TEXAS AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 180 OCTOBER, 1915

DIVISION OF ENTOMOLOGY

THE TURNIP LOUSE

POSTOFFICE:
College Station, Brazos County, Texas

AUSTIN, TEXAS
Von Boeckmann-Jones Co., Printers
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BY

F. B. PADDOCK, B. S. E.

Entomologist in Charge; State Entomologist.

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*As of October 1, 1915.
**In Cooperation with the United States Department of Agriculture.

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THE TURNIP LOUSE.

By F. B. Paddock, B. S. E., Entomologist in Charge; State Entomologist.

INTRODUCTION.

For several years complaints have been made of a plant-louse destroying the fall crop of turnips in various sections of the State. It became evident from the increased number of these letters that the insect was spreading, and that it was a serious menace to several truck crops during the winter. In the early fall of 1913 it was decided to undertake some investigations of this plant-louse, as it was causing widespread injury to turnips and related plants. When the work was started, it was supposed that this insect was the cabbage louse, *Aphis brassicae*, and that its habits and life history as observed in the South would probably vary considerably from the observations which had been made upon it in the North. Statements made in the literature up to this time were to the effect that in the South during the winter the cabbage louse was a serious pest of turnips grown as a winter truck crop.

After some preliminary observations, it was deemed advisable to consult descriptions of *A. brassicae*, in order that all the described forms might be recognized when met with. It was soon evident that the species which was being taken upon the plants about College Station did not coincide with the descriptions of *A. brassicae*. Material collected from turnips was sent to Prof. C. P. Gillette, of Fort Collins, Colorado, for his determination. His reply was that the specimens sent were evidently a species which had recently been described in manuscript by Mr. J. J. Davis, of Lafayette, Indiana, as *Aphis pseudobrassicae*. Material was then sent to Mr. Davis, and his identification confirmed that made by Professor Gillette. As soon as it was evident that the species which was being investigated was not the cabbage louse, we took the liberty of calling it the "turnip louse," as this would more clearly identify it for the truck grower.

During the fall of 1913 material was collected from turnips at Iredell, Wortham, Valley View, De Kalb, Daingerfield, Cooledge, McKinney and Hitchcock, Texas. Specimens collected at these places proved to be *A. pseudobrassicae* rather than *A. brassicae*. It was then evident that the turnip louse rather than the cabbage louse, was doing much of the injury to the winter turnip crop. It was thought that further study might show this louse to be generally distributed over the State. Preliminary observations were made during the fall of 1913 upon the habits of the turnip louse, and some work was conducted with practical control measures.

In January of 1914 cage experiments were started to ascertain some of the details of the life history and number of generations of the louse. The work was continued until August, 1914, at which time the lice died out in the cages. The work was resumed in September, 1914,

and continued for one year. During the fall of 1914 control measures were undertaken on a much larger scale than in the previous season. Studies on the distribution of the species were also continued. Reports were received from all sections of the State, and these indicated that the turnip louse was present, and in every case it was considered a serious pest. Trips have been made to both the northern and southern limits of its range in Texas and considerable time has been devoted to a study of the varying life history at and between these points.

The turnip louse is now known to be a serious pest in the winter truck regions of the State. The injury is perhaps most noticeable upon turnips, though the louse attacks most any of the plants of the family *Cruciferae,* especially cabbage and mustard. Not only is this insect a serious pest in the winter truck regions, but the home gardens everywhere are often entirely destroyed. It is not possible to estimate the loss caused by the presence of this insect, but the total sum must be very large indeed. Often the home gardens are planted twice and truck growers often lose an entire planting; a big loss when competition is keen for early crops. In some of the sections the truck growers will be forced to abandon the growing of crops attacked by the turnip louse, unless it is brought under control.

HISTORICAL.

In his description of this species,* Mr. Davis says the first specimens were sent him from Geneva, New York, taken from cabbage in July, 1912. Later in the same year Mr. Davis received specimens on kale and mustard from Evansville, Indiana. During the fall of 1913, he also reported the species abundant upon radishes and turnips at Lafayette, Indiana.

DISTRIBUTION.

It will probably be found after more observations have been made upon this species that it is generally distributed over the United States, especially where *A. brassicae* is found, as *A. pseudobrassicae* feeds upon many of the same plants, especially the cultivated species. In the past the later species of plant louse has probably been mistaken for the former in many instances. The turnip louse has already been reported from New York (Schoene), Indiana (Davis), Minnesota (Maxson), Oklahoma (Sanborn), Louisiana (Tucker), Florida (Mason), and Texas. Reports received from all the Southern States, Georgia excepted, indicate the presence of this species, though examination of material from various localities should be made to avoid the confusion of this form with the cabbage louse.

Reference to the accompanying map will give an idea of the distribution of the turnip louse in Texas, as determined up to January, 1915. We now have received 89 reports from 76 towns located in 60 counties, showing the presence of the louse. The general distribution is probably well confined to the more humid sections of the State. At present the species is found between the 26th and 34th parallels of latitude.

*Canadian Entomologist, XLVI, 7, p. 231.

FOOD PLANTS.

Aphis pseudobrassicae has been taken upon turnip, radish, cabbage, cauliflower, mustard, kale, rutabaga, lettuce and bean in our work at College Station. In addition to these plants this species has been reported from sections of Texas upon rape, kale, kohl-rabi and collard.

Mr. A. C. Maxson, of Longmont, Colorado, sent us specimens of this louse which had been taken on rutabaga at St. Cloud, Minnesota. Mr. Davis described the species from specimens taken on radishes, turnips and rape at Lafayette, Indiana. He also records the receipt of speci-

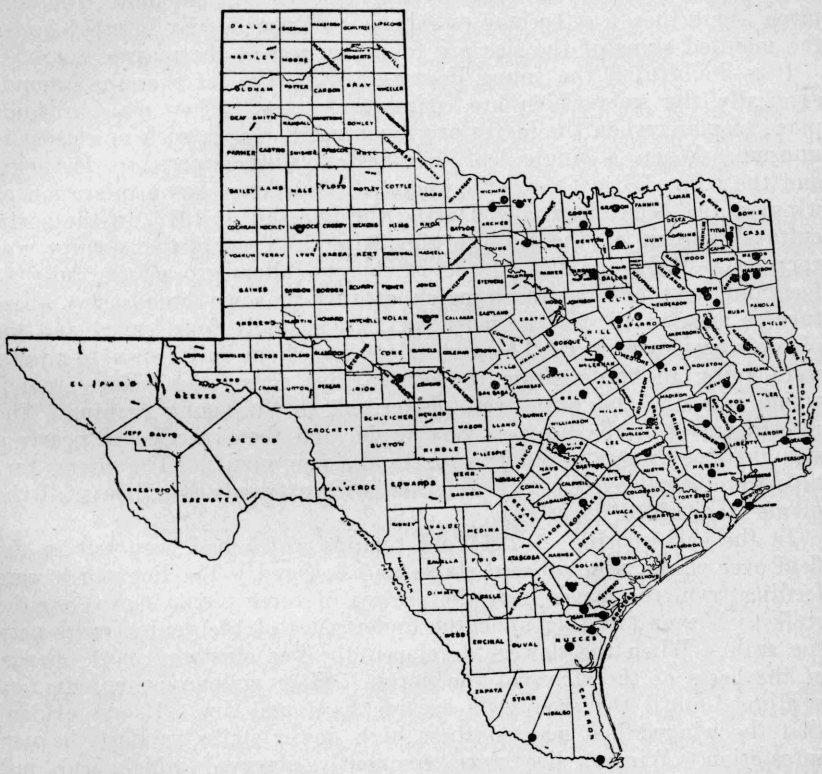

Fig. 1.—Map of Texas, showing distribution of the Turnip Louse as determined up to January, 1915 (Original).

mens from Mr. J. W. Schoene at Geneva, New York, taken from cabbage with the note that they likewise occur on kale and mustard. Mr. A. C. Mason has sent us specimens of this species taken on cabbage at Gainesville, Florida.

FEEDING HABITS.

This louse feeds for the most part upon the tender leaves of the host plants, and usually upon the under sides. In the case of turnips the infestation starts upon the leaves of medium size, though these leaves often become quite large by the time the infestation is severe. When

this stage is reached the under sides of the leaves are almost entirely covered with the masses of lice. The more tender leaves near the center of the crown are sought by the young ones when the large leaves become crowded. When the infestation is very heavy these central leaves are crowded on both sides with the lice. Under normal conditions the lice do not move about much; if the infestation is not heavy the young ones establish themselves very close to the parent. In fact, the female is often forced to swing the rear end of her body around in order that room may be found for additional young. If the leaves are crowded the young lice are active for a time in search of a good feeding place, but under normal conditions they do not move from the place where they first become established. Upon heavily infested leaves the moulted skins of the lice are found on top of the masses.

It is doubtful if the young lice can travel very far over the ground, especially the soils which are coarse and loose. They may go from plant to plant when the leaves are touching, but even such migration is unusual. When a single leaf becomes crowded pupae are developed and the winged lice fly to other plants. Only once has a migration of wingless lice been observed. During the late fall of 1913, in the horticultural garden of the College the infestation upon the turnips was very heavy. On one side of the patch was fallow ground for fully 15 feet and next to this was a patch of turnips sown broadcast. These turnips were small, for the most part, having only four leaves, and the plants were scattering. These wingless lice, from half-grown to adults, were going in hordes from the old turnips across the fallow ground, which was dry and quite well pulverized, to the young turnips. The rate of travel of the lice was very rapid, and they traveled in nearly a straight line from the old turnips to the new plants. The young turnips were soon covered with lice, and within twenty-four hours all the plants were killed.

In the early spring of 1914 old turnips which had been left in the field over winter sent up seed stalks and flowered. The lice which were feeding upon the leaves near the crowns of these plants moved up the stalk as it grew, feeding upon the under sides of the young leaves near the axils. When the flowers developed the lice clustered in the heads, at the bases of the stems of the florets. Here viviparous reproduction continued until the seed pods became hard and dry. It was evident that the winged lice selected these high flower stalks to start the new infestation. Winged lice were frequently observed which had just alighted from the flowers or had but recently gone in among the stems of the florets and given birth to one or two young. Throughout the spring the feeding of the lice upon the turnips was confined to the flower or seed stalks. When the seed pods were first formed the lice fed upon the stem, or in case of heavy infestation, upon the pod itself. When the seed pods became hard and the stalks dry, the lice left the turnips, possibly in search of some alternative host.

During the winter the lice migrate from the outer portions of the plants and mass upon the small leaves at the center of the crown. Here they prefer to feed upon the under sides of the leaves. They also may be found upon the upper sides of the bases of the smallest leaves. This change in place of feeding is for protection from the winter weather, as

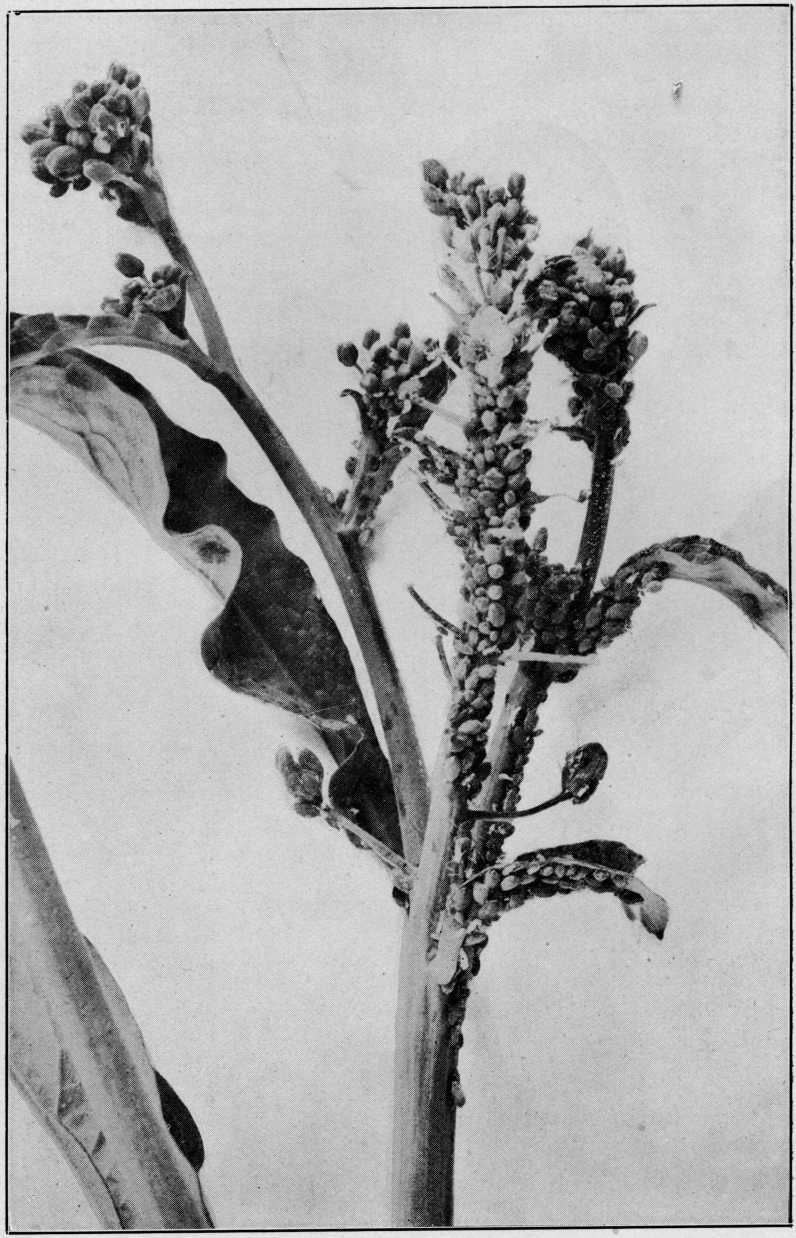

Plate I—Turnip lice feeding in the flower head of mustard. (Original.)

the lice are thus protected from snow and rain, from wind and to some extent from cold temperatures. After a very hard freeze in the winter the lice become active in the search of leaves which may be in good condition for food.

Upon radishes the feeding habits of the lice are much the same as upon turnips. Apparently the infestation can become heavier upon single radish plants than upon turnips before pupae are developed and the winged lice fly to new plants. In the spring and early summer the lice may be found feeding in the flower heads of this plant in the same manner as they feed upon the flowers of turnips. As late as May 18, 1915, the lice were found on the flowers of some isolated radishes. Young radishes in the same garden were but lightly infested at that time. During the two seasons in which observations have been made in one garden, the radishes and turnips were sown side by side. Both years the infestation in the garden started upon the radishes, and even spread for a time on this plant before starting upon the turnips. The radish plants are easily killed by a severe infestation.

Upon mustard the lice are found mostly in the deep curls of the smaller leaves, but they do not attack this plant as readily as they do the radishes and turnips. During the fall of 1913 the radishes and turnips were dying before the mustard in the same garden was attacked, and during the fall of 1914 the lice left the mustard to go to the radishes and turnips in the same garden. During the winter of 1914 lice were observed upon mustard plants which had gone to seed. Here the lice were feeding in the stems of the florets exactly as they had been upon the turnips in the spring. The lice attacking mustard at this time were entirely in the flower head. Both the winged and wingless forms were observed feeding in this manner upon the mustard.

When feeding upon cabbage the lice may be found upon the under sides of some of the outer leaves. This is especially true when the infestation is started on young plants. If the plants are of much size, as they often are, the winged females go to the smaller leaves near the inside of the head. Here the lice may be found upon the upper sides of the leaves also, but usually upon the under sides. The lice are found mostly along the larger veins of the leaves, especially when the infestation is just starting. During the winter those lice which live over upon cabbage are found very close to the base of the leaf and upon those leaves just outside of the head. Very close inspection is necessary to detect the lice upon this plant during the winter.

In the case of cauliflower the lice have been observed only upon small plants, and the feeding habits here were the same as upon cabbage.

Upon lettuce the lice were found feeding upon the tender leaves of a head variety in much the same manner as upon cabbage.

When feeding upon beans the lice were entirely upon the under sides of the leaves, near the bases.

Often an infestation in a garden will start from one spot and spread from this in all directions. Where such an infestation starts the plants are usually killed before most of the garden is even infested. A garden may be infested in several places at once, and the infestation from each source will spread until meeting that from other sources.

VIVIPAROUS DEVELOPMENT.

In Texas the normal form of reproduction in the turnip louse is asexual throughout the entire year. No sexes have so far been observed either in the breeding cages or the fields. It seems that each generation is made up entirely of viviparous females. Webster* states that south of the 35th parallel the sexual forms of plant-lice have been observed but rarely, except at high altitudes. The farthest north in Texas that observations have been made upon *A. pseudobrassicae* is Wichita Falls, just south of the 34th parallel. It is evident that at this point sexes do not occur and the viviparous females survive the winters.

Mr. Davis in his original paper (l.c.) says: "The sexes have not been found, and our present knowledge leads us to believe that the more usual means of passing the winter is as viviparous females." Recently Mr. Davis wrote that their searches had not revealed the sex forms at Lafayette, Indiana.

SEASONAL HISTORY.

Most of the field observations on the turnip louse have been made at College Station, though some time has been spent in the two extreme sections of the State, Brownsville in the south and Wichita Falls in the north. The field notes made on the turnip louse during two seasons at College Station are briefly reviewed here.

1913-1914.

As the work of this season was not organized early, the first observations were not made until October 9. At that time the turnips in this vicinity were very heavily infested with the louse, though the extreme infestation had not existed long enough to induce the formation of winged lice. However, within a week afterwards fully 50 per cent. of the lice found upon turnips were winged females. In another week fully 75 per cent. of the lice were winged and the pupae were abundant. The very large proportion of winged females at this time resulted later in an extensive infestation of the host plants in this vicinity.

About the time of the heavy infestation and production of winged lice on the turnips, the radishes in the College garden became infested. The winged lice migrated from the crowded turnips to the radishes in the same field. At the end of two weeks these radish plants were heavily infested, at which time only 1 per cent. of the lice present were winged but fully 25 per cent. were pupae. This tendency to the formation of winged lice was to be expected, as the radishes and turnips in the garden had suffered severely from the extreme infestation. Within a month after the first appearance of the lice upon the radishes the winged lice were leaving the plants. During that month, however, the radishes were almost killed by the extreme infestation.

It was not until November 1, 1913, that the turnip louse was first observed upon cabbage in this vicinity, three weeks after the maximum

*Bureau of Entomology, Bulletin No. 110, p. 47.

infestation upon turnips. This infestation on the cabbage started so late that the low temperatures at that time materially retarded the rate of reproduction. For some time the lice increased slowly upon the cabbage, but within three weeks from the time they were first observed there was a decided migration from the cabbage to some other host plant. By the middle of November, when the infestation was slight, fully 50 per cent. of the lice were winged. From that time on the lice gradually disappeared from the cabbage.

Early in November the lice were very abundant upon mustard in the same garden where the radishes and turnips had been so heavily infested. In two weeks after the lice were first observed upon the mustard the infestation there was much more severe than upon the other host plants in the garden. While the mustard suffered some from the presence of the lice it did not show the effects of the infestation to the extent that the radishes and turnips did. Perhaps this was due to the fact that the lice migrated back to the radishes and turnips after those plants had recovered from the previous attack.

In the College garden, well along in the season, the lice were very abundant upon turnips, radishes and mustard. As all of these plants began to suffer from the severe infestation, there was need for new food. Beans which were planted between mustard and radishes were found to be infested with the turnip louse on November 21. The colonies of lice at that time were scattered upon the under sides of the leaves. The infestation did not persist long, due to natural control factors, but it is doubtful if the lice could continue long upon this host. The infestation upon this host was very light, consisting of scattered individuals, both winged and wingless lice, with no well-defined colonies.

Upon the turnips in the College garden the lice continued to increase to such an extent that unsprayed plants were dead by November 21, at which time the lice were found upon most every variety of plant then in the garden. Fully 30 per cent. of the lice on the infested plants were winged females and 50 per cent. were pupae, so that a general migration took place which infested the sprayed plants.

During the last week of November and the first week of December very heavy rains occurred which apparently killed every louse upon all the plants in this vicinity. From December 19, 1913, to March 5, 1914, no lice were found on any plant in the fields. From December 20, 1913, lice were kept in breeding cages out doors for general observation purposes. From this date through January and February all study of the lice was made in these cages. The reproduction during these months was quite constant though governed strictly by the temperatures, since the lice reacted quickly to a change in temperature. On February 6, 1914, a sudden drop in temperature to 17 degrees F. occurred, but hardly 5 per cent. of the lice succumbed, these being the old females. Winged lice emerged in great numbers in the cages during the latter part of February, at which time it was quite cool. The host plants in the cages became heavily infested by March 1, and the lice were purposely allowed to fly from them to infest the experimental fields.

From the cages the lice infested the turnips in the immediate vicinity only, the migration seeming to be very limited. This migration

from the cages continued throughout March and April. The plants which were first infested close to the cages never suffered, as the lice seemed to remain upon them but a couple of weeks and then the resulting winged lice migrated to other plants. During the latter part of April the winged lice were particularly active in the air during the warm afternoons. Some turnips in an adjoining field which had gone to seed seemed to attract many lice. Throughout April there was a general migration of the lice from the turnips in the cages and from the plants in the fields. During this time the infestation was never heavy upon the turnips and there was a continuous production of winged lice. The small colonies upon the turnips continued to grow smaller all the time, as a portion of each brood developed into pupae and later to winged lice. By May 1 there were but few lice upon the turnips in the field, though it was possible to find lice as late as June 6. By this time the turnips ceased to grow well on account of the heat and drouth.

1914-1915.

