15</td>
</tr>
<tr>
<td><em>Nysson spp.</em></td>
<td>44</td>
<td>2.0</td>
<td>11.6</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td><em>Sceliphron caementarium</em></td>
<td>46</td>
<td>1.0</td>
<td>1.0</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td><em>Philanthus anna</em></td>
<td>18</td>
<td>3.9</td>
<td>22.5</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td><em>Chloralictus spp.</em></td>
<td>2</td>
<td>2.1</td>
<td>25.4</td>
<td>9.5</td>
<td>10</td>
</tr>
<tr>
<td><em>Philanthus gibbosus</em></td>
<td>30</td>
<td>5.9</td>
<td>3.4</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td><em>Sphecodes arvensiformis</em></td>
<td>26</td>
<td>2.0</td>
<td>8.3</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td><em>Halictus c. arapahonum</em></td>
<td>2</td>
<td>24.8</td>
<td>7.4</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td><em>Apis mellifera</em> (honey bee)*</td>
<td>14</td>
<td>4.8</td>
<td>3.8</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td><em>Trichodes ornatus</em></td>
<td>30</td>
<td>2.4</td>
<td>1.2</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td><em>Tubifera hirta</em></td>
<td>30</td>
<td>0.0</td>
<td>2.0</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td><em>Cerceris minax</em></td>
<td>18</td>
<td>0.0</td>
<td>12.2</td>
<td>0</td>
<td>8</td>
</tr>
</tbody>
</table>

* There were 4 plots each year with 11 observations in 1954, 10 in 1955, 9 in 1956, and 10 in 1957.
weather conditions, crop rotation, manuring practices, and waste disposal. Species of *Tubifera* (Syrphidae) and Stratiomyidae commonly breed in water of high organic content, and it is not surprising that these groups were relatively scarce in 1955 when the plots were on a high, well-drained bench. The great abundance of *Hippodamia* and other ladybird beetles in 1957 was the result of an aphid infestation on an adjacent field of peas grown for seed. Finally, a major factor affecting abundance of nearly all species was competition from other pollen and nectar sources in the area. This is a difficult factor to assess for even a single species, and for such a complex as we were dealing with the task would be overwhelming.

Daily and weekly fluctuations were much greater for some species than others. Seasonal fluctuations of some of the more abundant species in 1955 are shown in table 2. Many species followed no discernible trends during the month-long blooming period, but in general bees were most numerous in the middle of the period when pollen was most abundant, whereas muscoid flies and drone flies (genus *Tubifera*) were most numerous later in the season when flowers with dehisced anthers were still secreting nectar. Ceratopogonids (*Dasyhelea* sp.), which composed the majority of the insects in the cages admitting only tiny insects, were most abundant in the first half of the period. The same was true of most species of stratiomyids. In 1955 *Syritta pipiens*, the dominant insect in the open plots, increased in numbers throughout the season, but in 1954 and 1956 its

---

**Table 2. Season population fluctuations of insects on carrot flowers, Logan, Utah, 1955 (number per plot on open plots)**

<table>
<thead>
<tr>
<th>Date</th>
<th><em>Apis mellifera</em></th>
<th><em>Andrena prunorum</em></th>
<th><em>Halictus c. araphalimum</em></th>
<th><em>Philanthus gibbosus</em></th>
<th><em>Syratta pipiens</em></th>
<th><em>Tubifera broussi</em></th>
<th><em>Tubifera sericata</em></th>
<th><em>Plasencia glabra</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>July 11</td>
<td>0</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>July 13</td>
<td>13</td>
<td>4</td>
<td>10</td>
<td>24</td>
<td>6</td>
<td>11</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>July 15</td>
<td>18</td>
<td>3</td>
<td>9</td>
<td>14</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>July 20</td>
<td>18</td>
<td>14</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>July 25</td>
<td>20</td>
<td>9</td>
<td>14</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>July 27</td>
<td>27</td>
<td>9</td>
<td>7</td>
<td>7</td>
<td>12</td>
<td>12</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>July 29</td>
<td>29</td>
<td>7</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>17</td>
</tr>
<tr>
<td>Aug. 3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>Aug. 8</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>24</td>
</tr>
</tbody>
</table>
populations merely fluctuated up and down. In 1956 a count was made when the primary flower heads were first opening. At that time a moderate amount of nectar but only a little pollen was available, and many of the sphexid wasps and tiny flies Madiza glabra Fall., Desmometopa sordida (Fall.), Piophila casei (Linn.), and Dasyhelea spp. were abundant. However, Syrilla pipiens, which a few days later became the dominant insect, had not yet appeared. Several species of stratiomyids were also common during this early period, but they were mostly absent the remainder of the season. Such seasonal fluctuations are probably affected by the weather, condition of the carrot flowers, amount of competing bloom, and abundance of insects in the surrounding area. Honey bees appeared to be affected primarily by competing bloom. They usually appeared in greatest numbers after nearby fields of alfalfa had been cut for hay.

