fruits for the control of canker worms *provided the weather conditions are favorable*. It is *not recommended*, however, for general practice as there can be no guarantee of what the weather may be after the application of the arsenical.

3. It is *very strongly recommended*, when necessary to use an arsenical upon stone fruits, that the *basic type of lead arsenate be used exclusively*. In order that this slower acting poison may be effective, it will be necessary to keep a close watch of the orchards and make the application while the worms are very young.

WILD VEGETATION AS A SOURCE OF CURLY-TOP INFECTION OF SUGAR BEETS¹

By P. A. BONCQUET, *Bacteriologist, Collaborator,*² and C. F. STAHL, *Scientific Assistant, Truck Crop and Stored Product Insect Investigations, Bureau of Entomology*

The curly-top condition of sugar beets has for some time been a subject of investigation by phytopathologists, but on account of the failure to discover a specific organism responsible for the physiological injury to the plant, the problem has been peculiarly baffling. Although the connection of the jassid leafhopper, *Eutettix tenella* Baker, with the disturbance has been definitely established, conclusive evidence has not previously been available as to the exact nature of the trouble, or as to the part played by the leafhopper in the dissemination of the virus. It is believed that the results secured as herein related may be of assistance in establishing in part the nature of the disorder, the identity of its probable alternate hosts and the conditions governing its somewhat periodical or sporadic appearance in beet fields.

A brief review of the investigations leading to the experiments which will be mentioned may serve to emphasize the significance of the results obtained.

The connection of *Eutettix tenella*, known both as the sugar-beet leafhopper and the curly-top leafhopper, with the condition was first definitely established in 1909.³ Soon afterwards it was found that a single leafhopper in any stage was capable of producing the condition

¹ Published by permission of the Honorable Secretary of Agriculture.

² Since this article was first presented for publication, Doctor Boncquet has been absent in Argentina. He has not, therefore, had the opportunity of approving some of the corrections in the manuscript.

³ Ball, E. D. The Leafhoppers of the Sugar Beet and Their Relation to the "Curly-leaf" Condition. U. S. Dept. Agr. Bur. Ent. Bul. 66, pt. 4, p. 33-52, pl. 1-4, 1909.

by feeding on a healthy beet for two minutes.¹ In these experiments it was further demonstrated that insects reared from the egg stage on healthy beets were unable to produce the characteristic condition.

The curly-top leafhopper feeds on a number of species of wild plants, in addition to its attacks on the sugar beet. Specimens collected from wild host plants were accordingly tested on healthy beets, but without bringing about the curly-top condition.² They acquired the ability to cause the characteristic symptoms of the condition by feeding on affected beets. This ability was lost in from 15 to 35 days if the insects were transferred daily to healthy beets. A period of incubation, dependent on temperature, and lasting at least two days was required.³

The apparently sporadic occurrence of curly-top outbreaks in remote isolated desert regions, where beets had never before been grown suggested either that the leafhopper was capable of migrating to great distances, or that the virulent factor resided in other food plants than the beet, and was perpetuated either in a virulent form or in a symbiotic relation by these plants. The first being untenable, the second suggestion was investigated, the results obtained to the present time apparently justifying this paper.

RECENT INVESTIGATIONS

Early in the fall of 1915 it was observed that many mallow plants (*Malva rotundifolia*) (Pl. 17, fig. 1) growing in the vicinity of beets affected with curly-top showed signs of abnormal development (Pl. 18, fig. 1). The plants were dwarfed and the leaves were irregularly contorted, the growing bud stunted, showing only two or three extremely small leaves, indicating a widespread disturbance in growth. Several of these abnormal plants were examined microscopically, revealing internal lesions similar to those observed in beets affected with curly-top. The phloem was injured not only in the stem and roots but even in the extreme parts of the leaves. The medullary rays of the stem were also attacked and in some places showed total disintegration.

¹ Smith, R. E., and Boncquet, P. A. New Light on Curly-top of the Sugar Beet. *In* Phytopathology, vol. 5, p. 103, 1915. Connection of a Bacterial Organism with Curly-leaf of the Sugar Beet. *In* Phytopathology, vol. 5, p. 335, 1915.

² Boncquet, P. A. *Bacillus morulans*, n. sp. Thesis presented for degree of Doctor of Philosophy at the University of California. University Documents, 1915. The Comparative Effect upon Sugar Beets of *Eutettix tenella* Baker from Wild Plants and from Curly-leaf Beets (with W. J. Hartung). *In* Phytopathology, vol. 5, p. 348, 1915.

³ Smith, R. E., and Boncquet, P. A. New Light on Curly-top of the Sugar Beet. *In* Phytopathology, vol. 5, p. 103, 1915. Connection of a Bacterial Organism with Curly-leaf of the Sugar Beet. *In* Phytopathology, vol. 5, p. 335, 1915.

Special staining methods demonstrated that organisms¹ similar to those previously found in affected beets were present. This striking resemblance suggested the possibility of the mallow being an alternate host in beet infection, and experiments were started to determine the relationship. In order to verify these assumptions two different methods were devised which, if successful, would furnish unquestionable proof. These methods were only the consequence of previous results obtained during investigations relating to virulent and non-virulent insects.