The lice were first observed upon turnips in the College garden on September 10, at which tiime the infestation had just started. The infestation consisted almost entirely of wingless lice at the head of well formed colonies. On this date the lice were also found upon the radishes and mustard which were growing on either side of the turnips. The infestation in this garden started upon the radishes near the west end. The spread of the lice was from west to east, but this was evidently not due to the wind, as at that season the prevailing winds were from the south.

Within a week after the lice were first observed upon the turnips, the plants were heavily infested and a few winged lice were found, well scattered over the field. At this time pupae were developing, though not always in the places of heaviest infestation. Development of pupae at this time, when dissemination is general and rapid, appears to be normal. At other seasons of the year pupae develop only under the stimulus of excessive infestation. The radish plants seem to show the effects of severe infestation more readily than the turnips or mustard. When the general spread of the lice started the leaves of the radishes were larger than those of the other plants, and it may have been that the lice were attracted to them. At no time were the lice as bundant upon mustard as upon the turnips and radishes.

The infestation increased rapidly upon the radishes and turnips, and to such an extent that by the end of the second week the leaves of those plants were entirely covered with the lice. At that time fully 75 per cent. of the lice present were pupae and 10 per cent. were winged lice and, as a result, other fields in the vicinity were becoming infested. Some of the gardens were seemingly well isolated from any infested host, but the lice became well established upon all. As the radishes and turnips began to die, the lice became more plentiful upon the mustard, though the latter was evidently not as desirable a food as the other plants.

The very vigorous spraying conducted in the College garden doubtless altered the seasonal development of the louse at that time. The

pest was held in check after October 1, but there was a marked tendency toward the formation of winged lice only. At one time fully 90 per cent. of the lice present on the plants were pupae. On November 1, there were but few winged females present and but few wingless; though these were of all ages. At this time also a few winged lice were first observed upon cabbage, but this infestation was not lasting. Contrary to expectations, no lice could be found upon the cabbage during the winter.

The lice were present on the radishes and turnips in the gardens in this vicinity throughout the entire winter. There were no severe temperatures during the winter, so the infestation steadily increased. In February this species was present in sufficient numbers to result in a usual infestation of spring crops.

During the first part of March the infestation of lice on turnips was very light. This consisted of apterous individuals well scattered over the field. The feeding at this time was confined entirely to the flower heads of the fall turnips. During the latter part of April the lice began migrating from the flower stalks, though the winged females were never present in large numbers. The lice appeared on the spring planting of turnips in early May. This infestation consisted of large, well-defined colonies, which were found over the entire field. The lice never became abundant on these turnips. There never was a heavy production of winged females, but the lice entirely disappeared from the fields by the middle of June.

On March 1 the lice were quite abundant on the winter radishes in the gardens. By March 15, 75 per cent. of all the lice in the gardens were found on radishes. The infestation consisted of 50 per cent. of apterous lice of all ages, 30 per cent. pupae and 20 per cent. winged females. A few days later only apterous lice were found on the radishes. The feeding of the lice during this season was entirely in the flower heads of the plants. The spring planting of radishes was not infested with lice until April 6. This infestation was light and consisted mostly of apterous lice in small colonies. The lice increased on the radishes until April 20, and then the number decreased for a time. A light infestation of lice persisted on young radishes in the gardens throughout May. During the latter part of this month there was a continued production of pupae, though these were never abundant upon the plants. The winged females were seldom observed. The lice gradually disappeared from the plants, and by the middle of June no lice were observed in the gardens.

By the middle of March the lice were quite abundant upon mustard plants. This infestation consisted mostly of apterous lice, which were feeding on the leaves near the ground. These lice migrated to the flower heads about April 1. Though the infestation at this time was apparently of apterous lice, the spring mustard became infested during the first of April. During the first half of April the infestation on the old mustard increased heavily, and the lice moved from the flower heads to the young leaves near the top of the plants. A few pupae were observed at this time, but winged females were seldom seen. During the first part of May the infestation increased on the spring mustard.

About the middle of the month pupae developed, and gradually the lice disappeared from this plant.

During the last half of April there was a light infestation of lice on rutabaga turnips. These were planted in the same garden as the turnips, radishes and mustard, which has been discussed above. About the same time lice were found on kale in the same garden. This infestation consisted of immature apterous lice.

On June 1 a rape field was found heavily infested with lice. Fully 80 per cent. of the lice were pupae which were about ready to emerge as winged females. But few winged females were observed on the plants at this time. The apterous females were surrounded by small colonies of young. This heavy infestation practically killed the rape.

HIBERNATION.

From the foregoing observations made at College Station it is evident that the turnip louse continues to breed throughout the winter. Seldom is the temperature low enough to prevent reproduction, though the daily number of offspring is very low most of the time. There are a few days during the winter at College Station when the lice, especially the older females, do not reproduce. The temperatures below which the lice are not active are indicated in our cage records, which are shown in Table I.

Trips were made to Wichita Falls, the most northern Texas point known to be infested, and observations made on the winter conditions. Here the lice pass the winter upon turnips and mustard; seldom on radishes. The winter temperatures are sometimes quite low, 15 to 20 degrees F., and it is not uncommon to have snow. For much of the time during the winter the reproduction is indeed very slow, and there are many days at a time when the temperature is not above 32 degrees F. During such periods the lice do not reproduce, and in this we have the nearest approach to hibernation that occurs in the State. During the last of January, 1915, observations were made at Wichita Falls after a long cold spell. Apparently only a few lice had been killed by the cold and snow, and most of these were old females, still upon the leaves.

At Brownsville, the southernmost point visited, winter conditions are vastly different from those found at College Station or Wichita Falls. At Brownsville the conditions in January are very similar to those prevailing at College Station in October. The daily reproduction in the fields near Brownsville in January was four to six young, and in protected places it was as high as eight.

LIFE HISTORY.

The life history of *A. pseudobrassicae* in the various sections of the State is a perplexing problem. Although the louse is a pest in all parts of the State during the fall and early winter, we have been unable to determine where or how it passes the remainder of the year. In the fall the lice make their first appearance on the turnips about the time they develop four leaves. At Waco the lice are first noticed upon the turnips in August and are present continuously on turnips and radishes

until the following May. At College Station the lice do not make their appearance until September 1. The turnips and radishes are then attacked by the louse during the winter and until May of the next year. Further south, at Beaumont, Galveston and Beeville, the lice appear upon the turnips between September 15 and October 1. At Brownsvills the turnip crop is not up until about November 1, but the lice are found on mustard as early as August 1 and continue to infest this crop until the turnips are available. The turnip crop experiences the heaviest damage during November. By December most of the turnips have been either destroyed by the pest or harvested. Throughout the winter the lice feed upon radishes and mustard and on what turnips remain in the ground. In the spring the infestation extends to the new crops of turnips, radishes, etc., and increases in severity. At Brownsville, after May 1, practically all cruciferous crops, except mustard, are over with.

At Wichita Falls turnips are not available for the lice until about September 1, at which time the first infestation is observed. Were the turnips sown as early at Wichita Falls, or other northern points, as they are at Waco, the lice would probably appear on them as early as at the latter place. The time of appearance in fall seems to depend upon the availability of turnips for food. At Wichita Falls the winter is passed upon turnips and mustard, and in the spring the infestation extends also to radishes, continuing until July.

ALTERNATE HOST PLANTS.

A review of the life histories here given show that there is a portion of the year during which the louse is not found upon any cultivated host plant. At College Station the lice begin to migrate from the cultivated plants with the approach of hot, dry weather, during April. Throughout this month there is a decided tendency to the production of winged lice, even when the food supply is good. During this time the number of wingless lice gradually decreases and the infestation finally dies out. There are never very many winged lice present during May, as the reproduction seems to be much retarded. These winged females, while the migration is in progress, are not different in structure from those taken during the fall and winter. Also the first winged lice taken in the fall upon turnips are in no respect different from those found later.

With the approach of hot, dry weather there is a decided reduction in the number of young produced daily and all of the stages of the life history are lengthened, much the same as under winter conditions. It is quite evident that the summer conditions are even more trying than the winter. At College Station there are normally four months of the year when the turnip louse is not found upon cultivated plants. However, some of the host plants, such as mustard and radishes, are sometimes in the garden during the entire summer.

At Brownsville the radishes and turnips are in the ground from October 1 until the following May. Mustard is grown until June, and may be found in small patches during the entire summer. The early fall crop of mustard is available in August, but the lice do not become abundant on it until a month later. There is a period of four, and

perhaps five, months during the year when the turnip louse is not found upon the cultivated host plants. At Wichita Falls there is only one month—July—during which there are none of the cultivated host plants in the gardens. However, the lice are not found upon these plants from May until September, during which time the lice must exist upon some other host plant.

TABLE I.

First-born Generation Series.

1914 Date.	Temperature.		1st Generation.	2nd Generation.	3rd Generation.	4th Generation.	5th Generation.	6th Generation.	7th Generation.	8th Generation.	9th Generation.	10th Generation.	11th Generation.	12th Generation.	13th Generation.	14th Generation.	15th Generation.	16th Generation.	17th Generation.	18th Generation.	19th Generation.	20th Generation.	Humidity.	
	Maximum.	Miinmum.																					Maximum.	Minimum.
Jan. 18	76	58	B																				88	59
19	80	59																					98	85
20	70	46																					98	41
21	65	41																					98	34
22	70	41																					80	49
23	63	51																					98	69
24	70	40																					98	35
25	80	46																					91	28
26	75	45																					90	19
27	82	51																					76	30
28	79	65																					72	43
29	71	41																					87	58
30	50	32	4	B																			69	28
31	73	30	1																				77	21
Feb. 1	75	32	6																				98	37
2	75	43	8																				79	43
3	73	53	8																				90	55
4	69	57	4																				95	81
5	75	55	8																				98	71
6	68	27	1																				99	52
7	38	17	0																				67	36
8	42	27	2																				80	34
9	51	38	4																				88	47
10	76	48	5																				94	43
11	67	38	2																				95	32
12	69	53	2																				96	53
13	60	22	1																				93	49
14	40	28	2																				95	70
15	52	30	3																				93	50
16	71	35	1	2	B																		99	26
17	69	41	3	3																			93	55
18	71	59	4	3																			94	70
19	59	46	2	2																			93	66
20	62	41	2	1																			93	57
21	63	46	2	1																			92	66

TABLE I—Continued.

First-born Generation Series.

1914 Date.	Temperature		1st Generation.	2nd Generation.	3rd Generation.	4th Generation.	5th Generation.	6th Generation.	7th Generation.	8th Generation.	9th Generation.	10th Generation.	11th Generation.	12th Generation.	13th Generation.	14th Generation.	15th Generation.	16th Generation.	17th Generation.	18th Generation.	19th Generation.	20th Generation.	Humidity.	
	Maximum.	Minimum.																					Maximum.	Minimum.
22	67	48	4	4																			99	72
23	39	24	0	2																			99	43
24	35	23	D	2																			67	52
25	53	25		0																			85	33
26	51	30		2																			90	49
27	50	43		0																			98	68
28	62	41		0																			97	52
Mar. 1	67	42		2																			97	31
2	72	44		2																			97	40
3	64	49		3																			95	78
4	50	42		4																			95	61
5	68	34		4																			94	32
6	63	41		1																			93	25
7	57	40		0																			77	31
8	67	31		4																			92	29
9	76	44		6																			93	46
10	74	56		5																			92	58
11	66	45		1																			94	62
12	57	36		3																			77	33
13	66	34		3																			87	43
14	73	40		4																			91	40
15	76	42		D	3	B																	94	41
16	76	49			6																		99	40
17	80	50			3																		99	35
18	74	52			2																		77	48
19	60	40			2										....								99	67
20	50	33			1										....								77	49
21	52	42			2																		90	49
22	61	31			2																		93	29
23	65	36			4																		86	40
24	66	46			3																		92	67
25	80	70			6																		93	56
26	71	59			6																		93	74
27	76	59			8																		93	67
28	75	67			4	1	B																93	77

	29	74	67			5	2																		98	74
	30	79	64			2	6																		99	63
	31	78	67			9	9																		91	65
April	1	83	62			2	9																		91	47
	2	77	52			6	7																		99	34
	3	74	52			D	11																		98	37
	4	64	51				9	2	B																91	57
	5	73	46				5	8																	100	37
	6	74	46				6	6																	99	49
	7	69	41				8	10																	100	85
	8	43	36				1	2																	100	66
	9	54	26				2	1																	100	43
	10	64	33				6	4																	100	61
	11	81	55				1	7																	100	56
	12	59	44				6	2																	100	81
	13	70	46				2	3																	100	49
	14	82	46				2	4																	100	42
	15	92	56				3	3																	100	33
	16	88	59				D	4																	100	38
	17	80	64					3																	100	69
	18	79	62					3	3	B															100	40
	19	77	53					4	4																93	29
	20	86	48					3	2																100	32
	21	84	58					4	4																100	40
	22	75	68					4	4																100	68
	23	75	65					3	5																97	83
	24	85	69					3	6																99	66
	25	78	66					1	8																100	74
	26	77	63					D	7																100	75
	27	73	63						6	3	B														100	94
	28	82	64						8	7															95	60
	29	86	62						6	7															96	48
	30	83	67						5	6															95	71
May	1	77	67						6	5															99	80
	2	79	69						5	9															99	78
	3	81	68						5	8															99	80
	4	91	73						6	9															95	50
	5	96	69						D	9	4	B													93	49
	6	96	73							7	6														100	61
	7	94	74							8	7														100	57
	8	78	61							5	6														90	36
	9	84	56							4	7														91	38
	10	87	67							D	7														89	45
	11	85	69								6														90	59
	12	77	64								5														100	95
	13	66	58								5	2	B												99	77
	14	74	57								4	4													92	57
	15	72	57								5	5													94	50
	16	79	63								4	4													98	49
	17	85	59								4	5													98	49

B, born; D, died.

TABLE I—Contin e .

First-born Generation Series.

1914 Date.	Temperature		1st Generation.	2nd Generation.	3rd Generation.	4th Generation.	5th Generation.	6th Generation.	7th Generation.	8th Generation.	9th Generation.	10th Generation.	11th Generation.	12th Generation.	13th Generation.	14th Generation.	15th Generation.	16th Generation.	17th Generation.	18th Generation.	19th Generation.	20th Generation.	Humidity.	
	Maximum.	Minimum.																					Maximum.	Minimum.
18	76	69								5	4												100	80
19	74	66								3	4												99	75
20	82	66								5	9												98	63
21	82	68								4	7	4	B										99	61
22	83	64								5	6	5											99	52
23	86	62								4	7	8											99	46
24	86	65								3	8	8											99	60
25	88	68								D	8	10											99	59
26	86	67									9	8											100	64
27	78	66									7	8											100	83
28	82	68									5	10	5	B									98	63
29	83	68									3	10	6										97	63
30	83	67									D	9	7										98	64
31	83	69										7	9										97	54
June 1	87	68										7	9										98	48
2	86	67										4	8										100	59
3	85	67										3	8	4	B								100	66
4	88	70										D	12	9									100	58
5	88	81											11	11									100	62
6	88	65											9	10									100	61
7	87	83											9	10									100	65
8	92	81											8	10									100	50
9	92	68											5	10									100	44
10	91	73											D	11	3	B							100	48
11	93	69												7	5								100	46
12	93	71												7	7								100	50
13	93	69												7	6								100	50
14	95	71												6	6								100	48
15	95	72												D	8								100	45
16	92	74													8	2	B						97	52
17	95	75													8	8							96	45
18	90	75													6	10							97	61
19	96	71													6	10							97	47
20	94	73													7	9	5	B					97	45
21	94	72													3	9	3						96	48

22	95	71													2	9	6						96	47
23	93	72													D	5	8						99	52
24	96	70														4	6	2	B				98	44
25	95	70														4	5	3					99	42
26	95	70														4	4	4					99	42
27	96	71														4	2	7					98	41
28	98	71														4	1	6					98	35
29	101	70														3	3	5					94	30
30	99	72														1	5	4					95	41
July 1	97	73														1	4	5	1	B			98	41
2	97	72														D	5	4	4				98	37
3	96	73															3	3	4				97	39
4	97	72															2	4	4				97	39
5	97	69															2	2	4				97	38
6	100	61															4	2	4				97	33
7	103	72															5	3	1				96	34
8	104	69															3	4	1				86	38
9	101	77															0	3	0	1	B		88	40
10	96	71															3	3	1	1			100	47
11	97	74															1	D	1	3			99	44
12	98	73															1		0	3			99	43
13	100	72															D		0	3			99	44
14	102	71																	0	0			100	43
15	100	77																	0	0			100	45
16	101	78																	0	2			100	42
17	103	80																	0	2			100	41
18	101	78																	D	2			100	40
19	101	74																		3			100	29
20	102	75																		5			98	25
21	100	74																		4			84	33
22	102	73																		3			88	30
23	97	72																		2			89	34
24	99	72																		D	2	B	88	31
25	99	74																			4		88	31
26	100	73																			4		88	23
27	102	69																			4		89	29
28	102	72																			3		99	24
29	102	73																			1		98	30
30	105	75																			1		89	36
31	103	74																			3		99	30
Aug. 1	91	72																			3		97	42
2	100	74																			D		99	33
3	98	74																					63	45
4	100	74																					93	61
5	99	70																					90	66
6	85	71																					91	83
7	77	68																				D	100	75

B—born. D—died.

REARING METHODS.

The rearing work, when not otherwise stated, was conducted under as nearly normal conditions as was possible in outdoor cages. Turnips were used for the host plants in all the cage experiments; plants of some size were transplanted from the field to large flower pots. These plants were so trimmed that only three or four small leaves remained and as the new leaves became established the old ones were cut off, one at a time. With this reduced leaf area, it was possible to study the habits of the lice carefully, and it was not difficult to locate the old and young lice. The turnips were kept in the best possible growing condition and a single plant was never used for more than a single generation. The turnips were transplanted some time before they were to be used, in order that they would be well established in the pots. Large lantern globes were used to cover the plants, and on top of these white lawn was drawn tightly. The pots were placed on a stand in the open and this stand was so arranged that the plants could be protected in times of severe wind and storms. In May, 1915, a cage shelter was constructed along lines suggested by Mr. J. J. Davis of the Bureau of Entomology.

On June 23, 1915, all lice were transferred to radishes for host plants. The turnips could not be grown well at this time of the year and the lice could not be kept under proper conditions. Observations and some preliminary tests showed that the lice even prefer radishes at this season.

The generation series were started in January, 1914, and continued until August, 1914. From June 10 until August 6 the work was conducted by W. W. Marshall, then Assistant Entomologist in this Division. His services are here acknowledged. The series was started again in September, 1914, and conducted throughout one year. The first-born of each generation was transferred to a new host, and all other young produced by each female were counted and taken from the plant. The lice were handled with a very small sable hair brush, which did not seem to injure them in any way. When once a generation was established upon a plant the lice were moved as little as possible throughout their life cycle. While removing the young lice the adults were disturbed only when necessary, so they often remained in the same position for days at a time.

DESCRIPTION OF FORMS.

The following descriptions of the forms of this louse taken in our work are the original ones made by Mr. J. J. Davis, which appeared in the *Canadian Entomologist,* Vol. XLVI, No. 7, p. 232:

Wingless Viviparous Female.

Entire body pale whitish green, head slightly dusky. Abdomen with a longitudinal row of impressed dots along each side in a line with the cornicles; also on each side of the median dorsal line is a row of transverse shining areas with a reticulated surface, those on the last four or five segments usually united; and a similar row of smaller areas on each side. These shining reticulated areas contrast with the rest of the body, which is dull and very slightly pul-

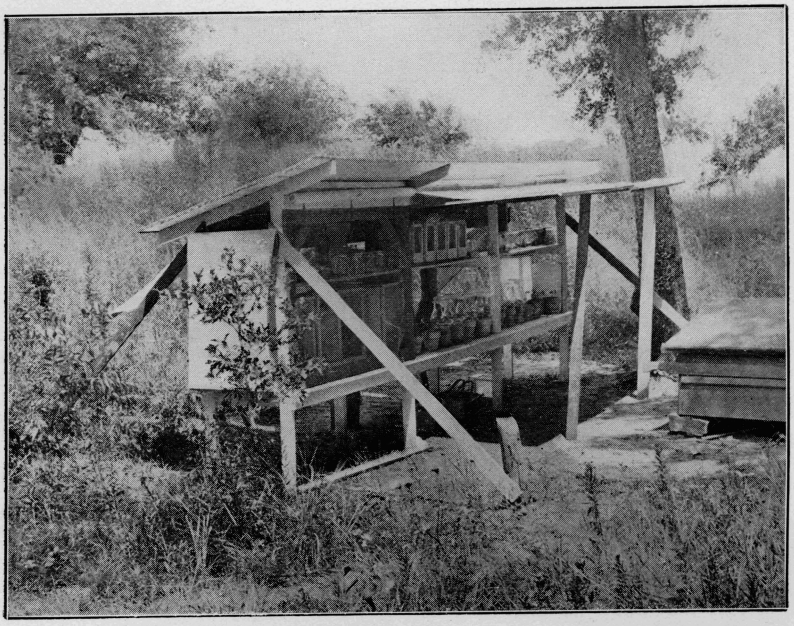

Plate II. Above, shelter in which the cage experiments were conducted with the turnip louse; below, an infested garden, showing radishes which were killed by a severe infestation of the turnip louse. (Original.)

verulent. Thoracic segments with similar transverse areas. In specimens just moulted the entire body appears shining and reticulated.