In 1955 predatism was an important factor affecting the numbers of small bees. Halictus confusus arapahonum Ckll., which had been building up until July 25 to an effective population, suddenly diminished in the open plots during the remainder of the season (table 2). Philanthus gibbosus (Fab.), a bee-storing sphexid wasp, also reached its peak on July 25 and was busily preying on the halictids. By July 27 the bees had nearly disappeared from the open plots, but the wasps were still there searching for prey. On the same day arapahonum appeared for the first time in large numbers in the cages designed to exclude larger insects, and here they found sanctuary from the wasps.

**EFFICIENCY OF POLLINATORS**

The abundance of the various species on the flowers is a poor measure of their relative importance as carrot pollinators. Bees, for example, are many times more efficient than minute flies in transferring pollen from the anthers of one carrot flower to the stigmas of another. Efficiency in this operation depends upon size, hairiness, type of pulvilli, and activities on the flower heads. The more "flighty" insects are also more likely to accomplish cross-pollination than are those that spend more of their time on one head. In the case of honey bees the pollen collectors literally wade across the heads, swinging their abdomens back and forth and scraping the pollen from stamens with their fore legs. The nectar collectors stand higher on the flowers, move about less, and lap up droplets from the exposed nectaries. In other species of bees the females usually behave like pollen-collecting honey bees and the males like nectar-collecting honey bees.

The pollinating efficiency of the more abundant species of insects was compared on the basis of the amount of loose pollen carried on their bodies, their size, flightiness, and contact with stamens and stigmas as they move across the flower heads. Ratings for representative species are illustrated in table 3. Groups of species can also be evaluated in general terms as to their
Table 3. Efficiency ratings* of representative carrot pollinators, Logan, Utah

<table>
<thead>
<tr>
<th>Species</th>
<th>Loose pollen on body</th>
<th>Size of insect</th>
<th>Flightiness and action on heads</th>
<th>Efficiency rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apis mellifera</td>
<td>...........................</td>
<td>6</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Pollen collectors</td>
<td>.......................</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Nectar collectors</td>
<td>.......................</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Halictus c. arapahonum</td>
<td>..........</td>
<td>4</td>
<td>4</td>
<td>3.5</td>
</tr>
<tr>
<td>Females</td>
<td>..........................</td>
<td>2</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Males</td>
<td>..........................</td>
<td>2</td>
<td>4</td>
<td>2.5</td>
</tr>
<tr>
<td>Cerceris nigrescens</td>
<td>..........................</td>
<td>2</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Tachytes utahensis</td>
<td>..........................</td>
<td>5</td>
<td>5</td>
<td>4.5</td>
</tr>
<tr>
<td>Chrysis sp.</td>
<td>..........................</td>
<td>5</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Phaenicia spp.</td>
<td>..........................</td>
<td>3</td>
<td>3</td>
<td>2.5</td>
</tr>
<tr>
<td>Tubifera brousii</td>
<td>..........................</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Syrissa pipiens</td>
<td>..........................</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Stratiomys barbata</td>
<td>..........................</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Madiza glabra</td>
<td>..........................</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Dasyhelea sp.</td>
<td>..........................</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Leptocoris trivittatus</td>
<td>..........................</td>
<td>3</td>
<td>0.01</td>
<td>1</td>
</tr>
</tbody>
</table>

* Ratings based on an arbitrary scale of 0.01-6.0; the higher the number the greater the efficiency.
† Loose pollen given greater weight than other factors.

pollinating efficiency. However, an evaluation that in some instances applies to families, in other instances may apply to orders or merely to genera or species. For example, the highly efficient rating given to Apidae applies in the Sphecidae only to a few genera such as Tachytes. Furthermore, exceptions must often be made, especially in unusually large or small members of a group. It is sometimes necessary to divide a taxonomic unit into larger and smaller species. Group evaluations for the insects found most commonly on carrot flowers in the vicinity of Logan are shown below.