Eyes black. Antennae blackish excepting segments I, II, and basal half of III, which are pale, reaching a little beyond the middle of the body; segment III longest, it being a half to three-fourths longer than VI filament; segments V and VI base with the usual distal sensoria. Beak reaching to coxae of second pair of legs. Legs pale with dusky joints the tips of the tibiae and all of the tarsi black. Cornicles pale with tip dusky, slightly swollen towards the tip and constricted just before the apex, and noticeably longer than the cornicles of *A. brassicae*. Cauda conical, and dusky to blackish.

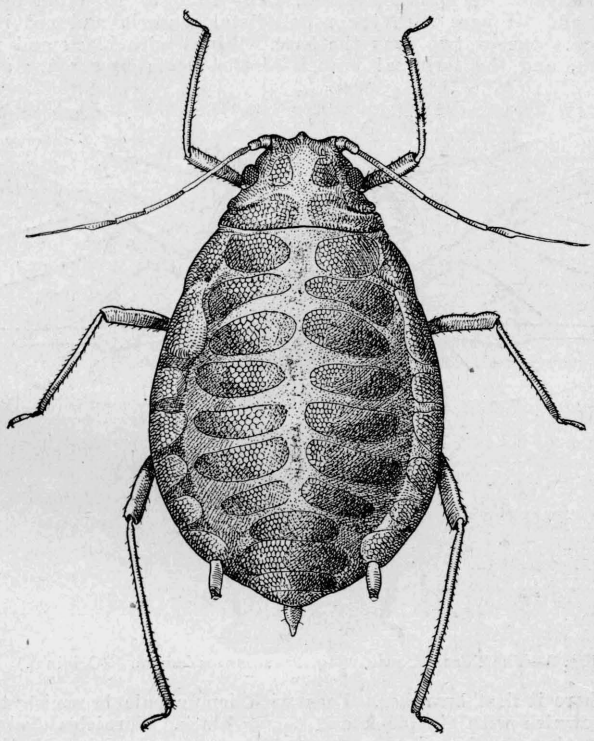

Fig 2—The Turnip Louse, wingless viviparous female. (Original.)

Measurements are as follows (averages from six individuals): Length of body, 1.66 mm.; width, 1.00 mm.; cornicle, 0.226 mm.; cauda, 0.140 mm.; antennae I, 0.080; II, 0.061; III, 0.399; IV, 0.202 mm.; V, 0.160; VI, base, 0.122; VI, filament, 0.287; total average length, 1.311 mm.

Pupa.

Head dusky, remainder of the body cream color or with a faint greenish tint, and covered with a slight whitish pulverulence, excepting the shining areas, which are covered with a noticeable reticulation, and which are placed as follows: A row of oval or transverse areas on each side of the median dorsal line and a row of smaller and more circular ones laterad of these on each side, about in line with the cornicles.

Eyes black. Antennae pale dusky, the distal ends of segments being more so, relative lengths of segments as in the winged female. Wing pads blackish. Legs pale dusky with the joints, distal end of tibiae and tarsus blackish. Cornicles

dusky, paler at middle, blackish at tips, and similar in shape to those of the wingless female.

Winged Viviparous Female.

Head and thorax black. Abdomen pale apple green with a tint of nile green and a row of three black spots on each side anterior to the cornicles; a row of small impressed dots on each side dorsad of the larger spots; and in addition a few scattered inconspicuous dusky markings on the dorsum, and the last three segments with black transverse dorsal median markings.

Eyes black. Antennae black; almost reaching to base of cornicles; segments III and VI filament subequal; segment III with 19 to 26 moderately tuberculate circular sensoria irregularly placed, IV with 6 to 10, often more or less in a row, V and VI base with the usual distal sensoria and not infrequently segment V bears one or two near the base. Wings with black and rather conspicuous veins, and the terminal branch of the media nearer the apex of the

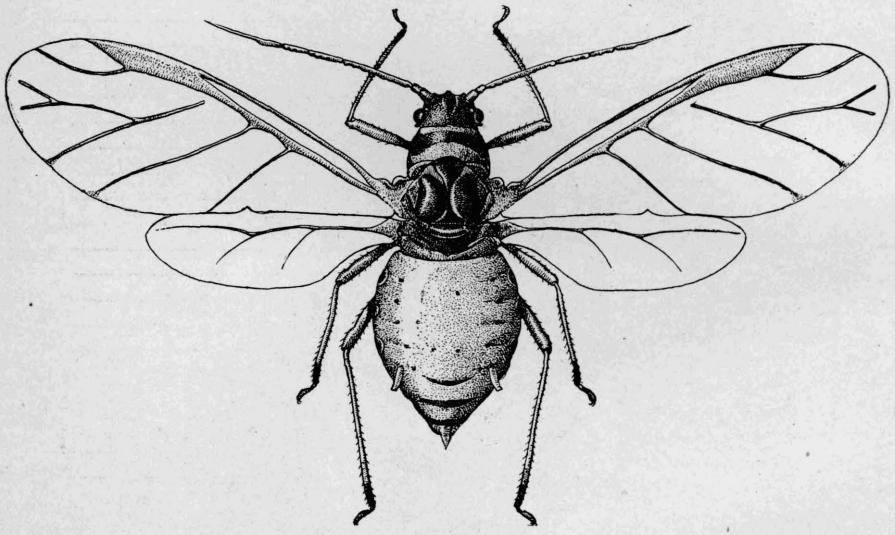

Fig. 3—The Turnip Louse, winged viviparous female. (Original.)

wing than where it first branches. Legs with femur pale brownish to blackish, tibia pale brownish with tip black and tarsus black. Cornicles dusky, paler at tips, and shaped as in the wingless form. Cauda concolorous with the abdomen or paler.

Measurements as follows (averages from six individuals): Length of body, 1.4 mm.; width of body, 0.66 mm.; length of wing, 2.4 mm.; width of wing, 0.9 mm.; antennae I, 0.069; II, 0.061; III, 0.363; IV, 0.191; V, 0.165; VI, base, 0.126; VI, filament, 0.358; total average length, 1.333 mm.; length of cornicles, 0.172 mm.; of cauda, 0.134 mm.

TABLE II.

First-born Generation Series.

Date.	Temperature		1st Generation.	2nd Generation.	3rd Generation.	4th Generation.	5th Generation.	6th Generation.	7th Generation.	8th Generation.	9th Generation.	10th Generation.	11th Generation.	12th Generation.	13th Generation.	14th Generation.	15th Generation.	16th Generation.	17th Generation.	18th Generation.	19th Generation.	20th Generation.	21st Generation.	22nd Generation.	23rd Generation.	24th Generation.	25th Generation.	26th Generation.	27th Generation.	28th Generation.	29th Generation.	30th Generation.	31st Generation.	32nd Generation.	33rd Generation.	34th Generation.	35th Generation.	Humidity.	
	°F. Maximum.	°F. Minimum.																																			Maximum.	Minimum.
1914																																						
Sept. 14	93	77	B																																		92	55
15	97	72																																			98	41
16	96	72																																			98	41
17	94	70																																			97	45
18	93	65																																			95	20
19	87	68																																			98	55
20	90	66																																			98	29
21	92	70																																			97	53
22	96	73	3	B																																	97	50
23	83	68	3																																		96	32
24	85	57	3																																		93	30
25	89	60	4																																		85	33
26	86	57	6																																		97	30
27	92	56	3																																		96	31
28	86	60	8																																		96	30
29	87	60	6																																		82	41
30	81	60	7																																		98	52
Oct. 1	81	62	8																																		90	54
2	89	63	7																																		97	42
3	82	62	7																																		98	45
4	90	62	6																																		97	40
5	92	68	5																																		97	37
6	89	65	5	4	B																																95	38
7	92	68	6	7																																	96	50
8	94	70	5	7																																	96	45
9	97	74	4	7																																	95	40
10	97	75	4	6																																	95	45
11	95	73	D	7																																	95	50
12	88	70		5																																	96	46
13	72	61		3																																	90	29
14	70	47		2																																	78	29
15	76	43		2																																	92	24
16	78	44		2																																	95	27
17	92	48		6	4	B																															90	17
18	81	58		4	6																																93	49

TABLE II—Continued.

First-born Generation Series.

Date.	Temperature		1st Generation.	2nd Generation.	3rd Generation.	4th Generation.	5th Generation.	6th Generation.	7th Generation.	8th Generation.	9th Generation.	10th Generation.	11th Generation.	12th Generation.	13th Generation.	14th Generation.	15th Generation.	16th Generation.	17th Generation.	18th Generation.	19th Generation.	20th Generation.	21st Generation.	22nd Generation.	23rd Generation.	24th Generation.	25th Generation.	26th Generation.	27th Generation.	28th Generation.	29th Generation.	30th Generation.	31st Generation.	32nd Generation.	33rd Generation.	34th Generation.	35th Generation.	Humidity.	
	°F. Maximum.	°F. Minimum.																																			Maximum.	Minimum.
19	87	62		4	5																															92	47
20	88	68		4	6																															93	51
21	84	68		4	7																															93	54
22	81	69		5	6																															92	60
23	83	64		6	7																															93	54
24	74	64		5	6																															92	57
25	74	64		4	5																															93	54
26	77	64		4	6																															93	35
27	70	52		D	5																															69	29
28	76	48		6	6																															90	29
29	84	40		6	5																															90	18
30	80	47		5	6																															63	21
31	83	52		5	6		B																													92	35
1	85	50		6	8																															92	47
2	78	55		8	8																															98	38
3	81	54		8	8																															100	38
4	83	56		5	9																															100	60
5	74	52		D	7																															95	35
6	83	52			8		6	B																												100	48
7	83	59			9		6																													100	57
8	76	55			10		8																													95	67
9	78	62			10		10																													95	29
10	75	39					8																													100	33
11	66	38					9																													100	76
12	64	54					9																													100	98
13	64	60					7																													99	77
14	77	58					6																													100	49
15	77	50					D																													100	51
16	64	51					6																													100	25
17	61	44					8		3	B																										78	83
18	59	33					5		3																											83	52
19	69	50					4		3																											52	99
20	70	39					4		4																											99	85
21	74	32					2		4																											85	98
22	77	40					3		4																											98	97
23	77	50					3		7																											97	95
	74	54					D		7																											95	53

24	64	56						5																														100	61
25	58	55						6																														98	84
26	57	55						5																														99	92
27	54	51						4																														100	93
28	54	51						5																														98	81
29	77	41						5																														100	48
30	74	54						5																														100	60
Dec. 1	65	56						4	2	B																												99	88
2	61	52						4	3																													100	95
3	62	46						3	3																													99	57
4	69	41						3	2																													95	51
5	50	41						3	2																													100	85
6	62	43						2	2																													96	55
7	55	49						2	2																													98	82
8	51	44						2	3																													98	65
9	50	33						2	2																													96	46
10	46	31						2	2																													89	46
11	48	24						1	2																													92	39
12	56	47						1	1																													56	47
13	47	30						0	1																													83	47
14	40	23						0	1																													69	44
15	48	22						D	1																													91	35
16	45	26							1	1	B																											89	42
17	43	35							1	1																												100	57
18	43	36							2	2																												100	93
19	47	41							1	2																												98	94
20	50	41							2	3																												98	92
21	48	40							2	3																												98	78
22	50	40							2	3																												98	61
23	44	40							1	2																												98	97
24	46	41							2	2																												98	87
25	49	43							2	2																												98	87
26	45	34							1	2																												90	39
27	47	29							2	3																												98	54
28	58	30							2	3																												99	55
29	59	43							1	2																												99	51
30	55	32							2	2																												85	33
31	59	29							3	4																												94	30
1915 Jan. 1	64	30							2	3																												96	29
2	68	34							2	2																												100	34
3	45	34							2	2																												96	51
4	67	45							2	2																												90	32
5	67	48							2	2	1	B																										93	70
6	59	42							2	2	1																											100	41
7	63	33							2	2	1																											97	29
8	66	43							2	2	1																											97	45
9	65	33							2	2	2																											100	34
10	64	51							2	2	1																											100	40
11	54	42							2	2	2																											86	45

B, born; D, died.

TABLE II—Continued.

First-born Generation Series.

Date.	Temperature °F. Maximum.	Temperature °F. Minimum.	1st Generation.	2nd Generation.	3rd Generation.	4th Generation.	5th Generation.	6th Generation.	7th Generation.	8th Generation.	9th Generation.	10th Generation.	11th Generation.	12th Generation.	13th Generation.	14th Generation.	15th Generation.	16th Generation.	17th Generation.	18th Generation.	19th Generation.	20th Generation.	21st Generation.	22nd Generation.	23rd Generation.	24th Generation.	25th Generation.	26th Generation.	27th Generation.	28th Generation.	29th Generation.	30th Generation.	31st Generation.	32nd Generation.	33rd Generation.	34th Generation.	35th Generation.	Humidity. Maximum.	Humidity. Minimum.
12	62	29							2	2	2																										100	30
13	66	38							0	2	2																										100	60
14	72	43							0	2	2																										100	26
15	73	42							D	2	1																										100	53
16	65	45								2	1																										99	35
17	45	33								2	2																										78	62
18	50	28								1	2																										100	35
19	63	33								2	2																										86	41
20	71	38								2	3																										99	35
21	72	41								0	3																										100	44
22	66	36								0	2																										99	74
23	37	27								D	0																										80	48
24	37	28									2																										94	51
25	50	23									2																										100	48
26	52	36									2																										100	77
27	50	43									2	1	B																								100	68
28	45	39									2	1																									92	74
29	58	42									2	1																									99	74
30	65	54									2	1																									99	97
31	68	52									2	2																									100	36
Feb. 1	58	36									2	2																									95	47
2	62	33									2	2																									99	40
3	76	43									3	3																									96	55
4	69	51									3	2																									100	27
5	58	41									2	2																									86	38
6	57	35									2	2																									91	37
7	70	31									2	2																									95	24
8	72	33									2	3																									88	28
9	71	39									2	2																									100	46
10	72	52									2	3																									96	47
11	74	53									3	4																									98	40
12	72	57									2	4																									98	53
13	71	53									2	3																									100	32
14	70	45									2	D																									98	32
15	66	43									2	2	2	B																							86	36

16	70	41										2	2																									84	27
17	66	44										2	2																									76	41
18	70	41										2	1																									96	64
19	66	44										2	3																									100	60
20	64	47										2	2																									99	84
21	69	55										2	2																									99	79
22	71	59										3	2																									99	26
23	62	40										1	2																									89	43
24	65	38										3	1																									98	35
25	67	42										2	3																									92	38
26	54	48										2	1																									100	60
27	68	45										3	2																									100	47
28	56	43										1	1																									95	65
Mar. 1	55	37										1	1																									80	49
2	51	45										2	2																									100	75
3	61	49										3	2																									100	98
4	64	50										2	2	3	B																							100	52
5	63	35										1	0	3																								100	39
6	65	41										1	1	2																								99	65
7	49	33											1	2																								95	50
8	40	33											1	2																								82	63
9	38	32										D	1	1																								100	74
10	44	36											1	1																								95	63
11	56	34											2	2																								96	47
12	62	46											2	3																								86	50
13	62	40											2	3																								98	41
14	70	40											3	4																								99	37
15	69	48											4	5																								100	41
16	56	36											1	1																								85	43
17	53	35											2	1																								99	50
18	73	35											3	3																								100	33
19	63	42											1	2																								100	52
20	55	31											2	2																								85	33
21	49	34											1	1																								82	29
22	68	27											2	2																								84	30
23	57	34											1	1																								100	34
24	73	37											3	3																								90	39
25	82	54											3	3																								98	50
26	69	55											5	4																								90	66
27	58	46											3	4																								99	67
28	65	51											3	3																								98	74
29	77	57											3	3	3	B																						100	57
30	87	54											5	4	5																							92	34
31	61	45											2	3	4																							94	34
April 1	55	40											0	0	1																							100	39
2	60	41											2	3	2																							100	36
3	66	34											2	2	3																							87	26
4	74	44											3	3	5																							92	35
5	74	55											3	2	5																							96	53

B, born; D, died.

TABLE II—Continued.

First-born Generation Series.

Date.	Temperature																																	Humidity.	
	°F. Maximum.	°F. Minimum.	1st Generation.	2nd Generation.	3rd Generation.	4th Generation.	5th Generation.	6th Generation.	7th Generation.	8th Generation.	9th Generation.	10th Generation.	11th Generation.	12th Generation.	13th Generation.	14th Generation.	15th Generation.	16th Generation.	17th Generation.	18th Generation.	19th Generation.	20th Generation.	21st Generation.	22nd Generation.	23rd Generation.	24th Generation.	25th Generation.	26th Generation.	27th Generation.	28th Generation.	29th Generation.	30th Generation.	31st Generation.	32nd Generation.	33rd Generation.	34th Generation.	35th Generation.	Maximum.	Minimum.
6	77	60											3	4	7																					98	53
7	74	62											D	5	6																					97	64
8	85	65												4	7																					98	45
9	73	66												3	6																					99	66
10	84	66												3	5	3	B																			99	51
11	81	60												3	5	3																					98	44
12	84	56												D	4	6																					99	36
13	85	57													7	4																					100	34
14	83	55													6	6																					99	36
15	85	57													6	6																					97	30
16	83	58													6	6																					100	36
17	77	54													5	3																					100	57
18	78	61													5	4	2	B																			99	57
19	78	58													D	5	4																					100	65
20	76	57														7	6																					100	78
21	83	65														8	8																					96	63
22	79	69														5	8																					99	75
23	73	61														3	7																					100	89
24	72	62														7	7																					100	95
25	74	67														3	7																					100	94
26	79	69														6	8																					100	80
27	79	68														5	8																					100	72
28	83	68														4	8	8	B																			100	70
29	86	69														5	5	10																					100	75
30	81	66														2	5	8																					100	75
May 1	81	67														2	5	8																					99	64
2	82	70														D	7	12																					90	76
3	72	61															5	9																					100	80
4	85	64															3	6																					100	69
5	68	59															D	8	3	B																		100	72
6	81	61																8	4																				100	74
7	83	60																8	7																				100	71
8	74	53																6	5																				100	54
9	75	56																6	8																				96	33
10	82	61																3	9																				99	41

11	82	57																3	5																			100	33
12	88	58																D	7																			99	35
13	91	61																	9	2	B																	93	37
14	92	61																	8	6																		100	39
15	88	62																	7	5																		100	48
16	88	65																	7	5																		100	48
17	87	63																	10	8																		100	46
18	87	64																	10	10																		100	49
19	86	72																	4	11																		98	64
20	90	73																	D	9																		98	55
21	89	75																		9	6	B																100	57
22	90	71																		8	8																	99	47
23	92	73																		8	10																	99	52
24	92	74																		7	8																	99	54
25	90	75																		8	10																	95	56
26	90	76																		4	8	3	B															94	56
27	86	71																		3	7	7																99	63
28	84	66																		D	7	6																100	37
29	92	60																			7	7																100	48
30	88	67																			9	10																100	65
31	79	65																			7	7																91	65
June 1	84	62																			5	5																92	47
2	89	61																			5	7																100	47
3	93	69																			3	7	6	B														100	47
4	89	74																			D	5	5															99	61
5	92	72																				6	6															100	53
6	92	69																				5	7															100	47
7	95	71																				5	7															100	39
8	88	69																				7	7															92	54
9	90	69																				7	7															100	56
10	92	71																				5	8															100	50
11	92	75																				3	8	5	B													98	50
12	94	76																				D	6	3														97	54
13	96	76																					8	5														98	48
14	98	72																					7	5														98	44
15	96	61																					6	4														100	53
16	93	72																					6	6														100	55
17	92	74																					3	6														100	52
18	94	74																					3	7														99	51
19	95	74																					D	6														100	50
20	96	74																						4														99	49
21	97	70																						4	2	B												100	47
22	97	72																						3	3													100	44
23	97	71																						3	5													100	43
24	97	74																						4	6													100	46
25	96	75																						5	7													100	45
26	95	75																						5	6													100	46
27	97	77																						5	7													99	45
28	98	77																						5	7	3	B											98	39
29	101	75																						5	7	7												100	32

B, born; D, died.

TABLE II—Continued.

First-born Generation Series.

Date.	Temperature		1st Generation.	2nd Generation.	3rd Generation.	4th Generation.	5th Generation.	6th Generation.	7th Generation.	8th Generation.	9th Generation.	10th Generation.	11th Generation.	12th Generation.	13th Generation.	14th Generation.	15th Generation.	16th Generation.	17th Generation.	18th Generation.	19th Generation.	20th Generation.	21st Generation.	22nd Generation.	23rd Generation.	24th Generation.	25th Generation.	26th Generation.	27th Generation.	28th Generation.	29th Generation.	30th Generation.	31st Generation.	32nd Generation.	33rd Generation.	34th Generation.	35th Generation.	Humidity.	
	°F. Maximum.	°F. Minimum.																																			Maximum.	Minimum.
30	98	73																					3	7	8											100	35
July 1	97	75																					3	8	8											97	41
2	98	77																					D	7	9											99	44
3	92	72																						8	10											100	54
4	92	72																						7	10	3	B									100	53
5	90	72																						6	9	7										98	47
6	92	70																						3	6	8										100	57
7	95	77																						D	7	8										99	51
8	96	79																							7	10										95	50
9	96	74																							5	8										100	44
10	96	75																							3	8	3	B								99	48
11	97	74																							D	6	6									99	49
12	99	77																								5	7									98	46
13	98	74																								5	6									100	40
14	97	75																								5	7									100	39
15	97	73																								4	5									100	38
16	99	72																								4	6									100	44
17	99	74																								3	6									100	42
18	99	73																								3	5	3	B							99	39
19	100	72																								0	3	3								99	38
20	103	76																								0	2	3								98	37
21	90	76																								D	2	3								90	51
22	91	67																									3	4								91	35
23	94	65																									3	3								90	31
24	95	63																									3	4								87	35
25	95	63																									3	4	3	B						92	35
26	96	68																									4	5	5							98	44
27	92	72																									4	5	5							100	54
28	99	75																									3	4	5							100	54
29	100	71																									3	5	5							100	37
30	98	73																									3	3	3							99	42
31	101	73																									0	3	3	3	B					99	37
Aug. 1	102	78																									D	3	3	3						97	38
2	102	76																										3	3	4						100	38
3	92	71																										3	3	3						100	52

4.	91	66																											2	2	3							89	38
5.	101	69																											2	2	2							98	33
6.	103	73																											2	2	2							94	31
7.	101	75																											2	3	3							95	34
8.	98	71																											2	2	3	4	B					98	33
9.	98	70																											2	2	3	3						98	36
10.	95	73																											1	2	2	3						97	43
11.	93	69																											1	1	2	2						98	29
12.	100	63																											1	1	1	2						97	30
13.	88	75																											1	1	1	1						98	32
14.	95	71																											0	2	2	3						98	43
15.	96	69																											D	2	2	3						98	40
16.	89	76																												2	2	3	2	B				87	37
17.	81	74																												1	1	1	1						
18.	82	73																												2	2	2	2						
19.	86	74																												2	2	2	2						
20.	90	70																												3	3	3	3						
21.	96	71																												2	2	2	2					98	47
22.	93	74																												2	2	2	2					98	45
23.	94	75																												2	3	3	3					99	40
24.	91	71																												1	3	3	3					99	58
25.	83	75																												0	3	3	3					99	59
26.	94	76																												0	3	3	3	2	B			99	53
27.	90	75																												D	3	3	3	3				98	50
28.	82	73																													3	3	3	3				99	59
29.	86	71																													3	3	3	3				99	47
30.	80	65																													2	2	2	3				95	63
31.	83	63																													2	2	2	3				100	46
Sept. 1.	85	60																													2	3	3	4				100	48
2.	87	61																													1	3	4	4				99	45
3.	91	66																													0	3	4	4	3	B		99	41
4.	94	69																													D	3	3	4	4			99	42
5.	94	70																														2	3	3	3			100	38
6.	95	70																														3	3	4	4			100	45
7.	94	72																														2	3	4	4			100	45
8.	94	70																														2	4	4	4			100	43
9.	95	72																														0	3	3	3	3	B	100	50
10.	95	76																														D	4	4	4	3		100	48
11.	95	73																															3	3	3	3		100	46
12.	92	72																															2	2	2	2		100	52
13.	93	75																															2	2	2	2		100	52

B, born; D, died.

MOULTING.

The process of moulting is much the same in *A. pseudobrassicae*, as is elaborately described in Webster (l.c.) for *Toxoptera graminum*, Rond. Accurate records have not been kept upon the actual time required for the lice to moult, but the processes necessary for the louse to liberate itself from the old skin have been constantly observed. Records have been made continually throughout the life history studies upon the number of moults and the periods between them. From these observations it is evident that the wingless and winged lice moult four times. The following table is taken from the records to show the characteristic features of the periods of moulting in this species:

TABLE III—SHOWING MOULTS OF WINGLESS LICE.

Date of Birth.	M–1*	M–2	M–3	M–4	Produced First Young.
Jan 30	Feb. 1	Feb. 5	Feb. 11	Feb. 14	Feb. 16
Feb. 16	Feb. 20	Mar. 4	Mar. 8	Mar. 13	Mar. 16
April 4	April 7	April 9	April 13	April 16	April 18
May 5	May 6	May 8	May 10	May 12	May 13
May 13	May 14	May 16	May 18	May 20	May 21
June 10	June 11	June 12	June 14	June 15	June 16
June 24	June 25	June 26	June 28	June 29	July 1
July 9	July 11	July 14	July 17	July 21	July 24

*M–1—Indicates the first moult; M–2 second moult, etc.

TABLE IV—SHOWING MOULTS OF WINGED LICE.

Date of Birth.	M–1	M–2	M–4	M–4	Produced First Young.
Sept. 22	Sept. 24	Sept. 27	Oct. 1	Oct. 5	Oct. 7
Nov. 14	Nov. 16	Nov. 20	Nov. 24	Nov. 30	Dec. 2

No experiments have been conducted to determine the exact variation of the length of the instars, but from the many observations made it is evident that such a variation does exist, even when the individuals are born at the same time and are kept under exactly the same conditions. This variation is more pronounced during the cooler parts of the year when there is some considerable period between the moults.

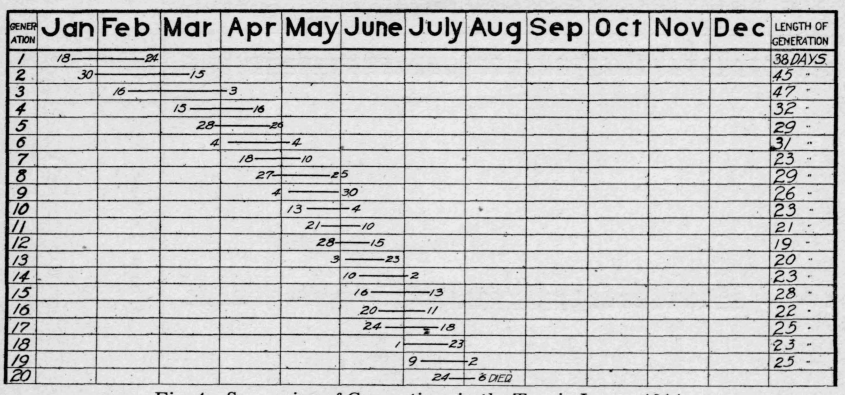

Fig. 4—Succession of Generations in the Turnip Louse, 1914.

NUMBER OF GENERATIONS.

In January, 1914, a study of the successive generations of *A. pseudobrassicae* was commenced. This work was continued without a break until August 7. During the latter month it was hot and dry, so the host plants did not grow well, and the lice gradually died. It is doubtful if the lice can be raised throughout the year upon the turnips, since it is quite probable that there is an alternate host plant. However, the lice were reared upon turnips in the cages long after they disappeared from the fields. The cage studies were again started on September 14, the time that the lice returned to the turnips in the fields. This series was continued for one year, until September 14, 1915. After June 23, 1915, radishes were used for host plants, as in the fields the lice seemed to prefer them to turnips, which naturally do not grow well at this season of the year.

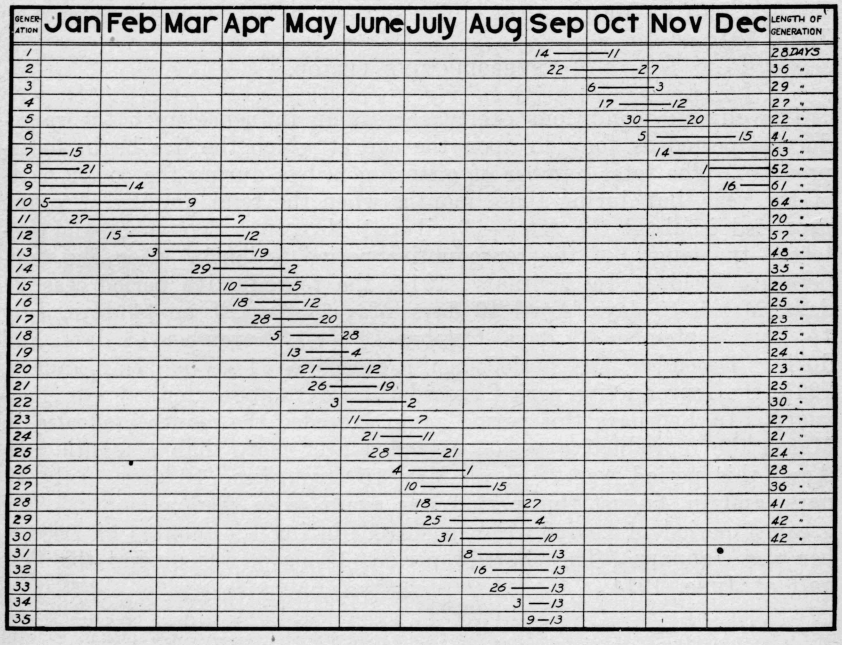

Fig. 5—Succession of Generations in the Turnip Louse, 1914-1915.

No sex forms have ever appeared in the cages, and only twice have winged agamic females developed in the cages. The sex forms have never been observed in the field, though a search was made for them in the extreme northern part of the State.

The generation series given in Tables I and II are of the first born individuals only, and give but the maximum number of generations which may occur in a given time. There will naturally be a variation in the number that will occur in a year, as there is a variation in the life history of the individuals. From January 18, 1914, to August 3, 1914, twenty generations were obtained in the cages. From

September 14, 1914, to September 14, 1915, thirty-five generations were secured. These experiments were conducted out-of-doors, under as nearly natural conditions as it was possible to imitate.

AGE AT WHICH THE FEMALES BEGIN REPRODUCING.

Climatic conditions, and especially temperature, exert a very great influence upon the age at which the lice begin to reproduce. In January, 1914, the average time from the birth of the louse to the date of its first offspring was 12 days, during February 17 days, March 13 days, April 12 days, May 8 days, June 5 days, July 11 days, September 11 days, October 12 days, November 10 days, and during December 17 days. In January, 1915, the average time of this period was 21 days, in February 17 days, in March 23 days, in April 9 days, in May 6 days, in June 7 days, in July 6 days, and in August 8 days. The greatest length of this period occurred during the latter part of February and the first half of March, 1914. The shortest period, 4 days, occurred in June, 1914.

REPRODUCTIVE PERIOD.

The climatic conditions exert as great an influence upon the reproductive period as they do upon the age at which the lice begin to reproduce. The total number of offspring is less during the cooler parts of the year, but during those months when the total number of young produced is about the same—April and May, and September and October—the length of the reproductive period is longer when the temperature is low. In February, 1914, the reproductive period was 24 days, March 19 days, April 19 days, May 17 days, June 14 days, July 15 days, September 19 days, October 19 days, November 15 days, and during December the period again exceeded 31 days. In January, 1915, the reproductive period exceeded 31 days and extended into February. In February this period again exceeded the month, and also in March the reproductive period extended over more than a month. In April this period was 22 days, May 15 days, June 18 days, July 19 days, and in August this period was again more than a month. The greatest period of reproduction occurred during the months of December and January. The shortest period, 12 days, was during the first half of June, 1914.

TABLE V—LINE OF GENERATIONS—1914.

Date of Birth.	Date of Maturity.	Date of First Young.	Age, Days.	Date of Last Young.	Reproductive Period, Days.	Total Young.	Average Per Day.	Maximum Per Day.	Date of Death.	Total Days of Generation.
Jan. 18	Jan. 29	Jan. 30	12	Feb. 22	24	79	3.3—	8	Feb. 24	38
Jan. 30	Feb. 15	Feb. 16	17	Mar. 14	27	64	2.4—	6	Mar. 15	45
Feb. 16	Mar. 13	Mar. 15	27	April 2	19	76	4.0	8	April 3	47
Mar. 15	Mar. 25	Mar. 28	13	April 15	19	96	5.0+	11	April 16	33
Mar. 28	April 3	April 4	7	April 25	22	84	3.8+	10	April 26	30
April 4	April 16	April 18	14	May 4	17	86	5.0+	8	May 5	32
April 18	April 26	April 27	9	May 9	13	87	6.7—	9	May 10	23
April 27	May 4	May 5	8	May 24	20	99	4.9+	7	May 25	29
May 5	May 12	May 13	8	May 29	17	97	5.7+	9	May 30	26
May 13	May 20	May 21	8	June 3	14	101	7.2+	10	June 4	23
May 21	May 27	May 28	7	June 9	13	106	7.9+	12	June 10	21
May 28	June 2	June 3	6	June 14	12	102	8.5+	11	June 15	19
June 3	June 9	June 10	7	June 22	13	75	5.7+	8	June 23	21
June 10	June 15	June 16	6	July 1	16	87	5.3+	9	July 2	23
June 16	June 20	June 20	4	July 12	23	81	3.5+	8	July 13	28
June 20	June 23	June 24	4	July 10	17	64	3.8+	7	July 11	22
June 24	June 30	July 1	7	July 11	11	25	2.2+	4	July 18	25
July 1	July 8	July 9	8	July 23	15	34	2.2+	5	July 23	23
July 9	July 23	July 24	15	Aug. 3	.....	.....	.....	.....	Aug. 3	.....
July 24	.....	.....	.....	.....	.....	.....	.....	.....	Aug. 7	.....

TABLE VI—LINE OF GENERATIONS—1914-1915.

Date of Birth.	Date of Maturity.	Date of First Young.	Age, Days.	Date of Last Young.	Reproductive Period, Days.	Total Young.	Average Per Day.	Maximum Per Day.	Date of Death.	Total Days of Generation.
Sept. 14	Sept. 21	Sept. 22	8	Oct. 10	19	100	5.2+	8	Oct. 11	28
Sept. 22	Oct. 5	Oct. 6	14	Oct. 26	21	98	4.6+	7	Oct. 27	36
Oct. 6	Oct. 16	Oct. 17	11	Nov. 2	17	99	5.8+	8	Nov. 3	29
Oct. 17	Oct. 29	Oct. 30	13	Nov. 11	13	96	7.4+	10	Nov. 12	27
Oct. 30	Nov. 4	Nov. 5	6	Nov. 19	15	95	6.3+	10	Nov. 20	22
Nov. 5	Nov. 13	Nov. 14	9	Dec. 14	31	103	3.3+	7	Dec. 15	41
Nov. 14	Nov. 30	Dec. 1	17	Jan. 14	45	80	1.7+	2	Jan. 15	63
Dec. 1	Dec. 14	Dec. 15	14	Jan. 20	37	78	2.1+	4	Jan. 21	52
Dec. 15	Jan. 3	Jan. 5	20	Feb. 13	40	75	1.8+	3	Feb. 14	61
Jan. 5	Jan. 25	Jan. 27	23	Mar. 8	40	83	2.1—	4	Mar. 9	64
Jan. 27	Feb. 13	Feb. 15	19	April 6	50	104	2.1—	5	April 7	70
Feb. 15	Mar. 1	Mar. 3	16	April 11	40	103	2.5+	5	April 12	57
Mar. 3	Mar. 28	Mar. 29	25	April 18	22	103	4.9+	7	April 19	48
Mar. 29	April 9	April 10	12	May 1	22	103	4.9+	8	May 2	35
April 10	April 17	April 18	8	May 4	17	103	6.0	8	May 5	26
April 18	April 27	April 28	10	May 11	14	103	7.3+	9	May 12	25
April 28	May 4	May 5	7	May 19	16	103	6.4+	10	May 20	23
May 5	May 12	May 13	8	May 27	16	103	6.4+	11	May 28	25
May 13	May 20	May 21	9	June 3	14	100	7.0	10	June 4	24
May 21	May 25	May 26	5	June 11	17	102	6.0	10	June 12	23
May 26	June 2	June 3	8	June 18	16	99	6.2—	8	June 19	25
June 3	June 10	June 11	8	July 1	21	96	4.5+	7	July 2	30
June 11	June 20	June 21	10	July 6	16	96	6.0	8	July 7	27
June 21	June 27	June 28	7	July 10	13	92	7.0	10	July 11	21
June 28	July 3	July 4	6	July 18	15	86	5.7+	10	July 21	24
July 4	July 9	July 10	6	July 30	20	87	4.3+	7	Aug. 1	28
July 10	July 17	July 18	8	Aug. 13	26	77	2.9+	5	Aug. 15	36
July 18	July 24	July 25	7	Aug. 24	31	77	2.4+	5	Aug. 27	41
July 25	July 30	July 31	6	Sept. 2	34	79	2.3+	4	Sept. 4	42
July 31	Aug. 7	Aug. 8	8	Sept. 8	32	81	2.5+	3	Sept. 10	42
Aug. 8	Aug. 15	Aug. 16	8							
Aug. 16	Aug. 25	Aug. 26	10							
Aug. 26	Sept. 2	Sept. 3	8							
Sept. 3	Sept. 8	Sept. 9	6							
Sept. 9										

LONGEVITY.

The life of this louse is much longer in the spring and fall than in the summer, but is longest during the winter months. During this time a single generation may live over a considerable period of time. The length of the life of a generation upon the alternate host plant may vary much from that ascertained when turnips were used. The length of the life of each generation is shown in Tables V and VI.

AVERAGE NUMBER OF YOUNG DAILY.

The averages here given are made from the total number of young produced during the reproductive period of a generation. During January, 1914, this daily average was 1.8, during February 2.5, March 4.1, April 5.0, May 6.4, June 6.0, July 2.3, September 4.8, October 5.4, November 6.2, and during December 2.2. During January, 1915, the daily average was 1.9, February 2.1, March 2.5, April 5.0, May 6.7, June 5.4, July 5.3, and August 2.3.

RATE OF INCREASE.

To those who are not familiar with plant lice it seems strange, indeed, that a turnip patch can be destroyed in such a short time by lice. When the rate of reproduction is known, it is possible to appreciate how the lice can increase in number so as to destroy a field of turnips. Many estimates have been made on the possible reproduction of plant lice, and the numbers obtained are so large as to be beyond meaning to the human mind. The turnip louse is among the most prolific of the plant lice. In the cage experiments 35 generations were obtained in twelve months. None of the lice produced less than 25 young, and most of the females gave birth to 80 to 100 young each. The greatest daily reproduction was 12, but 8 per day was not uncommon, and 6 young was very frequent. It is not surprising, when these figures are considered, that if a few lice are left when the turnips are sprayed, the plants will be covered again in the course of a few days.

The following table gives the comparison of the reproduction in the winged and wingless lice. The table shows that the reproductive period of the winged lice is shorter than that of the wingless lice. The daily number of offspring is less in the winged lice, and of course the total number of young produced by them is much less than the number produced by the wingless females.

TABLE VII—REPRODUCTION IN WINGED AND WINGLESS LICE.

Date.	Temp.		Wingless.											Winged.										Humidity.	
	Max.	Min.	1	2	3	4	5	6	7	8	9	10	11	a	b	c	d	e	f	g	h	i	j	k	Max.	Min.
1914																										
Sept. 22	96	73	B											B											97	50
23	83	68																							96	32
24	85	57																							93	30
25	89	60																							85	33
26	86	57																							97	30
27	92	56																							96	31
28	86	60																							96	30
29	87	60																							82	41
30	81	60																							98	52
Oct. 1	81	62																							90	54
2	89	63																							97	42
3	82	62																							98	45
4	90	62																							98	40
5	92	68	M											M											97	37
6	89	65	4																						95	38
7	93	68	7											4											96	50
8	94	70	7											3											96	45
9	97	74	7											3											95	40
10	97	75	6											2											95	45
11	95	73	7											0											95	50
12	88	70	5											2											96	46
13	72	61	3											2											90	29
14	70	47	2											2											78	29
15	76	43	2											2											92	24
16	78	44	2											2											95	27
17	92	48	6											3											90	17
18	81	58	4											2											93	49
19	87	62	4											0											92	47
20	88	68	4											0											93	51
21	84	68	4											0											93	54
22	81	69	5											D											92	60
23	83	64	6																						93	54
24	74	64	5																						92	57
25	74	58	4																						93	54
26	77	52	4																						93	35
27	70	48	D																						69	29
Dec. 16	45	26		B											B										89	42
17	43	35																							100	57
18	43	36																							100	93
19	47	41																							98	94
20	50	41																							98	92
21	48	40																							98	78
22	50	40																							98	61
23	44	40																							98	97

	24	46	41																										98	87
	25	49	43																										98	87
	26	45	34																										90	39
	27	47	29																										98	54
	28	58	30																										99	55
	29	59	43																										99	51
	30	55	32																										85	33
	31	59	29																										94	30
	1915																												96	29
Jan.	1	64	30																												
	2	68	34																										100	34
	3	45	34																										96	51
	4	67	45		M												M	M											90	32
	5	67	48		1																								93	70
	6	59	42		1												1												100	41
	7	63	33		1												1												97	29
	8	66	43		1												0												97	45
	9	65	33		2												1	1											100	34
	10	64	51		1												0	1											100	40
	11	54	42		2												1	2											86	45
	12	62	29		2												1	2											100	30
	13	66	38		2												1	0											100	60
	14	72	43		1												0	1											100	26
	15	73	42		1												0	1											100	53
	16	65	45		2												1	0											99	35
	17	45	33		1												2	0											78	62
	18	50	28		2												1	0											100	35
	19	63	33		2												1	0											86	41
	20	71	38		3												1	1											99	35
	21	72	41		3												1	1											100	44
	22	66	36		2												0	1											99	74
	23	37	27		0												0	1											80	48
	24	37	28		2												0	1											94	51
	25	50	23		2	M											0	1											100	48
	26	52	36		2	0											0	1											100	77
	27	50	43		2	1											1	1											100	68
	28	45	39		2	1											1	1											92	74
	29	58	42		2	1											0	1											99	74
	30	65	54		2	1											0	2											99	97
	31	68	52		2	2											0	2											100	36
Feb.	1	58	36		2	2											0	1											95	47
	2	62	33		2	2											0	1											99	40
	3	76	43		3	3											0	1											96	55
	4	69	51		3	2											0	1											100	27
	5	58	41		2	2											1	1	M										86	38
	6	57	35		2	2											1	1											91	37
	7	70	31		2	2											0	1	2										95	24
	8	72	33		2	3											1	1	0										88	28
	9	71	39		2	2											1	1	1										100	46
	10	72	52		2	3											1	1	2										96	47
	11	74	53		3	4											1	1	0										98	40

M, matured; B, born; D, died.

TABLE VII—REPRODUCTION IN WINGED AND WINGLESS LICE—Continued.