Highly efficient
- Female Apoidea
- Stratiomyidae

Large Syrphidae
Tachytes (Sphecidae)

Moderately efficient
- Most Sphecidae
- Large Muscoidea
- Large Vespidae
- Small male Apoidea

Moderately inefficient
- Small Syrphidae
- Chrysidae
- Small Vespidae
- Ichneumonidae
- Rhopalidae
- Small Muscoidea

Highly inefficient
- Very small Diptera
- Chalcidoidea
- Miridae
- Coccinellidae
- Braconidae
- Nymphal Acrididae

Although the efficiency ratings for individual species lack precision and
Table 4. Pollination indices of the 25 most important species of pollinators on the open plots, Logan, Utah

<table>
<thead>
<tr>
<th>Species</th>
<th>1954</th>
<th>1955</th>
<th>1956</th>
<th>1957</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syritta pipiens</td>
<td>478</td>
<td>274</td>
<td>264</td>
<td>11</td>
<td>257</td>
</tr>
<tr>
<td>Andrena prunorum</td>
<td>200</td>
<td>40.4</td>
<td>11.2</td>
<td>0</td>
<td>63</td>
</tr>
<tr>
<td>Cerceris nigrescens</td>
<td>192</td>
<td>3</td>
<td>29.4</td>
<td>24</td>
<td>62</td>
</tr>
<tr>
<td>Phaenicia sericata</td>
<td>180</td>
<td>13.6</td>
<td>5.2</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>Apis mellifera</td>
<td>70</td>
<td>24</td>
<td>19</td>
<td>55</td>
<td>42</td>
</tr>
<tr>
<td>Stratiomys unilimbata</td>
<td>64</td>
<td>0</td>
<td>104</td>
<td>0</td>
<td>42</td>
</tr>
<tr>
<td>Lindenius columbianus</td>
<td>6</td>
<td>1</td>
<td>100</td>
<td>48</td>
<td>39</td>
</tr>
<tr>
<td>Eulalia arcuata</td>
<td>56</td>
<td>41</td>
<td>23</td>
<td>27</td>
<td>37</td>
</tr>
<tr>
<td>Halictus c. arapahonom</td>
<td>8</td>
<td>99.2</td>
<td>29.6</td>
<td>12</td>
<td>37</td>
</tr>
<tr>
<td>Sceliphron caementarium</td>
<td>138</td>
<td>3.0</td>
<td>3.0</td>
<td>0</td>
<td>36</td>
</tr>
<tr>
<td>Nysson spp.</td>
<td>110</td>
<td>5</td>
<td>27.8</td>
<td>0</td>
<td>36</td>
</tr>
<tr>
<td>Chloralictus spp.</td>
<td>7</td>
<td>7.4</td>
<td>88.9</td>
<td>33</td>
<td>34</td>
</tr>
<tr>
<td>Philanthus anna</td>
<td>54</td>
<td>11.7</td>
<td>67.5</td>
<td>0</td>
<td>33</td>
</tr>
<tr>
<td>Tubifera brousi</td>
<td>32</td>
<td>51</td>
<td>50</td>
<td>0</td>
<td>33</td>
</tr>
<tr>
<td>Tubifera hirta</td>
<td>120</td>
<td>0</td>
<td>8</td>
<td>0</td>
<td>32</td>
</tr>
<tr>
<td>Philanthus gibbosus</td>
<td>90</td>
<td>17.7</td>
<td>10.2</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>Leptocoris trivittatus</td>
<td>30</td>
<td>0</td>
<td>86.4</td>
<td>0</td>
<td>29</td>
</tr>
<tr>
<td>Senotainia trilineata</td>
<td>90</td>
<td>0.4</td>
<td>4.5</td>
<td>0</td>
<td>24</td>
</tr>
<tr>
<td>Sphecodes arvensiformis</td>
<td>65</td>
<td>5</td>
<td>20.8</td>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td>Chalybion californicum</td>
<td>66</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>17</td>
</tr>
<tr>
<td>Colletes simulans</td>
<td>20</td>
<td>24</td>
<td>18</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>Cerceris minax</td>
<td>36</td>
<td>0</td>
<td>24.4</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>Stratiomys barbata</td>
<td>48</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>Trichodes ornatus</td>
<td>45</td>
<td>3.6</td>
<td>1.8</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>Hippodamia spp.</td>
<td>1.4</td>
<td>.18</td>
<td>.05</td>
<td>28</td>
<td>7</td>
</tr>
</tbody>
</table>

The pollination indices are somewhat subjective, it is believed that, when multiplied by abundance, they give a much truer pollination index than does abundance alone. The 25 species with the highest indices are listed in table 4. Many of the most abundant species drop out of the picture when their efficiency is considered. Of the less efficient species, only Syritta pipiens, by virtue of its exceedingly high populations, is able to hold its position of importance. In table 5 the populations of the major groups of pollinators are compared with their pollination indices. The indices for all insects should represent a fair estimate of the total intensity of insect pollination in the open plots each year.

Since all insects on flower heads feed on available supplies of pollen and nectar, large numbers of inefficient pollinators tend to reduce rather than increase pollination, provided that a potentially effective population of more efficient pollinators is present in the area.

2 The figures for 1957 are less accurate than those for the preceding years. In 1957 the proportions of species were obtained by sweeping a small field to one side of the plots. The ratios were then applied to total counts made in the experimental plots. In the middle of the season ladybird beetles invaded the plots from an adjacent pea field but did not become abundant in the field used for sweeping. Consequently, a correction factor had to be applied to make allowance for the known percentages of ladybirds in the plots.
Table 5. *Populations and pollination indices of various categories of pollinators on carrot flowers, Logan, Utah*

<table>
<thead>
<tr>
<th>Category of insect</th>
<th>1954</th>
<th>1955</th>
<th>1956</th>
<th>1957</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number per plot</td>
<td>Index</td>
<td>Number per plot</td>
<td>Index</td>
<td>Number per plot</td>
</tr>
<tr>
<td>Honey bees</td>
<td>14</td>
<td>70</td>
<td>5</td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td>Other bees</td>
<td>178</td>
<td>432</td>
<td>44</td>
<td>180</td>
<td>53</td>
</tr>
<tr>
<td>Sphecoid wasps</td>
<td>368</td>
<td>1021</td>
<td>27</td>
<td>82</td>
<td>185</td>
</tr>
<tr>
<td>Other Hynenoptera</td>
<td>100</td>
<td>163</td>
<td>11</td>
<td>23</td>
<td>47</td>
</tr>
<tr>
<td>Larger Diptera</td>
<td>348</td>
<td>767</td>
<td>41</td>
<td>98</td>
<td>78</td>
</tr>
<tr>
<td>Syritta pipiens</td>
<td>478</td>
<td>478</td>
<td>274</td>
<td>274</td>
<td>264</td>
</tr>
<tr>
<td>Tiny Diptera</td>
<td>984</td>
<td>84</td>
<td>62</td>
<td>8</td>
<td>385</td>
</tr>
<tr>
<td>Other insects</td>
<td>192</td>
<td>110</td>
<td>8</td>
<td>5</td>
<td>159</td>
</tr>
<tr>
<td>Insects less</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>honey bees</td>
<td>2648</td>
<td>3055</td>
<td>467</td>
<td>670</td>
<td>1171</td>
</tr>
<tr>
<td>All insects</td>
<td>2662</td>
<td>3125</td>
<td>472</td>
<td>695</td>
<td>1175</td>
</tr>
</tbody>
</table>
METHODS OF INCREASING POLLINATORS

The following methods of increasing the supply of carrot pollinators are suggested: (1) Locate enough colonies of honey bees in the area to provide effective populations on the flower heads; (2) avoid the presence of competing bloom; (3) restrict plantings of carrots for seed to avoid dilution of the pollinator population; (4) choose areas with varied habitats capable of supporting large numbers of a wide variety of pollinators; (5) take steps to increase populations of wild pollinators in the area.

For most large seed-producing areas a combination of the first and second methods is likely to prove the most practical. Among the wild pollinators, species of Diptera that breed in decaying vegetation are probably the most practical to propagate. Extensive breeding can probably be maintained in thick layers of green manure or wastes from food processing plants. The decaying material should be kept moist under a thin scattering of soil. Of course, such a method might increase pest or disease-spreading species and would have to be carefully considered in that respect. Another species to be considered for propagation would be the alkali bee which readily gathers carrot pollen and is an efficient pollinator. Bohart has already suggested methods for increasing alkali bees in alfalfa-seed producing areas of the Northwest.