Date.	Temp.		Wingless.											Winged.											Humidity.	
	Max.	Min.	1	2	3	4	5	6	7	8	9	10	11	a	b	c	d	e	f	g	h	i	j	k	Max.	Min.
12	72	57		2	4										2	1	0								98	53
13	71	53		2	3	M									3	1	1								100	32
14	70	45		D	2	0									2	1	1								98	32
15	66	43			2	2									1	0	1								86	36
16	70	41			2	2									1	D	1								84	27
17	66	44			2	2									1		2								76	41
18	64	47			2	1									1		2								96	64
19	70	51			2	3									0		2								100	60
20	64	57			2	2									0		2								99	84
21	69	55			2	2									D		3								99	79
22	71	59			3	2											2								99	26
23	62	40			1	2											0								89	43
24	65	38			3	1											0								98	35
25	67	42			2	3											2								92	39
26	54	48			2	1											2								100	60
27	68	45			3	2											3	M							100	47
28	56	43			1	1											0	0							95	65
Mar. 1	55	37			1	1											0	0							80	49
2	51	45			2	2	M										3	1							100	75
3	61	49			3	2	0										0	0							100	98
4	64	50			2	2	3										0	2							100	52
5	63	35			1	0	3										D	0							100	39
6	65	41			1	1	2											0							99	65
7	49	33			1	1	2											0							95	50
8	40	33			1	1	2											0							82	63
9	38	32			D	1	1											0							100	74
10	44	36				1	1											0							95	63
11	56	34				2	2											1							96	47
12	62	46				2	3											0	M						86	50
13	62	40				2	3											0	0	M					98	41
14	70	40				3	4											L	0	0					99	37
15	69	48				4	5												0	0					100	41
16	56	36				1	1												1	0					85	43
17	53	35				2	1												0	0					99	50
18	73	35				3	3												0	1					100	33
19	63	42				1	2												1	1					100	52
20	55	31				2	2												0	0					85	33
21	49	34				1	1												0	0					82	29
22	68	27				2	2												1	1					84	30
23	57	34				1	1												1	1					100	34
24	73	37				3	3												1	1					90	39
25	82	54				3	3												1	1					98	50
26	69	55				5	4												1	2					90	66
27	58	46				3	4												0	1					99	67

28	65	51				3	3	M											0	2					98	74
29	77	57				3	3	3											L	2					100	57
30	87	54				5	4	5												2					92	34
31	61	45				2	3	4												1					94	34
April 1	55	40				0	0	1												0					100	39
2	60	41				2	3	2												1					100	36
3	66	34				2	2	3												1					87	26
4	74	44				3	3	5												1	M				100	39
5	74	55				3	2	5												2	0				100	36
6	77	60				3	4	7												2	1				87	26
7	74	62				D	5	6												2	3				92	35
8	85	65					4	7												2	2				96	53
9	73	66					3	6	M											2	3				98	53
10	84	66					3	5	3											1	2				97	64
11	81	60					3	5	3											2	2				98	45
12	84	56					D	4	6											2	3				99	66
13	85	57						7	4											2	1				99	51
14	83	55						6	6											0	2				98	44
15	85	57						6	6											D	4				99	36
16	83	58						6	6												1				100	34
17	77	54						5	3												1	M			99	36
18	78	61						5	4	2											3	0			97	30
19	78	58						D	5	4											2	3			100	36
20	76	57							7	6											0	2			100	57
21	83	65							8	8											1	3			99	57
22	79	69							5	8											1	1			100	65
23	73	61							3	7											0	1			100	78
24	72	62							7	7											0	3			96	63
25	74	67							3	7											D	4			99	75
26	79	69							6	8												3			100	89
27	79	68							5	8												4			100	95
28	83	68							4	8	8											4			100	94
29	86	69							5	5	10											2			100	80
30	81	66							2	5	8											3			100	72
May 1	81	67							2	5	8											4			99	64
2	82	70							D	7	12											3			90	76
3	72	61								5	9											0			100	80
4	85	64								3	6											D			100	69
5	68	59								D	8	3													100	72
6	81	61									8	4													100	74
7	83	60									8	7											M		100	71
8	74	53									6	5											4		100	54
9	75	56									6	8											4		96	33
10	82	61									3	9											4		99	41
11	82	57									3	5											2		100	33
12	88	58									D	7											5		99	35
13	91	61										9	2										3		93	37
14	92	61										8	6										4		100	39
15	88	62										7	5										5		100	48
16	88	65										7	5										3		100	48

M, matured; B, born; D, died; L, lost.

TABLE VII—REPRODUCTION IN WINGED AND WINGLESS LICE—Continued.

Date.	Temp.		Wingless.											Winged.											Humidity.	
	Max.	Min.	1	2	3	4	5	6	7	8	9	10	11	a	b	c	d	e	f	g	h	i	j	k	Max.	Min.
17	87	63	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	8	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	.....	100	46
18	87	64	.....	.....	.....	.....	.....	.....	.....	.....	.....	10	10	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	100	49
19	86	72	.....	.....	.....	.....	.....	.....	.....	.....	.....	4	11	.....	.....	.....	.....	.....	.....	.....	.....	.....	4	.....	98	64
20	90	73	.....	.....	.....	.....	.....	.....	.....	.....	.....	D	9	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	98	55
21	89	75	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	9	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	100	57
22	90	71	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	8	.....	.....	.....	.....	.....	.....	.....	.....	.....	D	.....	99	47

EFFECT OF TEMPERATURE ON DEVELOPMENT.

The winter of 1913-14 presented many unusual climatic conditions and afforded an excellent opportunity to study the effect of weather conditions upon the habits of the lice. On January 17, 1914, when the generation experiments were started, the weather was warm. At this time the females were producing from 5 to 8 young per day. For some time previous to this it had been quite cool and the increase in temperature stimulated reproduction and the females responded very quickly to the changes in temperature. On the night of February 6, 1914, the temperature suddenly fell to the unusual point of 17° F. The next day was cool, and the following night was quite cool, 32°, but the following day was much warmer. On this day the females under observation gave birth to an average of 2 young. Several winged lice also developed on the plants in the cages. During the week of February 10 to 17, 1914, two quite hard freezes occurred, but the days were warm. The daily reproduction did not seem to be seriously affected by the low night temperatures. Winged females continued to develop in the cages during this time. The latter part of February was quite cold for a period of a week. The reproduction at this time was very materially reduced, and but few winged females developed in the cages.

During early March a patch of turnips was artificially infested with *A. pseudobrassicae.* At that time it was quite warm and the females soon became established upon the plants. Within a week after the lice were transferred, good-sized colonies were found around each female. Reproduction materially increased during the warm days and decreased on the cool days. The period from March 20 to 30 was cooler than the preceding two weeks and the drop in reproduction was very noticeable. The warm period which followed caused the daily reproduction to go up from 3 or 4 to 7, 8 or 9. April 7 to 12 was again cool, and the rate of reproduction dropped to 2 young per day.

SUMMER REPRODUCTION.

During the summer months the reproduction is low. When the hottest days of the summer occur there is no reproduction, even for days at a time. It is quite evident that the summer conditions are much harder for the lice to withstand than are the winter conditions.

OTHER SPECIES FOUND.

There are two other species of plant lice which may be found upon the same plants on which the turnip louse feeds. Very often one or both of the species have been taken upon the plant at the same time.

The cabbage louse, *A. brassicae* Linn, is often found upon cabbage, especially in the fall, and is often mistaken for the turnip louse. Wherever the cabbage louse is found it is a serious pest upon the plants attacked. The cabbage louse is known to feed upon most of the known host plants of the turnip louse. In Texas the writer has observed the cabbage louse upon plants other than cabbage but once; in the spring of 1915 a few colonies were found upon turnips. In the past it has

been thought that the cabbage louse was responsible for the injury to winter turnips, and there is no doubt that the turnip louse has not yet been recognized in many sections. In reply to inquiries, several entomologists stated that the cabbage louse was known to be present and that the winter turnips suffered from the attacks of a plant louse.

It is a comparatively easy matter to distinguish the cabbage louse from the turnip louse. This is especially true of the wingless female, which in the case of the cabbage louse is covered with a cottony substance, whereas the turnip louse is bare. The winged females of the cabbage louse have distinct transverse bands upon the abdomen, which are not found upon the turnip louse.

The Green Peach-Aphis, *Myzus persicae* Sulz, sometimes called the "garden aphis," has very often been found upon turnips, and by some has been mistaken for the turnip louse. The variation in appearance and the great range of host plants has caused much confusion in the determination of this species. The synonyms of this species are listed by Gillette,* who also describes the various forms. Those forms which have been taken during the investigations on the turnip louse are called by Prof. Gillette the apterous viviparous female, second generation and the spring migrant. This species is most always present upon turnips and radishes, though never in sufficient numbers to do any injury. The louse was present in numbers in the out-of-door cages during the winter of 1913-14. This species is much more hardy than the turnip louse, though it is not nearly as prolific. During the winter the low temperatures did not affect the garden aphis nearly as much as they did the turnip louse. During the fall of 1913, when the fungus disease, *Empusa,* was working such destruction of the turnip louse, the garden aphis was not attacked until most of the turnip lice were destroyed. Under such conditions the garden aphis served to carry over the fungus until the turnip louse again appeared. The parasites, which were abundant, did not attack the garden aphis until the food supply of the turnip lice was almost exhausted. Only when the turnip lice were about gone would the coccinelids feed upon the garden aphis. The garden aphis was always found very closely associated with the turnip louse, the colonies of the two species being often intermingled upon the same leaf.

The young of these two species are quite similar in general appearance under casual observaton. The apterous females of the garden aphis are pale green in color with no markings upon the body, though occasionally the eyes of the young appear as pink spots on the abdomen. The general shape of the body of this species is much elongated. The winged females of the garden aphis closely resemble the turnip louse at first appearance, but when the two species can be closely compared it is found that the former seems much darker, due to the presence of several black lines across the abdomen. The body of the winged form of the garden aphis is elongate, as are the wingless forms.

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*Journal of Economic Entomology, Vol. I, No. 6, p. 359.

NATURAL ENEMIES.

The enemies of *A. pseudobrassicae* are not a few, and the assistance which they give the grower can hardly be estimated. These enemies may be grouped into parasites, or enemies, which develop within the body of the host, predaceous enemies, or those which feed upon the lice externally, and disease which grows upon the outside of the lice. There are two species of parasites which have been very important in the control of the turnip louse, *Dieretus rapae* Curt., and *Lysiphlebus testaceipes* Cress. Other parasites have been taken in the study of the louse, but they were always present in limited numbers. Of the predaceous enemies two species of lady beetles, *Megilla maculata* DeG., and *Hippadmia convergens* Guer., have been very effective in checking this pest. Syrphid flies and lace-wing flies have been present in limited numbers. A fungus disease was very effective one season in the control of the turnip louse.

PARASITES.

Diaeretus rapae Curt.

The turnip louse has been very seriously attacked at College Station by this species of parasite.* During the season of 1913 it was present in great numbers, and was a very important factor in controlling the pest. It has not been taken at any other place in connection with the study of *A. pseudobrassicae*. The following descriptions are taken from Maryland Bulletin No. 152, by Mr. A. B. Gahan:

Diaeretus rapae Curt.; *Aphidius rapae* Curt.; *Trioxys piceus* Cress.; *Aphidius brassicae* Marsh.; *Diaeretus californicus* Baker.

Female: Length 2 mm. Head and thorax black, smooth and shining. Head transverse not wider than the thorax, the temples rather broad and convex, not sloping abruptly from the eye margin, clypeus transverse, about twice as wide as long. Mouth parts reddish yellow, the palpi often fuscous. Antennae 13-15-jointed, (most often 14-jointed), entirely black or dark brown. Parapsidal furrows present at the anterior lateral angles of the mesonotum; propodium with distinct median longitudinal and transverse carinae, the former dividing at the intersection with the latter and enclosing a short and very narrow areola at the base of the petiole, (this areola is variable in width, being hardly discernible in some specimens). Wings hyaline, veins and stigma brown; the postmarginal vein and stub of radius are nearly equal, the latter extending about one-third of the distance to the wing apex; the cubital vein recurrent nervure and cubital cross-veins are entirely effaced. Anterior legs including their coxae yellow; median and hind coxae mostly black, yellowish at the apices, their femora and tibiae brownish; tarsi all fuscous. Abdomen longer than the head and thorax, often entirely black but usually reddish brown.

Male: Antannae 16-18-joined. All legs usually dark brown, nearly black. Abdomen not longer than the head and thorax. Otherwise similar to the female.

Habitat: United States and Europe.

Host: *Aphis brassicae* Linn.

The details of the life history of this insect have not been worked out, but much time has been taken to carefully observe it under field conditions. There are a great many points in it which closely resembles

*Determined by Mr. A. B. Gahan through the courtesy of Prof. F. M. Webster of the Bureau of Entomology.

Lysiphelebus testaceipes Cress., the life history of which is given in detail by Webster (l.c.).

Egg-laying probably begins within a few hours after the adult parasite emerges from its host. We cannot say if the females will deposit eggs when the males are not present and if these eggs will hatch parthenogenetically, as is the case with *Lysiphlebus testaceipes* Cress. In some cages kept inside during February and March, 1914, the parasites which emerged gathered immediately on that side of the cage nearest the window. Here they were very active, going up the side until the top was reached, falling to the bottom and starting up again. Within the course of a few hours the parasites would return to the louse-infested plant. The manner of oviposition is much the same as in *Lysiphlebus testaceipes,* shown in Fig. 7. While ovipositing the females seem very excited and act as though they were prepared to make their escape at any time. Under natural conditions, it is very probable that only one egg is laid in a single louse, as in the cages we never observed more than one parasite developing within one louse.

In January, 1914, the adult parasites were kept alive for seven days, though it may be that the adult life is quite long at that time of the year. In October, 1913, we were not able to keep the adults confined in tubes over three days, and most of them died within two days. The parasites seem to prefer to oviposit in the younger lice, those which have passed the second or third moults. Most of the apterous lice mature and many of them reproduce for two or three days, producing as many as ten young in a few instances. However, the daily production is much reduced in the parasitized lice. Only once has a winged louse been observed that died from a parasite, and dead pupae have never been seen. The dead lice seem very securely fastened to the leaf on which they were feeding before death. A slight cocoon spun by the larva of the parasite is attached to the body wall of the louse and, through a hole which has been previously cut by the larva, to the leaf surface. The skin of the dead louse is dull brown in color, parchment-like in texture and seemingly water-proof. We have not been able to ascertain the number of lice that a single *Diaeretus* will parasitize, but it is evidently not as many as *Lysiphlebus* which, according to Webster (l.c.), averages 94.

This species of parasite was described from specimens of *A. brassicae.* The present experiments have been conducted entirely with *A. pseudobrassicae.* About May 7, 1914, when most of the turnip lice were dead, a few *Diaeretus* were taken from *Myzus persicae.*

Diaeretus was first taken in 1913 on October 9, when they were working on the lice feeding upon turnips. The lice were nearly all apterous, and the infestation was quite heavy. The first dead lice were taken just a few days later in the same patch. During the last two weeks of October but few parasites were observed, though the dead lice were abundant in all the fields in this vicinity. The parasites seem to be able to detect a heavily louse-infested area of plants and to move to it quickly. On November 2, all of the host plants of the lice in a garden had been sprayed or fumigated, except a few radishes. Here, two days later, the parasites were very abundant and hardly a one could be found around the treated plants. A week later these rad-

ishes were fumigated and then the parasites were found among mustard plants, where the louse infestation had just started. By November 19, 1913, fully 20 per cent. of the lice in the College garden were parasitized. The heavy rains which occurred from November 28 to December 8 killed almost every louse and apparently the parasites.

Diaeretus was next taken on January 13, 1914. In the out-door cages a few dead lice were seen, making it evident that the parasites had been present some time previous. The last week in December was very cold, but the first week in January was mild. Webster (l.c.) states that *Lysiphlebus* can survive very low temperatures in the full-grown larval stage. The larvae of *Diaeretus* must have been nearly full-grown before the very cold weather of late December and the warm spell during early January enabled them to pass through the pupal stage and emerge as adults on January 13. The parasites continued to emerge over a period of a week. On January 17, more dead lice were observed upon the caged plants, which was evidence that the adults of *Diaeretus* had been present for some time before. During the first seventeen days of January the average daily mean temperature was 50° F., and at this temperature the larval development was not stopped. Adult parasites emerged from the dead lice collected on January 17, sixteen days later, or on February 2. During this period the average daily mean temperature was 59° F.

On the night of February 6, the very low temperature of 17° F. occurred, at which time all of the turnips were badly frozen and 5 per cent. of the lice were killed. Some of the lice which died from parasites four days previous and which were exposed to this low temperature, were put in a cage inside but with no heat. Eleven days after the freeze, and fifteen days after the lice died, parasites emerged. They continued to emerge for a period of seven days. The pupal stage of this brood of parasites varied from 15 to 22 days, during which period the average daily mean temperature was 49° F. The reason for this variation is hard to explain. It is evident that the parasites in the pupal stage are able to withstand low tempratures and to develop at low temperatures. The adult parasites were again active in the out-door cages on February 21, at which time a few lice were observed and within the next two days many were seen. On March 9, 16 days from the maximum activity of the last brood, the parasites were active again. During this period the average daily mean temperature was 48° F.

The first *Diaeretus* taken in the field was on March 25. It is possible that these escaped from the cages and did not survive the winter in the field. The first dead lice were taken in the field only two days later, which is evidence that the parasites had been present for some time before they were observed. The number of dead lice increased rapidly for a few weeks and threatened the destruction of all the lice for experimental work. It was not possible to determine the entire life history, but from the observations made there is a decided overlapping of broods, especially during the periods of low temperature. The parasites were constantly present in the fields until May 13, at which time most of the turnip lice were dead.

On November 12, 1913, some heavily infested radish plants were

fumigated with tobacco stems. On the following day many parasitized lice were collected from these plants and placed in a cage in the laboratory. At the end of a week a parasite had emerged from every louse collected. This single experiment confirms the field observations that fumigation does not injure the pupae within the lice. Of course, there are many lice with parasite larvae in them, and as such lice dry up after the fumigation the parasites do not mature.

On November 17, 1913, some infested cabbage plants were sprayed with Black Leaf-40 and whale-oil soap. Parasitized lice were collected from these plants on the day following the application. These lice were placed in a cage in the laboratory. Within two days parasites had emerged from all lice in the cage. Our field observations confirm this experiment, that the soap and Black Leaf-40 sprays do not injure the pupae of the parasite within the body of the host. The lice which are struck by the spray dry up at once, and of course the larvae of the parasites are killed.

As only one case has been recorded of a winged louse being parasitized, it is hard to say that *Diaeretus* is disseminated to any great extent by the host flying from field to field. Webster (l.c.) says that a part, at least, of the dispersion of *Lysiphlebus* is due to this factor. It is very probable, however, that the winged turnip lice are parasitized to a greater extent than has been observed, which would certainly make such means of dispersion important in the case of this parasite. Throughout March, April and May the prevailing wind at College Station is from the South. During these months the wind is seldom in any other quarter for very long at a time. This south wind is never heavy, so the parasites may fly safely a great deal of the time. It is quite probable that *Diaeretus* flies to a considerable extent from field to field, as they are active in the field at all times when a hard wind is not blowing. This factor must exert much influence upon the dispersion of this parasite.

The temperature exerts much influence upon the activity of *Diaeretus*. During the month of January, 1914, the parasites were quite active in the outdoor cages when the daily mean temperature averaged 55° F. Parasites emerged from the lice in February when the average daily mean temperature was 53° F., though the adults were not active at this temperature. With the average daily mean temperature of 49° F., the rate of reproduction by the lice was but 2 young per day. Below 49° F. reproduction is almost negligible, while above this point its rate increases rapidly. The lice are, therefore, active at temperatures fully 6° lower than those required for the activity of *Diaeretus*. During March, when the average daily mean temperature was 57.5° F., the parasites were very active in the fields. During April they were active, with an average daily mean temperature of 64.5° F. At this time the average daily reproduction of the lice was 5 young. Whatever start the lice may have had was soon overcome by the parasites in the slightly warmer weather.

The parasites surely do not spread rapidly during times of much rain or periods of cold, misty showers. A shower followed by sunshine seems to stimulate the parasites to flight, but a slow, steady rain drives them to shelter under the leaves of the plants.

Lysiphlebus testaceipes Cress.

This parasite has been taken in limited numbers from *A. pseudobrassicae* in our work at College Station. It has also been taken at De Kalb, Wortham, McKinney, Iredell, and Hitchcock, Texas. In these places it was the only parasite present and was usually found in great numbers. It is without doubt an important parasite in the control of the turnip louse over the State. This parasite has been very efficient in the control of the "green bug," which has been found in many of the sections mentioned above. The following descriptions are taken from Maryland Bulletin No. 152, by Mr. A. B. Gahan:

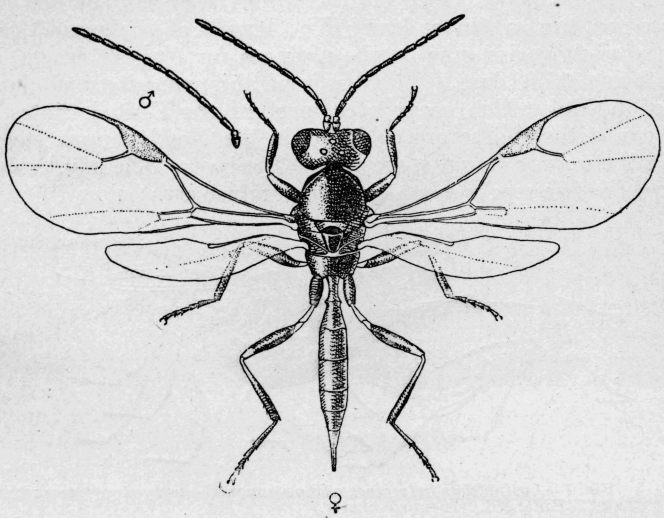


Fig. 6—*Lysiphlebus testaceipes* Cress., a parasite of the turnip louse. Adult female and antenna of male, greatly enlarged. (From Webster.)

Lysiphlebus testaceipes Cress.; *Aphidius testaceipes* Cress.; *L. tritici* Ashm.

Female: Length about 2 mm. Head distinctly transverse, as wide as the thorax at the tegulae, black, smooth and shining; the temples convex; not broad; clypeus transverse, about twice as wide as long; mouth parts usually yellowish, occasionally fuscous. Antennae 11-13-jointed, (usually with 13 joints) black or brown-black, the joints approximately equal in length throughout and about twice as long as thick; the two apical joints are sometimes connate, forming a single joint much larger than the others. Thorax black, smooth and shining, the parapsidal furrows absent or only faintly indicated at the anterior angles of the mesonotum, the propodium flattened or depressed posteriorly, the spiracles visible but not prominent. Wings hyaline, veins and stigma brown; the stub of cubitus varies somewhat in length but is never longer than the crossvein, usually shorter; the cubital crossvein is often indistinct, lacking the pigment, but can always be traced by a hyaline fold. Forelegs including their coxae yellow; middle and posterior coxae, femorae, and tibiae, usually though not always fuscous, often nearly clear yellow. Abdomen lanceolate, compressed at the apex, about one and a half times as long as the head and thorax, black or brown-black, except the petiole which is usually yellow; the ovipositor sheath black.

Male: Antannae 14-15-jointed; the joints slightly shorter than in the female. Abdomen scarcely longer than the head and thorax, rounded at the apex. Middle and posterior legs usually fuscous, occasionally clear yellow. In other respects the male is like the female.

To the list of host plants as given by Webster (l.c.) *Aphis pseudobrassicae* must be added.

The life history of this parasite, which is given in detail by Webster (l.c.), is briefly reviewed here.

The females usually begin ovipositing within a few hours after they emerge, even when the males are not present, and the eggs may hatch parthenogenically. The manner of ovipositing is shown in Fig. 7, though the attack is not always made in this way. Very seldom is more than one egg deposited in a single louse, and the number of lice which a single parasite will "sting" varies greatly, being sometimes over 200. *Lysiphlebus* prefers to oviposit in those lice which are in the second or third instars. Lice stung at these ages will mature and may reproduce for two or three days. The length of the period from the egg to the adult varies greatly, the averages for August, September and October being 15.9 days. The hosts of this parasite include several genera of Aphids which occur over most of the United States. *Lysiphlebus* can withstand severe cold, for in the North it may survive the winter in the mature larval stage within the host. The adults have been kept alive for two weeks when the temperature was below freezing.

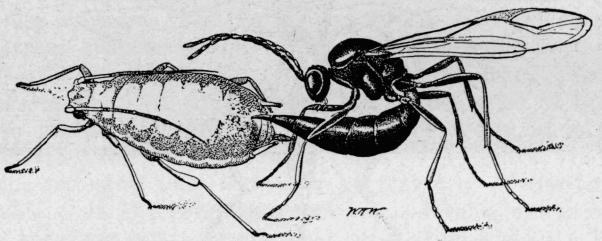


Fig. 7—*Lysiphlebus testaceipes* ovipositing in the body of a "green bug." Enlarged. (From Webster.)

Winds exert a great influence on the spread of this parasite and the parasitized lice in flying from field to field are a great factor in the dispersion of *Lysiphlebus*. This parasite is not active when the temperature is much below 56° F., and for this reason is not present in numbers as early in the spring as the lice are, which are active at a temperature of 50° F.

The parasites were not observed during the spring of 1915 in the gardens around College. On June 1, 1915, in a field of spring rape, which was heavily infested with lice, the parasites were found to be very abundant. The work of the parasite here was certainly reducing the number of lice.

PREDACEOUS ENEMIES.

Of the natural factors of control the predaceous enemies are of very considerable importance. For the past two years during which the turnip louse has been observed these factors have exerted much influence in keeping the pest in check. The past year (September, 1914, to September, 1915) the parasites were present only in the late spring, and the natural check of the lice was due entirely to the presence of

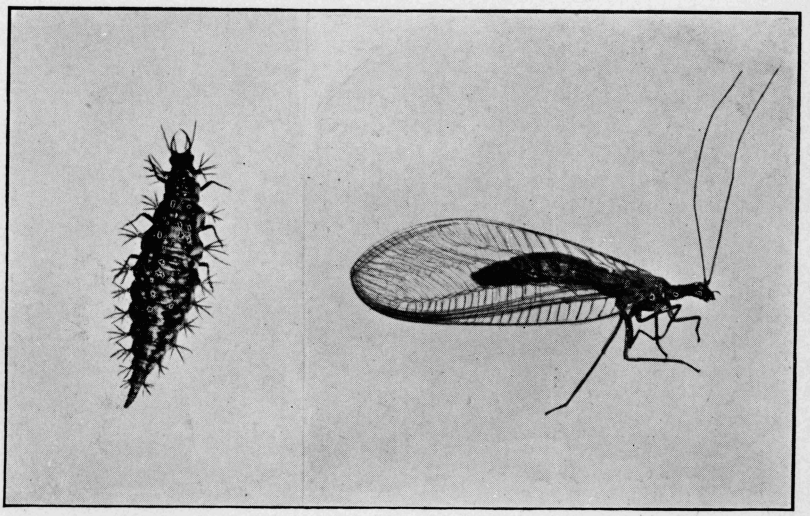


Plate III—Above, empty skins of parasitized lice on cabbage from which the parasites have emerged. (After Herrick, Cornell Bull. 300.) Below, larva and adult of Chrysopa or Lacewing fly, a predaceous enemy of the turnip louse. (After Hunter, Univ. Kans. Bull. IX, 2.)

the predaceous enemies. The same condition existed this year in many sections of the State where the turnip louse is a serious pest. The presence of the predaceous enemies does not depend to such an extent upon climatic conditions as does that of the parasites.

Lady Beetles.

Of the predaceous enemies, the most important are the ladybird beetles or coccinelids. These insects feed upon plant lice in both the larval and adult stages. Observations and reports indicate that the beetles are usually present in those parts of the State where the lice are a pest, but while present they seldom become abundant enough at the right time to eradicate the lice. At Beaumont the beetles apparently hold the lice in check and at Brownsville the latter are seldom a pest, probably due to the presence of the beetles in great numbers. At Henrietta, during the fall of 1914, the beetles were the only factor of natural control present and the louse infestation was not serious. The beetles are present in other sections of the State but never check the pest to such an extent.

It is hard to fully appreciate what a factor of natural control the ladybird beetles are until a study is made of their ability to destroy lice. The eggs are always laid close to the lice so the larvae of the beetles will have an abundance of food near at hand when they hatch. When full-grown these larvae attach themselves to a leaf on which are plenty of lice in order that the adult when it emerges will not have to seek long for food.

There are three species of ladybird beetles present in the gardens at College Station. They are *Hippodamia convergens* Guer.; *Megilla maculata* DeG., and *Coccinella munda* Say. The first two named species are about equally abundant and the last is present only in limited numbers.

Sanborn* found in 1906 at College Station that *H. convergens* adults collected in April deposited 556 eggs over a period of 34 days, a daily average of 16 eggs. These eggs hatched in 2 days, the larval period was 11 days, the pupil period was 4 days, making a total of 17 days from the deposition of the egg to the emergence of the adult. He found that a single larva may eat 396 lice during its life of 11 days, an average of 36 lice per day.

Webster (l.c.) records cases of the adult of *H. convergens* eating 30 lice per day. Hunter‡ states that by actual count these insects will devour from 30 to 100 lice in a day. Miss Palmer† states that the adults of this species ate daily from 36 to 180 lice.

In the work with *M. maculata*, Sanborn found that during August one adult deposited 219 eggs over a period of 24 days, an average of 9 eggs per day. During September and October, only 157 eggs were deposited in 47 days, an average of only 3 eggs per day. During August the egg stage was 2 days, the larval period was 9 days and the pupal

*Bulletin No. 98, Oklahoma Experiment Station.

‡Bulletin, Univ. Kan., Vol. IX, No. 2.

†Ann. Ento. Soc. Am., VII. 3, p. 215.

period 5 days, making a total of 16 days from the deposition of the egg to the emergence of the adult. He found that a single larva ate an average of 32 lice per day. The consumption of food by the adult depends much upon the season. In August the average number of lice eaten daily was 63, in September 46, in October 33 and in November 15.

The experiments conducted by Sanborn with *C. munda* were made in June and July. He found that a female may lay 448 eggs over a period of 36 days, an average of 12 eggs per day. The egg stage of this species was 2 days, the larval stage 9 days and the pupal stage 2 days, a total of 13 days from the deposition of the egg to the emergence of the adult. The larva of this species ate 553 lice in a period of 9 days, an average of 61 lice per day. The adults ate 706 lice during their life.

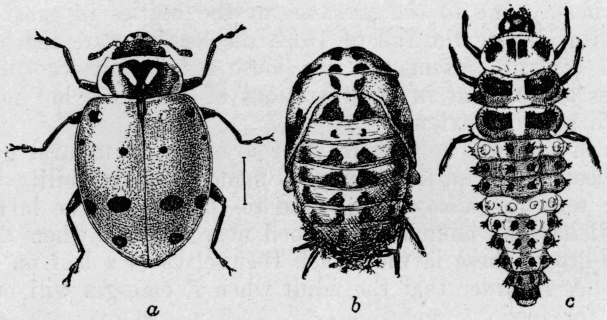


Fig. 8—The convergent lady-beetle (*Hippodamia convergens*), an enemy of the turnip louse. *a*, adult; *b*, pupa; *c*, larva. Enlarged. (After Chittenden from Bureau of Ento. Bull. No. 100.)

Under ordinary conditions the beetles will not travel far from their place of emergence, but if food becomes scarce they may fly some distance in search of better feeding. On November 4, 1913, most of the beetles were feeding upon lice on radishes which were heavily infested. These plants had not been sprayed or fumigated, and it was evident that all of the beetles in the garden had gathered on them where there was an abundance of lice. This condition was again evident on November 10.

The adult beetles are not injured with the sprays which have been used in the spraying experiments against the lice. After the application of each material an examination was made and no dead beetles could be found. Many larvae were observed unharmed after the applications of the soap solutions. On September 8, 1914, one larva was found dead where Black Leaf-40 had been used. While fumigating on November 12, 1913, many beetles were present upon the plants. After the fumigation was completed these beetles ran about in a very excited manner, but did not seem to be injured in any way.

The very hard rains which occurred during the latter part of November and the early part of December, 1913, apparently killed most of the beetles which were then present in the fields. It was not until January 7, 1914, that a single specimen of *H. convergens* was observed. During January, February and March of 1914 the beetles were present

in limited numbers but were a source of much trouble, as they worked upon the outdoor host plants and nearly cut off the supply of lice. The beetles would probably have eradicated the lice if measures had not been taken to prevent it. On March 10, 1914, *H. convergens* was the only species present, but by March 31, *M. maculata* was present in limited numbers. On April 4 quite a few larvae were observed working on the lice upon the turnips; these larvae were one-third to two-thirds grown. The first pupa was taken on April 10, 1914, and many larvae were observed on the same day that were almost full grown. From April 24 to 28 *M. maculatia* was the most common species present in the fields, but two days later *H. convergens* was again most common. Pairs of *M. mumulata* were observed *in coitu* on April 25 and of *H.*

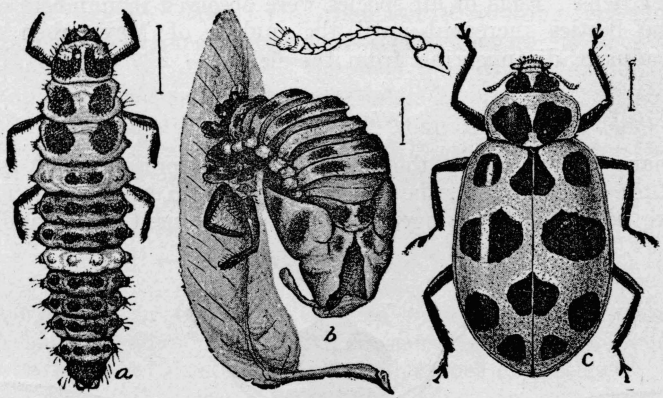


Fig. 9—The spotted lady-beetle (*Megilla maculata*), an enemy of the turnip louse. *a*, larva; *b*, empty pupa skin; *c*, adult. Enlarged. (After Chittenden from Bureau Ento. Bull. No. 110.)

convergens on April 29. Through the month of May, *H. convergens* was the most abundant species on the turnips. There were only a few *M. maculata* present during this time, and not a single *C. munda* was observed.

By September 18, 1914, the ladybird beetles were present in numbers upon the turnips which were infested with lice about September 5. The beetles were very abundant by September 29, mostly *H. convergens*. One pair of this species was observed *in coitu* on September 26 and another pair on the 29. By October 12, *M. maculata* was quite abundant and *H. convergens* was present only in limited numbers. On October 29, larvae, pupae and adults of *H. convergens* were observed on turnips. On November 3, 1914, the adults of this species were found in numbers at Amarillo, Texas. On the following day at Wichita Falls the adults of this species were observed in numbers on turnips which had just recently become infested with the lice. On November 6, at Henrietta, this species was quite common in the gardens which were louse-infested. At the latter place, *H. convergens* was the only species which had been present during the entire season. At Brownsville in January, 1915, the beetles were present in the fields in large numbers. Here *H. convergens* was the most common species

at that time, but during some other periods *M. maculata* is the most abundant.

In the College garden some adult *M. maculata* were observed on radishes on February 3. Coccinelids were not observed again until March 12. At that time most of those in the garden were *H. convergens*. A few larvae were also observed on this date. One pair of this species were observed *in coitu* on this date. During the last half of March the coccinelids increased rapidly in the gardens. *H. convergens* was always most numerous, though the proportion of *M. maculata* increased. During this time copulation among the beetles was frequently observed, but no eggs were found until the middle of April. During the early part of April *C. munda* was found in limited numbers. On April 15 *M. maculata* was the most abundant species in the gardens. Eggs of all species were observed in numbers on April 20. The beetles increased until the middle of May, when the lice were gradually disappearing from the fields.

Syrphid Flies.

In many places where the turnip lice are present, and especially where they are abundant, the syrphid flies are to be found. These insects are beautiful two-winged flies with prominent gold bands across

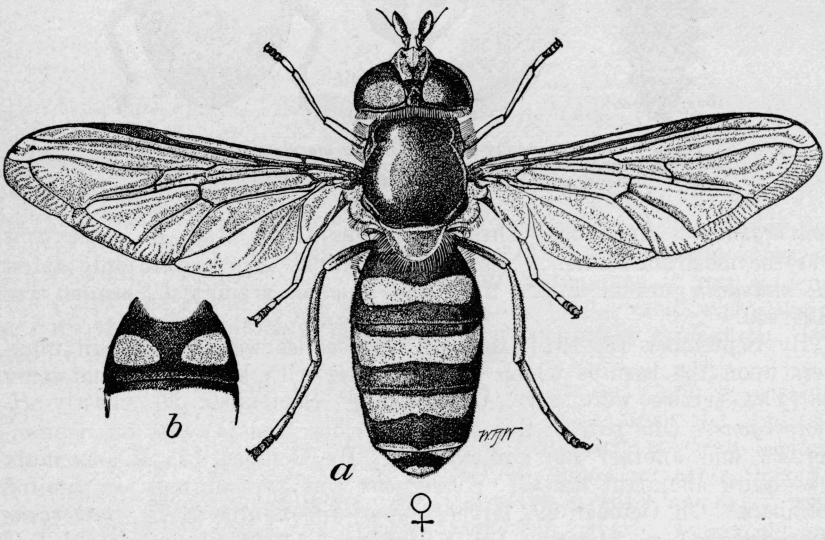


Fig. 10—*Syrphus americanus*, the larva feeds upon turnip lice. *a*, female fly; *b*, second abdominal segment of male. Enlarged. (From Webster.)

the abdomen. They have the peculiarity of poising in the air over the plants which are infested with lice. This has caused them to be called "hover flies". The syrphid flies resemble the honey bee somewhat but are readily distinguished from them by their peculiarity of remaining still in the air. The eggs of this insect are usually placed singly on the under sides of the leaves near the lice. The larvae are always

found where the food is most abundant. These larvae are slug-like and dirty gray in color. This is the only stage of the insect which preys upon the plant lice. The few observations which have been made upon this insect indicate that it has a wonderful appetite for lice.

During the season of 1913, the first syrphid fly was observed on November 21. This proved to be *Syrphus americanus,* Wied. It is quite probable that they had been present some time previous but had not been detected. Syrphid larvae were observed on December 19, 1913, upon turnips in cages, which were being used for host plants. No stage of the insect was observed again during the winter, and it is not known how that season of the year is passed. Larvae were again observed on March 31, 1914, at which time the lice were not very abundant on turnips. The flies were first observed in the fall of 1914 on September 25. A few days later when some spraying experiments were being conducted some larvae were seen. The adults were quite numerous until October 10, when the food supply was cut off by a more thorough application of spray materials.

On April 6, 1915, material was received from Brownsville which contained all stages of the oblique syrphid, *Allograpta obliqua* Say. A larva of this species was observed at College on April 15. The adults of both species of syrphids were unusually abundant during the latter half of April.

Lace-Wing Flies.

The lace-wing fly, or Chrysopa, is often present in localities where the turnip louse is abundant. Their presence is indicated by small white eggs on fine silk-like stalks on the under sides of the leaves. The adults or flies are light green in color, the wings are very large and have many lines running across them. The flight of the insects seems to be very difficult, as though they could only flutter along. The young larvae run about freely on the leaves of the plants in search of food. The plant lice are taken up by the larvae in their strong jaws and the juices sucked out. Webster (l.c.) states that one species which is very common in the Southwest hibernates over winter in the adult stage and begins depositing eggs when the first warm spells occur in the spring.

Eggs of Chrysopa were first observed in the spring of 1915 on April 6. During the first half of this month the eggs were observed frequently. The adults were often observed but never were abundant.

FUNGUS DISEASE.

This factor in the natural control of *Aphis pseudobrassicae* is very interesting because of its sudden appearance and its effectiveness in eradicating the pest. The fungus which was so prevalent in our work was undoubtedly *Empusa spp.* The growth and reproduction of *Empusa* as given by Thaxter* are briefly given here.

The infection is started with a conidial spore coming in contact with the skin of the louse. The entrance is made by means of hyphae of

*Mem. Bos. Soc. Nat. Hist., IV, 6, p. 139.

germination at some point where the skin is tender. When inside the body these hyphae develop very rapidly, at the expense of the soft body tissues. The growth of these hyphae may be by the formation of hyphal bodies which are reproduced by budding. Sometimes the hyphae branch in all directions forming mycelium within the body of the host. When the fungus has about completed its growth, at which time the louse is about to die, hyphal bodies are formed. At this time, if climatic conditions are favorable, the fungus will complete its development, but, if conditions are not favorable, a "chlamydospore" is formed, which encloses the contents of the hyphal bodies with a thick wall. The fungus may remain dormant in this stage for several weeks, if necessary, until proper conditions for growth present themselves. If the fungus has completed its growth and is ready for reproduction the hyphal bodies or the chlamydospores germinate rapidly. The hyphae from these grow very rapidly; one or more may come from a single hyphal body. These hyphae may grow directly to the outside or they may branch and each branch grow outward to become a "conidiophore." In *Empusa aphidius,* the hyphal bodies branch in all directions and in great numbers, to such an extent that the body of the louse is very much distended.

The germination of these hyphal bodies may result in the formation of sexual or asexual (resting) spores, or "conidiospores." When the latter is the result, the hyphae grow outward rapidly, break through the skin of the louse and form a spongy mass on the outside. When outside, these hyphae branch and the ends of each grow to the same height. The terminal portion of the conidiophore is usually swollen somewhat and is called the "basidium." At the tip of the basidium is a bud which grows from the rest and becomes the "conidium" after the separating wall has grown between. The conidium thus formed within the apex of the basidium absorbs water, expands and breaks through the wall surrounding it. As a result of this the spore is thrown out, sometimes for a considerable distance.

If these conidia, when liberated, come in contact with proper environment they send out hyphae of germination, which enter the body of the host as was first described. Such germination usually takes place soon after the conidia are discharged. If the conidia do not fall in suitable surroundings, they will form a secondary conidia after the same fashion. This serves as a means of further spread when the primary spore has not fallen well. The primary spore produces a hypha which grows upward, becomes swollen at the tip into the basidium in which develops a conidium similar to its origin and is discharged in the usual manner. This process may be repeated until the substance is exhausted, if the spore does not find suitable environment for growth.

If the germination of the hyphal bodies does not result in the formation of the conidia as just described, resting spores will be formed. This resting condition may be accomplished by a non-sexual process resulting in "azygospores" or by a sexual process resulting in "zygospores." The azygospores may be formed in several ways, by the contents of the hyphal body being converted directly into the spores, or the germination hyphae ending in the spore. When zygospores are formed the process may vary considerably. The simplest method is for the germinating hyphae to send out lateral shoots which meet midway be-

tween the hyphae. A bud then grows rapidly, absorbing the contents of the conjugating cells. Sometimes this conjugation takes place on the outside of the host. The causes of the formation of the resting spores cannot be satisfactorily explained.