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INSECTS VISITING CARROT FLOWERS
IN THE VICINITY OF LOGAN, UTAH, 1954 - 1957

HYMENOPTERA

Braconidae

Atanycolus simplex (Cress.)
Atanycolimorpha dissitus (Cress.)
Bracon nuperus (Cress.)

hyslopi (Vier.)
Apanteles medicaginus Mues.
Crempnops vulgaris (Cress.)
Chelonus sp. 1
sp. 2

Ichneumonidae

Ichneumon rufiventris Brulle
sp. nr. rufiventris Brulle
ambulatorius F.
sp. nr. ambulatorius F.
longulus Cress.
sp.

Coelichneumon mauros (Cress.)
Patroclus montanus (Cress.)
Stenicheumon salius pallidipennis (Vier.)
Compsocryptus resolutus (Cress.)
sp.
Trychosis sp.
Pimpla pedalis (?) Cress.
Glypta sp.

Perilampus sp.
Diplazon laetatorius (F.)
Pseudamblyteles sp.

Perilampidae

Perilampus hyalinus Say
Perilampus chrysopae Cwfd.
Pteromalidae
  Spalangia sp.

Eurytomidae
  Eurytoma sp.
  Bruchophagus gibbus (Boh.)
  Systole albibennis Walk.

Chalcididae
  Brachymeria coloradensis (Cress.)
  Leucospis affinis Say

Cynipidae
  Xyalophora quinquelineata Say
  Kleidotoma sp.

Gasteruptiidae
  Rhydinopus pattersonae (M. & B.)

Scelionidae
  Telenomus utahensis Ashm.

Chrysidae
  Hedychrum violaceum Brulle
  Holopyga ventralis (Say)
  Chrysis frey-gessneri Crib.
    dorsalis Aaron
    sp. 1
    sp. 2
    sp. 3
    pacifica Say
    intricata Brulle
  Elampus sp.

Mutiliidae
  Dasymutilla vesta (Cress.)
    fulvohirta (Cress.)
    ursula (Cress.)
  Timula grotei (Blake)

Formicidae
  Formica sp. (fuscus grp.)
    sp. (ruja grp.)
    sp.

Vespidae
  Stenodynerus blandoides R. Bohart
    valliceps R. Bohart
    hennicottianus (Sauss.)
  Ancistrocerus catskill (Sauss.)
  Symmorphus cristatus (Sauss.)
  Rychnochitum foraminatum (Sauss.)
    exoglyphum albovittatum (R. Bohart)
    hidalgo vierreckii (Cam.)
    dorsale (F.)
    annulatum sulphureum (Sauss.)
  Eumenes crucifera Prov.
  Polistes fuscatus (F.)
  Vespa maculata (L.)

Pompilidae
  Paracyphononyx funereus (Lep.)
  Pompilus seeleustus Cress.
  Anoplius tenebrosus Cress.
    aethiops (Cress.)
  Tachypompilus torridus unicolor (Banks)
  Episyrn snowi (Vier.)
    oregon Evans
    quinquenotatus hurdi Evans
  Evagetes hyacinthus (Cress.)
  Priocnemiodes unifasciatus cressoni (Banks)
  Cryptochelus terminatum (Say)
  Ceropales fraterna Sm.
    rugata Townes
  Ageniella conflictal Sm.
    arcuata (Banks)
    fulgifrons (Cress.)
    blaisdelli (Fox)
    sp.

Sphecidae
  Astata unicolor Say
    nubecula Cress.
    nevadica Cress.
  Lyroda subita (Say)
  Tachyes obscurus Cress.
    elongatus Cress.
    utahensis Banks
    sayi Banks
  Larropsis capax (Fox)
  Tachysphex glabrior Wms.
    terminatus (Sm.)
    ashmeadiii Fox
    aequalis Fox
    tarsatus (Say)
  Motes argentata (Palis.)
  Mimesa cressoni Pack
  Xylocelis sp.
  Sphex pilosus (Fern.)
    aberti (Hald.)
  Sceliphen caementarium (Dru.)
Sphecidae (cont.)

Chalybion californicum (Sauss.)
Podalonia lucutaosa (Sm.) communis (Cress.)
Chlorion elegans (Sm.) lucae (Sauss.)
Chlorion ashmeadii Fern. ichneumoneum (L.)
Nysson bicolor (Cress.) sp.
Sphecius grandis (Say)
Psammeius spilopterus (Handl.)
Gorytes simillimus Sm.
Harpactostigma laminiiferum (Fox)
Stizoides unicinctus (Say)
Bembix amoenus (Handl.)
Microbembex monodonata (Say)
Philanthus gibbosus (F.) ventilabris (F.) anna Dunn.
flavifrons Cress.
sp.
Cerceris nigrescens Sm.
nr. clypeata Dahlb.
sextoides Banks
conifrons Mick.
minax Mick.
Lindenius columbianus (Kohl)
Ecemnius dives (Lep. and Brulle) spiniferus (Fox)
alpheus Pate
Ecemnius chrysargyrus (Lep. and Brulle) continuus (F.)
lapidarius (Panz.)
dilectus (Cress.)
sp.
Lestica interrupta (Lep. and Brulle)
Oxybelus emarginatum Say
uniglumis 4-notatum Say

Colletidae

Colletes lutzi Timb.
fulgidus Swenk
mandibularis Sm.
simulans (?) Cress.
Hylaeus cressoni (Ckll.)

Andrenidae

Andrena candida Sm. cerastophii prunorum Ckll.
sola Vier.
cleodora Vier.
Nomadopsis scutellaris (Fwlr.)

Halictidae

Halictus rubicundus (Christ) ligatus Say
confusus arapahonum Ckll.
Halictus tripartitus Ckll.
farinosus Sm.
Lasioglossum sisybrii (Ckll.) pectoraloides (Ckll.)
sp. 1
sp. 2
sp. 3
Sphecodes arvensiformis Ckll.
sp. 1
sp. 2
Nomia melanderi Ckll.

Megachilidae

Osmia texana Cress.
seclusa Sandh.
Megachile periphera Ckll.
onobrychis Ckll.

Apidae

Melissodes agilis Cress.
Nomada sp.
Apis mellifera L.

DIPTERA

Cecidomyiidae
Anarete johnsoni (Felt)

Chironomidae
Hydrobaenus sp.

Ceratopogonidae
Forcipomya brevipennis (Macq.)
Dasyhelea spp.

Sciaridae
Bradyria sp.
Lycoria sp.
Scatopsidae
   Scatopse fusipes Meig.
   Ectaetia claripes Lw.

Stratiomyidae
   Stratiomys barbata Loew
      currani James
      unilimbata Loew
      adelpha Steyskal
   Eualia pilimanana (Loew)
      alticola (James)
      communis (James)
      pubescens (Day)
      virgo (Wd.)
   Hedriodiscus truquii (Bell.)

Tabanidae
   Pilima californica (Bigot)

Bombyliidae
   Anthrax irrorata Say
   sp.
   Villa molitor (?) (Loew)
      lateralis (Say)
      alternata (Say)
      agrippina (O.S.)
      utahensis Maughan
   Bombylius laticeps Bigot
   Toxophora virgata O.S.
   sp.

Phoridae
   Megaselia sp.
   Conicera sp.

Syrphidae
   Syricta picipiens (L.)
   Metasyrphus sp. 1
      sp. 2
   Syrphus sp. 1
      sp. 2
   Eupeodes volucris O.S.
   Paragus bicolor (F.)
      tibialis (Fall.)
   Pipiza sp.
   Sphaerophoria mentastri (L.)
   Sphaerophoria sp.
   Chrysogaster parva Shann.
   Eumerus strigatus (Fall.)
   Lejops lanulatus (Meig.)
   Helophilus latifrons Loew
   Mallota albipilis Snow

   Tubifera tenax (L.)
      broussii (Will.)
      hirta (Loew)
      anthophorina (Fall.)
      barda (Say)
   Spilomyia interrupta Will.
   Tenthredomyia tridens (Loew)

Conopidae
   Occemyia propinqua Adams
   loraria Loew

Otitidae
   Chrysonyza demandata (F.)

Sepsidae
   Sepsis punctum (F.)
      biflexuosa curvitibia M. & S.
   Saltella scutellaris (Fall.)

Piophilidae
   Piophila casei (L.)