The fungous disease was first observed during the fall of 1913, on November 12. At this time some radish leaves were collected for examination as to the condition of the lice upon them. The lice were found dead; some were dry and bronze-colored, while others were punky and orange-colored. These dead lice were mostly pupae, some immature apterous forms and a few winged lice. Just a week later the disease was found upon lice on mustard where fully 30 per cent. of those lice had recently died. Most of the dead lice were immature apterous forms, though there were many pupae and some winged lice. The fungus was also found on the lice feeding upon turnips, and it soon spread to all the gardens in the vicinity. The spread of the fungus threatened to exterminate the lice on some of the host plants, such as beans, lettuce and mustard. In two weeks from the time the fungus was first observed the lice were almost entirely destroyed.

On November 26 a very hard rain occurred, and this apparently checked the growth and spread of the fungus to such an extent that dead lice were seldom seen on the plants. The rains which occurred in the following two weeks killed nearly every louse on the plants, and the disease disappeared.

The fungus was next taken on lice in the fields on December 19. In some outdoor observation cages the lice were found to be dying rapidly from the disease on January 7, 1914. Two weeks before this it was cold but apparently not cold enough to prevent the fungus from developing. The dead lice found at this time were mostly apterous and only a few winged forms. Within the next week the lice were almost entirely killed in these cages. As they were wanted for experimental work, an effort was made to stamp out the disease. All of those leaves which had dead lice upon them were cut from the plants and destroyed. After repeating this operation several times the disease was apparently checked, and then all of the healthy lice were transferred to new plants in new cages. About a month later the disease was found again in the outdoor cages. This was shortly after the low temperature of 17° F., and a week during which low temperatures prevailed. During the last half of February it was quite cold and the fungus did not spread rapidly. It was not until March 10 that the disease was found to be spreading, but within two weeks most of the lice in the cages had died from it.

On March 24 material was collected to start some experiments in spraying louse-infested plants to disseminate the disease. Lice which had died from the disease were scraped from the leaves taken from badly infested plants. These were put into rain water and thoroughly shaken to break up the masses of fungus. The application of this mixture was made with a De Vilbiss atomizer. The plants were well covered with the spray, which was so applied that it would settle onto the plants as a mist and not as a driving spray, which would knock the lice off the leaves. It is not possible to say just how successful these experiments were, as it was not possible to properly isolate the check

plants from natural infection. During the time that these experiments were made the disease was very prevalent in the fields adjoining. Many lice died on all the sprayed plants, but not enough to say that the measures would be practical for the control of the pest. A very large per cent. of the lice which died were pupae. Most of the dead apterous lice were immature forms. Those lice which had contracted the disease could be distinguished by the straw color of the body, which became swollen just before death. When the lice die their bodies are much distended, orange in color and velvety in appearance.

The disease was found to be widespread in the fields on March 30, 1914. At this time but few lice could be found which did not show signs of having the disease. Most of the pupae present upon the plants were dead and the apterous lice of all ages were dying rapidly. In many gardens the disease had killed the lice out entirely. At that time of the year there was considerable dew upon the plants each morning, which was doubtless favorable to the reproduction of the fungus. Very often the dead bodies of the lice would be found in a small bead of dew. Under such conditions the spores of the fungus should develop rapidly.

The disease was prevalent in the fields throughout the month of April. By the first of May fully 25 per cent. of the lice on the turnips were dead from the fungus. By the end of another week 40 per cent. of the lice were dead, and in two weeks more at least 75 per cent. were dead. From that time on the lice gradually disappeared.

It is very evident that the fungus is a destructive enemy of the turnip louse, and that if it could be controlled it would be a big factor in eradicating the pest. The disease was very persistent throughout the fall of 1913 and the spring of 1914. During the fall of 1914 not a single louse was observed at College Station which had died from the disease. This is probably because the climatic conditions of the two seasons were so different. It does not seem possible to propagate the disease when the conditions are unfavorable.

In January, 1915, when at Brownsville, the writer was told that the lice were being held in check by lady beetles. Examination of the lice on the plants in the infested fields revealed the fact that the fungous disease was present and was working effectively. On the plants lice could be found which were about to succumb, as well as others that had but recently died. The punky bodies of the lice which had been dead for some time were abundant. The disease was spreading rapidly among the lice on the turnips. As the infestation of lice was light, most of those present were apterous. The lice which were dying were almost mature.

ARTIFICIAL CONTROL.

SEASON 1913.

As the study of the turnip louse was started rather late in the season, the experiments with control measures were not conducted under the best conditions. Naturally this work was of a preliminary nature, but it was expected that some results might be obtained which would serve as a basis for future work along this line. When the work was started, all of the turnips were heavily infested with lice and had been for some time.

SPRAYING.

Spraying was first investigated as a means of control for this pest. This work was started on a small scale, as the efforts were not well enough organized to undertake extensive experiments. The results of the work were not all that was expected of it. The difficulty was not in getting material to kill the lice but in getting the material onto the lice. Black Leaf-40, kerosene emulsion and whale-oil soap were selected for the trial work. The results of these experiments are briefly given here.

Turnips.

(Black Leaf-40.)

A small area of broadcasted turnips were sprayed on October 25th with a solution of this material. The spray was made according to the directions on the package, five ounces of the black leaf-40 and one pound of whale-oil soap to thirty gallons of water. The application was made with a bucket spray pump, equipped with a long hose, an extension rod, a 45° elbow and an agle type nozzle. The material was applied early in the morning while the dew was still on the leaves. Care was taken to cover all of the leaves so as to hit all of the lice. The plants were only four inches high, but the ground was covered by the foliage.

Immediately after the application was completed an examination was made, and no living lice could be found. There was a slight odor of tobacco present on the leaves. Two days later another examination was made, and no living lice were found upon the sprayed plants, but on the check plants the infestation was increasing rapidly. The tobacco odor had entirely left the leaves.

(Kerosene Emulsion.)

A patch of turnips, similar to the above, was sprayed with kerosene emulsion on October 30. A proprietary stock solution was diluted according to directions on the container to make a 5 per cent. solution of oil. This stock solution was well made, as no free oil had separated out. The day was cool and the application was made late in the afternoon. The outfit was the same as was used for applying the black leaf-40. While the application was being made there was a decided odor of kerosene, but none of the leaves showed signs of burning. Immediately after the application no living lice could be found on the plants. Two days later an examination showed that no lice were on these turnips. The odor of kerosene was gone and there were no burned leaves.

Another test of kerosene emulsion on turnips was made where the plants were in rows; the infestation on these plants was heavy. For this application home-made stock solution was used. It was made by the common formula of one-half pound of soap, one gallon of water and two gallons of kerosene. The usual care was taken in making the stock solution, but free oil separated out after it stood awhile. The application was made with a knapsack sprayer, which was placed on the ground so that the nozzle could be directed toward the under sides of the leaves.

The application was tedious and unsatisfactory, as many of the leaves were not touched with any of the material. As soon as the material dried, many leaves showed evidence of burning and before the spraying was finished the patch looked as though a fire had gone over it. Two days later all of the turnips were dead from the severe burning of this material.

The result of this spraying is evidence that kerosene emulsion is not always properly made by ordinary help and that such help will not take the proper care to apply a contact insecticide. It is clear that these two factors play an important part in the control of the lice.

(No. 6 Soap.)

On October 30 a patch of turnips which were planted in rows was sprayed with a solution of Good's Caustic Potash Tobacco Fish Oil Soap No. 6. The solution was made as directed, one ounce of soap to one gallon of water. The application was made with the bucket pump, previously described. The leaves of the plants were large and the foliage was dense, which made it difficult to apply the material effectively. An examination made after the spraying was completed showed that all of the lice had not been hit and the results could not be satisfactory. Two days later the lice were found well scattered over the plants.

As this application was not effective, another was made five days later. The same material and outfit were used again. More time and material were used in an effort to make a careful application. The examination made immediately after the spraying showed that some of the lice had not been hit this time. A week later the turnips were examined. On the check rows the infestation was very heavy; on those plants which were sprayed only once the lice were quite abundant. There were but few lice on those plants which had been sprayed twice. The second application following closely after the first proved to be a decided check on the lice.

Spraying will not entirely eradicate the lice when made under such conditions as these trials were conducted. The plants were too large and the infestation was too heavy when the spraying was started. All of the materials tried gave good results when properly applied. Turnips sown in rows are much easier to spray than those sown broadcast.

The cost of the concentrated solution of black leaf-40 seems very high, but when properly diluted the spray is not expensive. The material is easy to apply, it spreads well on the leaves and does not injure them. However, this material is more expensive than the other two. Kerosene emulsion is a good material to use, since the ingredients can be purchased any place and it can be made at home. But if it is not properly made more harm than good will be done by using it. The material spreads on the plants nicely and the odor does not persist long. On account of the danger of making a poor emulsion, this material is not to be recommended ahead of the other two materials. The No. 6 soap is a soft soap and dissolves readily in a small quantity of boiling water. This concentrate can easily be taken from place to place and the dilution made then as needed. The spray spreads easily on the leaves and dries off quickly. The odor of fish does not persist long. The cost is low if the soap is purchased in quantity.

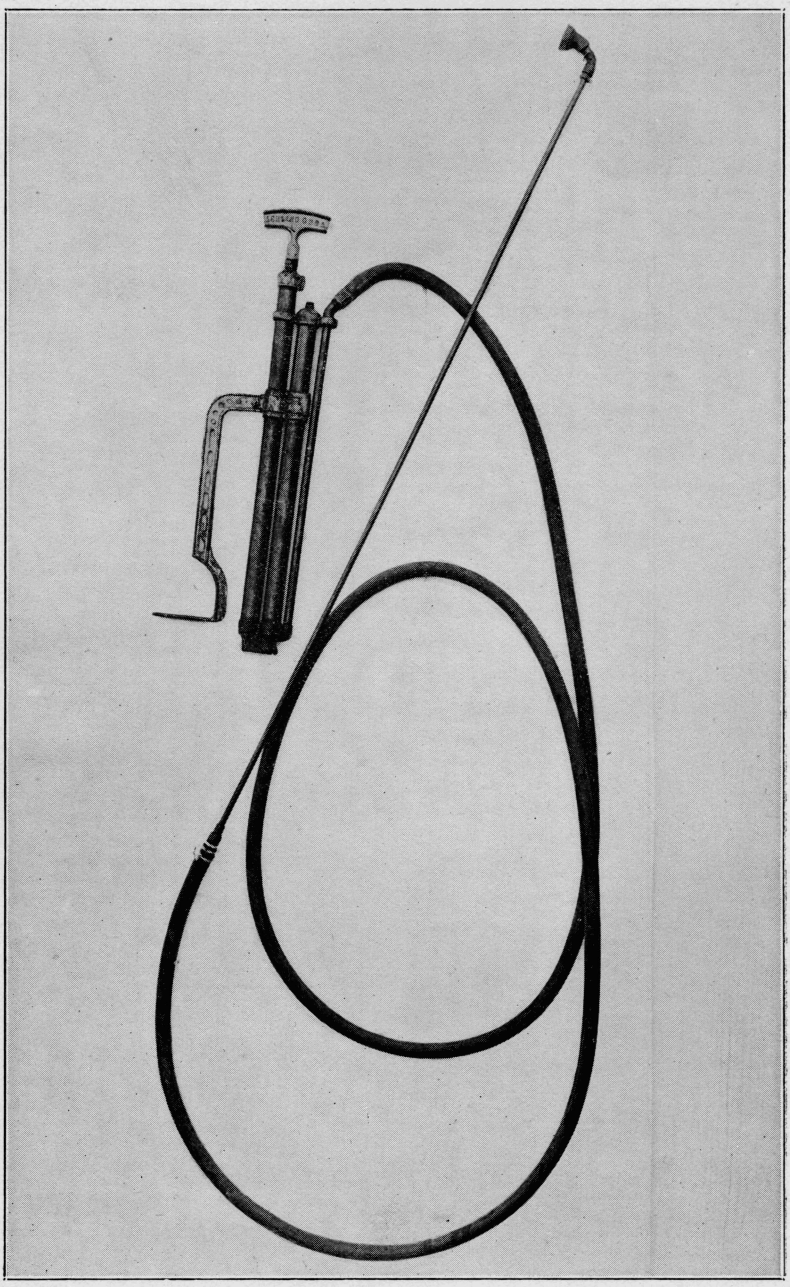


Plate IV—A bucket spray pump properly equipped for spraying against the turnip louse. (Original).

Cabbage.

The lice did not infest the cabbage this season until November 12th. The spraying was not started until five days later, when the infestation was well scattered over the patch. One-half acre of cabbage was used for these experiments. The outfit used was a hand-power pump equipped with two leads of those, each having a four-foot extension rod, a 45° elbow and an angle type spray nozzle. On the day the application was made there was considerable wind, which interfered with the work.

(Black Leaf-40.)

This solution was made of 8 ounces of the black leaf-40 and 2 pounds of hard whale-oil soap to 50 gallons of water. To this was added 3 pounds of rosin sticker soap, so that the material would spread evenly over the cabbage leaves. As the day was cloudy, the material did not evaporate quickly, but no ill effects from this were apparent. The ample force supplied by the pump was a decided advantage, as it was possible to drive the spray into the unfolding leaves where the lice were ordinarily protected. The examination made immediately after the application was completed showed that all of the lice had been killed. During the following week examinations did not reveal any lice upon the plants.

(No. 6 Soap.)

An adjoining patch of cabbage was sprayed with this material on the same day as the above. The solution was made of 1 ounce of soap to 1 gallon of water, and the rosin sticker soap was added at the rate of 3 pounds to 50 gallons of water. This material spread nicely on the leaves and killed every louse present. The addition of the sticker soap to these solutions made the cost high, but it is likely that further investigation will show that the sticker soap will partly replace the whale-oil soap in the formulae.

FUMIGATION EXPERIMENTS.

The spraying experiments during the early part of the season did not give entirely satisfactory results. It did not seem possible to apply the material so that it would be efficient and at the same time keep down the cost of materials and application. Fumigation was next considered in hopes of finding a cheaper and more efficient means of control of the louse. It was evident that it would not be practical to fumigate turnips which had been broadcasted. The best means of fumigating turnips apparently was to build a small portable fumigator, simple in construction and low in cost. The following fumigator seemed to meet the requirements: The frame was made of 1 x 2 and 10 feet long, with a brace of 1 x 2 put in the middle; the ends were 14 x 18 inches, made solid with ship lap; this frame was covered with muslin of the heaviest grade that could be purchased. This cloth was 36 inches wide and was put on the frame beginning at one edge of the top, going across it and down the side. This allowed a four-inch flap, on which dirt could be placed. The other side was covered with a half strip,

which also allowed for a flap. The cloth was oiled to make it gas-proof. The cost of the material for this fumigator was 28 cents.

Laboratory experiments were conducted to determine the materials which were best suited for use in the fumigator, and the time required for each to become exhausted. Unsatisfactory results were obtained from the use of tobacco papers, they seemed to smother out in the small confined space. Tobacco dust would not burn in the small space, even when ignited with kerosene. Tobacco stems gave satisfactory results when properly used. Tied in compact bunches, they burned nicely after being lighted in the open. They could be easily lighted by pouring a teaspoonful of kerosene on one end of the bundle. The bunches burned best in the fumigator when placed in an upright position with the burning end up.

Radishes.

The first fumigation experiments were made on November 10. The day was clear but cool. The radishes were large, the foliage was very dense and the infestation was extremely heavy. The charge of stems was placed in the center of the fumigator. The first charge of stems of one ounce was confined for twenty minutes. The lice were not even stunned by this fumigation. The second charge of 2 ounces was burned for twenty minutes, and it was estimated that 25 per cent. of the lice were killed. Two ounces of stems were used again, but burned for thirty minutes this time. As a result of this long exposure to the fumes of 60 per cent. of the lice were dead and upon the ground. The next charge was 3 ounces of stems, and they were burned for thirty minutes. Fully 95 per cent. of the lice were on the ground under the plants; about 8 per cent. of these were not killed but only partly overcome by the fumes.

On November 12 the fumigation experiments with radishes were continued. The day was cool and cloudy with a strong wind blowing. At times this wind was too hard for satisfactory results. The stems were placed in one end of the fumigator, as the wind seemed to push the smoke to the opposite end.

The plants were small and scattered on the ground; the infestation was heavy. The first charge was 3 ounces of stems, and these were burned for thirty minutes. The result of this was that 80 per cent. of the lice were found dead upon the ground. About 5 per cent. more were crawling about on the ground but did not seem to be injured by the treatment. The second charge was 3 ounces of stems burned for twenty-five minutes. Fully 90 per cent. of the lice were found upon the ground after this fumigation. Of these, 5 per cent. were not entirely overcome and would survive. The next charge was 3 ounces of stems, which were burned for thirty-five minutes. This killed 95 per cent of the lice and more were on the ground but were not entirely overcome by the fumes. The next test was under the same conditions, but 98 per cent. of the lice were found upon the ground.

Soon after the fumigations the foliage showed severe burning; some of the plants were entirely killed. This burning was more severe on the old leaves near the top of the fumigator. It was more severe and showed up quicker when the fumigation was prolonged. Those plants

where the charge was small and the exposure short did not show burning until the following day. The burning seemed to be more severe on those plants which had dew upon them when fumigated.

Turnips.

These plants were not as heavily infested as the radishes, but the foliage was much denser. The first charge of stems was 2 ounces and they were burned for thirty minutes. This fumigation killed 70 per cent. of the lice. The second charge was 2 ounces of stems, but these were burned for thirty-five minutes. Only 70 per cent. of the lice were killed this time. The additional time of confining the gas did not improve the results. Another charge of 2½ ounces of stems was burned for thirty-five minutes. This killed 90 per cent. of the lice, but the burning of the foliage was more decided. The turnips did not seem to be as susceptible to burning as the radishes. Those leaves which touched the fumigator at any place seemed to be most severely injured.

Mustard.

Not many trials were made with fumigating this plant, as the leaves burned so badly. With the minimum charge and exposure most of the leaves were seared, and the plants soon died.

The result of the fumigation experiments were not all that had been expected. The burning of the leaves was such that it would not be considered practical. The cost of the materials was about the same as for spraying. The cost of application was the same for both, but the cost of equipment was less for fumigation.

SEASON 1914.

This year it was possible to ascertain the beginning of the infestation of the lice in the garden. The spraying experiments were planned to start before the plants were large and the infestation was heavy. It was evident from the work of the previous year that spraying would hardly eradicate the lice after they were well established on large plants. Spraying as a control measure was undertaken again this year because the fumigation experiments of the previous year gave unsatisfactory results. The spraying of last year was too expensive to be practical on a large scale, so the aim in the work this year was to develop a cheap and efficient spray. More materials were tested and the work was conducted on a much more extensive scale.

SPRAYING.

The experiments were made in the vegetable garden of the Horticultural Department of the College. There were two plats, one consisting of 2 rows of radishes, 2 rows of mustard and 2 rows of turnips; the other of 5 rows of turnips. The rows were 400 yards long.

Radishes.

(Black Leaf-40.)

This solution was made of 12 ounces of the concentrate and 4 pounds of whale-oil soap to 100 gallons of water. The outfit was a barrel pump supplied with two leads of hose, each with a four-foot extension rod, a 45° elbow, and an angle type nozzle. The material spread on the leaves nicely and was effective in so far as the application was perfect. An odor of tobacco could be detected for a few hours after the material was applied. The leaves dried quickly after the application. With this outfit the application was very slow and unsatisfactory. The pump was not in good condition and would not properly supply the two leads of hose. It required a crew of 3 men two hours to apply the material to 1000 feet of plants. It is a great saving in time to use a good pump and much easier to make an effective application. With considerable force the leaves of the plants are raised and the spray can be put onto the lice with little effort.

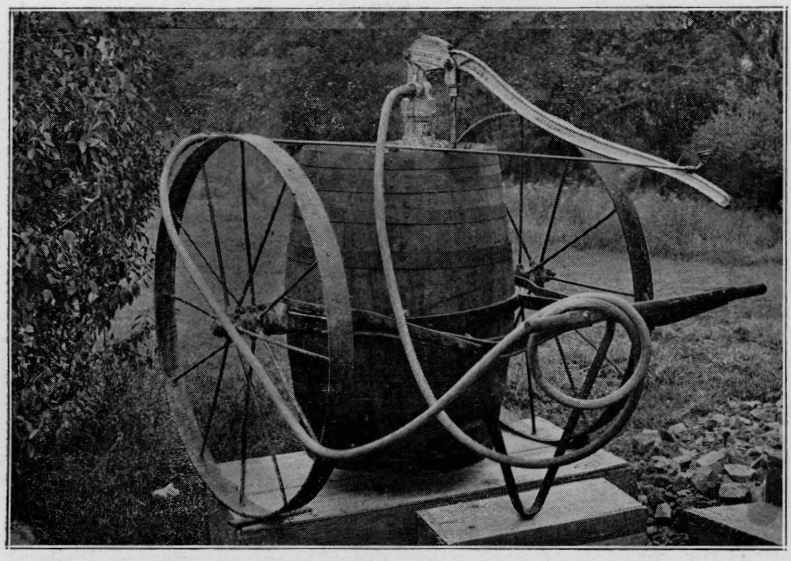
Three days after this application an examination was made, and many lice were found on these plants.

A second application was made just a week after the first. This time the outfit was a hand-power pump equipped with two leads of hose, each having a four-foot extension rod, a 45° angle Y and two angle type nozzles. The pressure was maintained at 75 pounds. The immediate results of the application were satisfactory, as apparently all of the lice had been killed. A barrel of the spray material cost 67 cents. Five hundred and sixty-four feet of plants were covered in twenty minutes by the crew of 3 men.

(Sulfur.)