Milichiidae
   Desmometopa sordida (Fall.)
   Madiza glabra Fall.
   Milichiella n. sp.
   Meoneura sp. 1
   sp. 2

Chloropidae
   Siphonella parva Ad.
      neglecta Beck
      sp. 1
   Hippelates pallipes Lw.

Ephyridae
   Atissa pygmaea Halid.
   Allotrichoma sp.
   Hydrellia proclinata Cress.

Tachinidae
   Promasiphya confusa (Ald.)
   Siphophyto turmalis Rein.
   Voria ruralis (Fall.)
   Winthemia rufopicta (Bigot)
   Peleteria iterans (Wlk.)
      sp.
   Fabriciella sp. 1
      sp. 2
Tachinidae (cont.)

- Rhodogyne fuliginosa (Meig.) sp.
- Phoranthella morrisoni Tns.
- Leucostoma simplex (Fall.)
- Cylindromyia armata Ald.
- Hyalomya aldrichi (Tns.)
- Hyalomyiopsis aldrichii Tns.
- Catalinovoria cauta Tns.
- Myiophasia oregonensis Tns.

Calliphoridae

- Phormia regina (Meig.)
- Lucilia illustris (Meig.)
- Bupolucilia silvarum (Meig.)
- Phaenicia sericata (Meig.)
- Pollenia rudis (F.)

Sarcophagidae

- Senotainia flaricornis Tns. trilineata (Wulf.) rubriventris Macq.
- Taxigrama heteroneura (Meig.)
- Euphytonima nomitiora James
- Wohlfahrtia opaca Coq.
- Sarcophaga rapax Meig.
- querula Wlk.
- haemorrhoidalis (Fall.)
- Sarcophaga coloradensis Ald.
- hunteri Hough
- iherminieri R.D.

Musciidae

- Graphomya maculata (Scop.)
- Muscina stabulans (Fall.)
- Musca domestica L.
- Limnophora argentiventris Mall.
- Hylemya citricula (Rond)

COLEOPTERA

Cerambycidae

- Anaplodera canadensis (Oliv.)

Chrysomelidae

- Chrysochus cobaltinus Lec.
- Epitrix suberinita (Lec.)
- Altica plicipennis (Mann.)
- Luperodes sp.

Coccinellidae

- Hippodamia convergens Guerin lecontei Muls.
- quinquesignata (Kirby)
- Coccinella transversoguttata Fals.
- 9-otata Hbst.

Dermestidae

- Trogoderma sp.

Bruchidae

- Megacerus discoideus (Say)

Melyridae

- Collops bipunctatus (Say)
- vittatus (Say)
- Malachius acenus (L.)

Curculionidae

- Hyopa punctata (F.)

Cleridae

- Trichodes ornatus Say

Anthicidae

- Anthicus sp.
LEPIDOPTERA

Pieridae
- *Pieris occidentalis* Reak.
- *rapae* (L.)
- *Colias eurytheme* (Bvd.)

Nymphalidae
- *Phyciodes mylitta* (Edw.)

Lycaenidae
- *Strymon melinus* (Hbn.)

HESPERIIDA

Hemiiptera

Miridae
- *Lygus elisus* Van Duzee
- *Microphylllus* sp.
- *Orthops scutellatus* Uhler
- *Chlamydatum associatus* Uhler

Rhopalidae
- *Leptocoris trivittatus* Say
- *Liorhysus hyalinus* (F.)

Coreidae
- *Harmostes reflexus* (Say)

Lygaeidae
- *Geocoris pallens* (Stal.)

HEMIPTERA

Lygaeus reclinatus Say
- *Nysius ericae* (Schilling)

Nabidae
- *Nabis ferus* (L.)

Berytidae
- *Jalysus wickhami* Van Duzee

Anthocoridae
- *Anthocoris musculus* (Say)
- *Orius tristicolor* (White)

Pentatomidae
- *Trichopepla grossa* Van Duzee

HOMOPTERA

Cicadellidae
- *Aceratagallia fuscoscripta* Oman
- *Dicraneura carneola* (Stal.)

NEUROPTERA

Chrysopidae
- *Chrysopa* sp.
ORTHOPTERA

Acrididae
Trimerotropis cyanipennis Bruner
Melanoplus bivattatus (Say)

DERMAPTERA

Forficulidae
Forficula auricularia L.

THYSANOPTERA

Thripidae
Frankliniella tritici Fitch