This material has been used some as a contact insecticide, both as a liquid and a dry spray. Russell (Jr. Econ. Ent., I, 6, p. 378) used it with much success against the red spider on beans. The sulfur was used at the rate of 1 ounce to 1 gallon of water. The sulfur was mixed with a small quantity of hot water, which was kept almost boiling for fifteen minutes. In this way it was hoped to more completely separate the particles of sulfur. The application was made on the same day as the above, under the same conditions and with the same outfit. Much difficulty was experienced in the application of this material, as the small particles of sulfur would clog the intake pipe of the pump and the nozzles were constantly stopped with sulfur. Later in the day it was necessary to take the pump apart, and particles of sulfur were found around all valve seats and the plunger. The pump did not work well until carefully cleaned.

The immediate results of this material were far from satisfactory, though the sulfur was well spread over the leaves. Since sulfur can only kill when it comes in contact but few lice were killed, as only few particles of sulfur actually hit them. Even those lice which were hit with the sulfur did not apparently suffer any. Soon after the application the film of water on the leaves collected in small globules, and the particles of sulfur were drawn on the surface of these drops of water. Many lice which had sulfur on them were able to crawl about, as soon



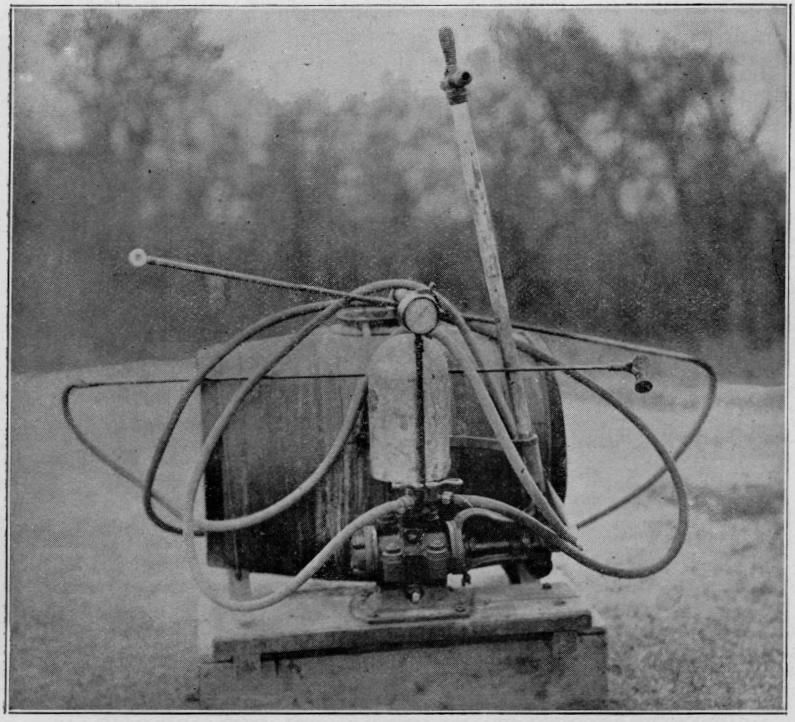


Plate V—Above, a barrel spray pump, with cart, showing one lead of hose and attachments for spraying against the turnip louse; below, a hand power pump, with barrel supply tank, showing proper attachments for spraying against the turnip louse. (Original.)

as they could get from under the water. Not a louse was killed by the appplication of this material. A barrel of the spray cost 35 cents. This amount covered 576 feet of plants and the time of application was thirty-five minutes.

(Lime Sulfur Solution.)

A commercial brand of lime sulfur testing 32° Baume was diluted 1 to 50 parts of water. The application was made with the hand-power pump described above. When first applied the material was spread evenly over the leaves, which gave the foliage a yellowish appearance. This thin film of liquid seemed to irritate the lice, and no doubt would have killed them if the lice *could have been* confined in it. However, in a short time this film contracted into small globules over the leaves and the insects crawled off unharmed. The leaves did not dry quickly and there was considerable residue left upon them. This residue did not seem to affect the plants any; it merely left them unsightly for a time.

(Soluble Sulfur Compound.)

This material is recommended for use in the same manner as the commercial lime sulfur solution. It is a powder which is dissolved in cold water at the rate of 1½ pounds to 50 gallons of water (for plant lice). The resulting liquid is yellowish in color, like the weak solution of commercial lime sulfur. The application of the spray was made with the same hand-power pump. The action of the soluble lime sulfur upon the leaves and on the lice was the same as the commercial lime sulfur. Three days after the lime sulfur sprays were applied an examination was made. The lice were found to be as abundant upon the sprayed plants as upon the check plants.

(Laundry Soap.)

For this purpose the "Clairette" brand of soap was used at the rate of 1 pound of soap to 5 gallons of water. The soap was shaved into a small quantity of boiling water and after dissolved diluted to the required amount. The soap does not dissolve readily, even in boiling water, and the results are not satisfactory if too small a quantity of water is used. The hand-power pump above described was used to make the application of this material. It spread onto the leaves nicely and dried off quickly, leaving no odor. It is very effective against the lice. This formula makes the solution too soapy, and it was diluted for further work. For this work the barrel of material required 10 pounds or 20 bars of soap, which cost 70 cents. The barrel of liquid was sprayed out in twenty minutes, and covered 700 feet of plants.

Two weeks later another test was made with this material, using 1 pound of soap to 7 gallons of water. The soap was dissolved in a larger quantity of water, and much better results were obtained. At the strength used the material was very effective against the lice. The cost of a barrel of this solution was now as low as any material which had been used.

(Fish Oil Emulsion.)

This material was made by dissolving 1 pound of soap in 1 gallon of water, then adding 2 gallons of fish oil. This was then agitated violently to make a perfect emulsion. The stock solution was diluted to contain 5 per cent. of oil. Upon standing some time there was a tendency for some of the oil to come to the surface, which indicated that the emulsion was not properly made. The application was made with the hand-power pump described above. This material spread on the leaves nicely and soon dried. At first there was a decided fish odor, but this did not persist long. The material was effective against the lice. The immediate results were satisfactory, but in three hours after the application the plants showed severe burning of the foliage. Most every plant was dead by the end of a week after the application was made. The cost of this material is too high to be practical; one barrel cost $1.25.

(No. 3 Soap.)

Good's Caustic Potash Fish Oil Soap No. 3 is a soft whale-oil soap. This makes a satisfactory material to use, as it dissolves readily in a small quantity of water. From that standpoint, it is superior to the hard whale-oil soaps. The formula used was 1 ounce of soap to 1 gallon of water. The hand-power pump was used in making this application. The material goes onto the leaves nicely and is very effective against the lice. The cost of a barrel of this material is 25 cents. A second trial was made with this material, and the results were again very satisfactory.

(Whale-Oil Soap.)

This was the hard soap, which is the form usually on the market. It was used at the rate of 1 pound to 7 gallons of water. The soap was shaved into boiling water, but it did not dissolve readily. In this respect, it is not as easy to use as the No. 3 soap. The spray goes onto the leaves well and is very effective against the lice. The leaves dry quickly and the odor of fish does not persist long. The cost of a barrel of this material was 50 cents.

Mustard.

The materials which have been discussed above were used on mustard plants, which were adjoining the radishes. In general, they were not as effective against the lice upon this plant as they were upon the radishes. The leaves of the mustard are so curly that it is difficult to force the spray into the small folds where the lice are usually found. The sulfur solution seemed to collect on the leaves of mustard more readily than on radishes. The lice were hardly inconvenienced by the application of thees materials. The mustard suffered much more from the application of the fish oil; not a single plant lived in the area sprayed by this material.

Turnips.

These same materials were tested on the turnips, which were also beside the radishes. The results of these trials were in every way the

same as those on radishes. The condition of these plants was such that more effective spraying could be done than on the radishes. The deposit of the sulfur materials was not so pronounced on the turnip leaves as on the radish leaves. When the turnips dried they looked as though they had been covered with lime.

In addition to the above tests, plat No. 2 of turnips was sprayed throughout the season with No. 6 soap only. This material had given satisfactory results in previous trials, so it was our aim to try it under actual control conditions. The first application was made on September 15 when the plants were six to eight inches high. At this time the infestation was not heavy, though the lice were well scattered over the patch. The usual formula of 1 ounce of soap to 1 gallon of water was used. The hand-power outfit previously described was used to make this application. It was estimated that 95 per cent. of the lice were killed with this spray.

On September 22 a second application was made on the turnips. This time the plants were 12 to 14 inches high, and almost covered the ground. The same formula for the spray and the same outfit were used. The first application was so effective and this one followed so closely that there were not many lice present, and these were well scattered over the patch. A barrel of spray covered 757 feet of plants and was applied in twenty minutes. This application killed 95 per cent. of the lice.

A third application of this material was made two weeks later. The same formula and the same spray outfit were used this time. The plants then entirely covered the ground, which made it difficult to apply the material without extreme care. The infestation was light and well scattered over the patch. Examinations made on several days following did not show a single living louse. This No. 6 soap certainly proved very effective against the lice, and the proper times for the application were indicated by these trials.

GENERAL REMARKS ON PLAT I.

At the time the first spraying was done on September 15 the radishes were 6 to 8 inches high and heavily infested with lice. The mustard was 4 to 6 inches high and only lightly infested. The turnips were 6 to 8 inches high and the infestation was light. The application was not effective, due partly to the improper application of the material and partly to the poor results of the materials used. The lice were just as abundant in a few days after the application was made as they had been before.

When the second application was made on September 22 many of the radishes were dead from the severe infestation. The lice were abundant on all the plants. The radishes and mustard did not grow much between the applications, but the turnips were quite large. Powdered arsenate of lead was added to all the material this time at the rate of 2½ pounds to 50 gallons of water. This was necessary, as the grasshoppers were becoming very destructive in the garden.

The third application was not made until October 6, two weeks after the second one. It was considered best to wait this long, as the second application had been quite effective and it was cool during this

period, so that the reproduction was low. When the application was made, it was evident that a mistake had been made in waiting so long. The lice had increased materially and the plants had suffered from it. The plants were very large, so that it was difficult to make an effective application.

Under these conditions, it was considered advisable to cut the large leaves from the turnips and destroy them. In this way many of the lice were carried away from the plants and destroyed, and it was a simple matter to spray effectively the few small leaves which remained. The infestation was quite severe on all the plants.

PREVENTIVE MEASURES.

In the control of the turnip louse, as in the control of most every insect pest, preventive measures are to be employed whenever possible. With the turnip louse these measures do not assure as much relief as is often the case in combating insect pests. But it is true here also that the actual control of the pest is made much easier when the preventive measures are employed. When the turnip louse becomes well established in turnips and radishes, the complete eradication is very difficult and unsatisfactory. While the natural factors may check the pest in time, such relief usually comes too late to be of real service. Complete control of the turnip louse can only be expected when all of the preventive measures have been used and judicious spraying has been employed.

ROTATION.

This very important factor of insect control is not as effective with the turnips louse as with many insect pests. It is, however, of sufficient importance to be practiced as much as possible. It does seem that injury by the turnip louse can be reduced by planting the new crops of the host plants as far as possible from where the old crops were grown. It is seldom feasible to abandon a garden site entirely, but the plantings of the host crops should be so planned that they will not come together at the same time in adjoining plats. In some cases where a succession of host plants (radishes and turnips) is employed, it would be advisable to discontinue a planting or two of each. This would make a break in the line of food and probably cause the lice to seek other gardens where such crops would be growing at that time. Whenever it is possible to arrange the rotation, radish should not precede the fall crop of turnips, and at best such a planting of radishes should not be next to the fall turnips. Where an early fall crop of mustard is grown, one should leave as much time as possible between the end of that crop and the fall turnip crop.

PLANTING.

It is the general opinion of gardeners that the early fall crop of turnips suffer most from the attacks of the louse. In the same way the early varieties of turnips seem to suffer more than the late varieties. It is true that in some sections there is not much chance for a

choice in the time of planting fall turnips, but wherever possible the planting of the main crop of fall turnips should be delayed for a time.

TRAP CROPS.

Such crops are those planted on a small scale at such a time as to attract most of the insects to feed. These crops are destroyed at such a time as the insect infestation upon them is at its height; not later than such a time as the main crop may prove attractive to the insects. If not destroyed early enough the trap crops will fall short of their duty, since they will serve as a breeding place for the insects until the main crops are ready. The trap crop, if properly employed, may be made to serve as a big factor in the control of the turnip louse; if not properly employed, it will work against the possible reduction of loss by the lice. For the trap crop, turnips may be used by planting a row very early along one side of the proposed turnip patch. If such a plan is not adapted to the locality, radishes may be used in the same way. In many localities, mustard is the best trap crop to use, but the lice will not remain long upon the mustard after the turnips are of much size.

DESTRUCTION OF FIRST COLONIES.

When the turnip louse is known to be a pest in a locality, it is advisable to inspect the fall crops from time to time to detect, if possible, the first colonies that start in the garden. Usually the lice will become established upon a few plants in a defined area; there may be two or three such areas. The destruction of these colonies at the start will do much to prevent further injury from the pest. It is necessary to repeat this process, for the lice will continue to come into the field for a considerable period of time and establish the small colonies. If a careful inspection is maintained and all colonies destroyed at the start, the injury to the field as a whole will be small. It is so much easier to eradicate the louse in small areas than to wait and attempt to spray the entire field. In one section of the State these small areas of infested plants are surrounded by a strip of crude oil, the plants covered with straw and burned. It is said that such treatment holds the pest in check. Any of the spraying suggestions given below may be used in the destruction of the first colonies of lice.

CLEAN CULTURE.

While we do not know that any of the common weeds about the garden serve as food for the turnip louse, nevertheless, it is advisable at all times to practice clean culture. It is not advisable to leave the remnants of the old crop in the ground when the new crop is coming on. Any of the fall crop of turnips and radishes should be pulled during the winter, or at least some time before the spring crops may be subject to attacks. It will not do to merely pull the crop and leave it on the ground, for most of the plants will be able to root enough to stay in a growing condition and be food for the lice.

SPRAYING.

To employ the preventive measures here suggested will surely reduce the possible injury by the turnip louse. However, it seems that the pest will not be entirely eradicated by those measures alone. After all of the above measures have been followed, the fall crop of turnips may still be infested with the lice. When the lice are present in the fields, spraying is the most satisfactory means of combating the pest.

MATERIALS.

The spraying experiments conducted show that the soaps are the most satisfactory materials to use. All of the whale-oil soaps were very effective, but, as they are not always available over the State, the use of laundry soap is advised. For this purpose a good grade of laundry soap should be purchased. The "Clairette" brand was used in the experiments. The formula given, 1 pound of soap to 7 gallons of water, is considered the best. The soap should be shaved into boiling water, at the rate of about 1 pound of soap to 2 gallons of water. The soap does not dissolve readily in any less water, and if the water is not boiling the soap will dissolve very slowly. It is necessary to frequently stir the shaved soap in the water to facilitate the dissolving. After the soap is dissolved, dilute to make the above formula.

The materials used for the spraying against the turnip louse are called "Contact Insecticides." Such materials kill only when they come in contact with or hit the insect. It can readily be seen that extreme care must be used in the application of such materials in order that they may be effective. Any louse which is not actually hit with some of the spray is not harmed in any way by the application. When the lice are known to be starting in a garden, preparations should be completed at once for the spraying. Any delay in this matter is serious, as the lice will spread rapidly and the eradication is much more difficult. Experience shows that it is almost impossible to hit and kill all of the lice with one application, especially by those people who have not had much experience in such work. Even with extreme care in the application of the material, some of the lice may remain upon the plants. Also, in the early part of the season, the first application of the material may be given before the migration of the lice has ceased. In this way a field which has been freed of the lice may become reinfested and make it necessary to spray again. A third application is usually necessary to hold the pest in check. These three applications should be given at intervals of seven to ten days; in some cases, it may be advisable to wait longer between the second and third application, but it is not best to wait too long. The spraying should be started early, while the plants are still small, for the smaller the leaves the easier it is to spray effectively. If the leaves of the plants are very large, most covering the ground, before the last application is made, it is advisable to pull most of the leaves, as for greens, and destroy them. In this way, many of the lice will be killed and the application can be very effectively made to the remaining leaves. That will allow a great saving in the amount of spray material necessary to cover the plants and in the time necessary to make the application.

APPARATUS.

For the application of any of the contact insecticides, it is necessary to have a good spray pump. When spraying to eradicate the turnip louse, it is necessary to have an extra good pump and outfit. As the lice feed almost entirely upon the under sides of the leaves, it is necessary to have some special accessories. With any pump, a fifteen-foot lead of hose is necessary for use against the turnip louse. The equipment for this purpose must include an extension rod; four feet length is the best length. To properly direct the material onto the under sides of the leaves, it is necessary to use an "angle" type of spray nozzle, which must be attached to the extension rod by means of a 60° elbow. The secret of success in spraying against the turnip louse is the use of the angle nozzle and the elbow. These accessories are necessary to any equipment for such spraying. There are three classes of spray pumps which may be used in this work. The class of pump which it is necessary to buy depends upon the amount of work that has to be done. Only a good outfit of any class should be purchased. A good spray pump will give good service, but a poor outfit will never give satisfaction.

The bucket pump, shown in Plate II, is an example of this class of pumps. The photograph shows the pump with the proper accessories for spraying against the turnip louse. Such a pump is quite limited in its range of usefulness. It is adapted only for use in the home garden, and is not large enough for the truck grower. The application of material with such an outfit is too slow and expensive for one who has much area to spray. If one is growing only a few turnips in an infested district, it is necessary to have some kind of a spray outfit, and a bucket pump will serve this purpose. Specifications and estimated cost of such an outfit are here given:

Brass spray pump, with 1 *angle* nozzle	$3.25
Rubber hose, ½-inch, 3-ply, 15 feet	2.50
One extension rod, 4 foot	.40
One brass 60 degree elbow	.25
	$6.40

The barrel pump, shown in Plate III, above, is an example of this class of spray pumps. The photograph shows the accessories for spraying against the turnip louse. In this photograph the pump is fitted with only one lead of hose. However, a good pump of this class should supply ample pressure for two leads of hose. Unless it will do this the outfit is not good enough to buy. It happens that at times the pump will not furnish good pressure to two leads of hose. Under such conditions, it is best to use only one lead with good pressure. Two leads of hose with poor pressure makes the application expensive and unsatisfactory. The experiments proved that it is best to use as high pressure as possible for all spraying work. It is not necessary to have the cart shown in the photograph, as the pump can be hauled about the field in a small wagon. A good barrel spray pump has a wide range of usefulness. It is best adapted to the needs of the small truck gar-

dener but may be used by the large growers. Very often it is advisable for two or more growers to purchase an outfit together. This will materially reduce the individual cost on the start. Specifications and estimated cost of a barrel sprayer adapted for the work against the turnip louse are here given:

One barrel pump, with brass cylinder, one brass cut-out, two leads of hose, ½-inch, 5-ply, 15 feet, two angle nozzles	$18.00
Two brass 60 degree elbows	.50
Two extension rods	.80
	$19.30

The hand-power pump, shown in Plate III, below, is a specimen of this class of spray pumps. This pump will supply ample pressure for two leads of hose, each having two nozzles. With such an outfit as here shown it is possible to spray turnips very effectively and economically. The cost of this outfit puts it beyond the reach of many truck growers, but if one has many crops to spray it is the best outfit to purchase. If two or more growers could go together for the purchase of this outfit the first cost would not be prohibitive. Specifications and estimated cost of such an outfit are here given:

One hand-power pump, 50-gallon barrel, mounted on sled, pressure gauge, two 15-foot leads of 7-ply hose, ½-inch, two extension rods 4 feet, two brass angle Y's, four angle nozzles	$35.00

It is possible to purchase a hand-power pump and accessories without barrel and sled for $29.25.

SUMMARY.

A new species of plant louse, commonly called the turnip louse, and not the cabbage louse, as was formerly supposed, does the damage to the fall turnips and winter truck. This damage is general over the entire State of Texas. Not only do the truck regions suffer, but every home garden is damaged by the turnip louse.

The food plants of the turnip louse are turnips, cabbage, mustard, cauliflower, kale, rutabaga and rape.

The normal form of reproduction of the turnip louse in Texas is asexual throughout the year. Observations have been made upon this louse in Texas from Brownsville, on the 26th parallel, to Wichita Falls, on the 34th parallel. True hibernation does not take place in Texas, even at the northernmost point of occurrence the lice reproduce some during the winter. The summer is the critical period in the life history of the turnip louse, as it is forced to sheltered locations and none of the cultivated host plants are grown at that time of the year. Thirty-five generations of the lice were reared in pot cages in one year.

Two other species of plant lice are often found closely associated with the turnip louse. These are the "garden aphis" and the cabbage louse.

The natural factors of control of the turnip louse are widespread over the State. Two species of parasites, *Diaeretus rapae* Curt., and *Lysi-*

phlebus testaceipes Cress., have been commonly found, the former at College Station and the latter in other sections. Three species of lady beetles have been observed to feed freely on the turnip louse. These are *Hippodamia convergens* Guer., *Megilla maculata* DeG., and *Coccinella munda* Say. Syrphid flies and lace-wing flies are usually found in limited numbers where the turnip lice are abundant. A fungous disease was very destructive to the turnip louse during the season of 1914 at College Station.

For the artificial control of the turnip louse, spraying is the most satisfactory method. Of the materials which can be used for spraying, laundry soap solution gives as satisfactory results as any and is easily obtainable. The secret of success in the control of the turnip louse is the use of the 45° elbow and an "angle" type spray nozzle. By the use of these it is possible to direct the spray on the under sides of the leaves, where the lice feed.

The preventive measures against the turnip louse are rotation, proper planting time, trap crops, clean culture, and the destruction of the first colonies.