EXPERIMENTS

In the first set of experiments two factors were most essential for success: (1) Insects must be used which were known to be non-virulent; and (2) beet plants must be used which had been grown under cover and were known to be healthy. Mallow plants (*Malva rotundifolia*) which showed signs of some disturbance (Pl. 18, fig. 1) were selected, growing in the field which contained a large number of beets affected with the characteristic curly-top. A microscopic examination disclosed internal disorders similar to those previously mentioned. Insects which had been kept under close observation for more than six months and which were known to be non-virulent were selected and placed on the mallow in small leaf cages. After several days these insects were removed and placed on healthy beet plants in specially constructed cages. These beet plants were kept under close observation and the first symptoms of curly-top noted (Pl. 18, fig. 2). One insect was placed on an affected beet instead of a mallow plant and was used as a check so that it could be ascertained whether or not the condition would develop normally during the fall season of the year. Table I shows the results of these experiments.

TABLE I.—EXPERIMENTS IN THE PLACING OF NON-VIRULENT SPECIMENS OF *EUTETTIX TENELLA* ON AFFECTED MALLOW PLANTS AND THEIR SUBSEQUENT TRANSFERENCE TO HEALTHY BEET PLANTS, RESULTING IN CURLY-TOP INFECTION

Exp. No.	Date Placed on Mallow	Date Transferred to Healthy Beet	Date of First Symptoms of Curly-top	No. of Insects Used
1	Oct. 22, 1915	Oct. 27, 1915	Dec. 17, 1915	1
2	Oct. 27, 1915	Nov. 5, 1915	Jan. 10, 1916	1
3	Oct. 27, 1915	Nov. 5, 1915	Remained healthy	1
4	Oct. 27, 1915	Nov. 5, 1915	Nov. 29, 1915	1
5	Oct. 27, 1915	Nov. 5, 1915	Dec. 22, 1915	1

(Check on affected beet plant)

¹ Boncquet, P. A. *Bacillus morulans* n. sp. Thesis presented for degree of Doctor of Philosophy at the University of California. University Documents, 1915. The Comparative Effect upon Sugar Beets of *Eutettix tenella* Baker from Wild Plants and From Curly-leaf Beets (with W. J. Hartung). In *Phytopathology*, vol. 5, p. 348, 1915.

After remaining on the healthy beets for about two weeks all insects employed in the foregoing experiment were transferred to other healthy beets and the results were duplicated. Actual dates were not recorded, but all cases developed somewhat more rapidly than usual, due to the fact that the plants were kept in the greenhouse where the temperature was much higher. It will be noted from these results that the time required for the symptoms to develop was quite long, in fact much longer than was the case during the preceding summer in experiments with other phases of the condition. This unusual length of time was due to the unfavorable weather conditions prevailing later. The days were cold and cloudy and growth of the beets was practically at a standstill. It has been observed in these and other experiments that the symptoms of the condition do not appear unless the plant is growing. Two causes may be responsible for the fact that No. 3 did not show curly-top symptoms. Either the mallow was not affected, or the weather and the conditions in the beet plant were such that the organism was killed before it had a chance to develop. This assumption was more strikingly borne out in the following results, obtained from similar experiments at a later date. December 1, 1915, one of the same mallow plants was selected and six non-virulent insects placed upon it in a lantern globe. After a period of seven days they were removed and placed singly on healthy beets. None of these transfers brought about the disorder, all beets remaining healthy. As this mallow plant had been proven to be infected in the past experiment there is no doubt that unfavorable conditions were responsible for the negative results obtained. There may perhaps be a latent period in the life cycle of the causative agent while in the plant, or the agent may have been unable to withstand the unfavorable temperature.

The actual production of the condition in a healthy mallow plant by a virulent insect, and its subsequent transfer from the mallow to a healthy beet by a non-virulent insect, is the crucial point in the experiment. Small seedling plants for this test were grown in insect-proof cages and used as soon as they were large enough to be easily handled. First, six insects known to be virulent were placed on each mallow plant and were allowed to remain for a considerable period, after which they were removed. Non-virulent insects were then placed on the same plant and allowed to remain at least one week, when they were removed and placed on healthy beets. This experiment was conducted in a room in the laboratory where conditions were more favorable for the development of the condition. The results obtained are given in Table II.

TABLE II.—EXPERIMENT IN THE INFECTION OF HEALTHY MALLOW PLANTS BY VIRULENT SPECIMENS OF *EUTETTIX TENELLA* AND THE TRANSFERENCE OF THE CURLY-TOP INFECTION TO HEALTHY BEETS THROUGH THE AGENCY OF NON-VIRULENT SPECIMENS OF THE INSECT

Exp. No.	Virulent Insects Placed on Mallow	Date Removed and Non-Virulent Insects Placed on Mallow	Date Placed on Healthy Beets	Date when first Symptoms of Curly-top Appeared	No. of Insects Used
1	Nov. 10, 1915	Nov. 30, 1915	Dec. 14, 1915	Jan. 20, 1916	6
2	Nov. 10, 1915	Nov. 30, 1915	Dec. 14, 1915	Feb. 15, 1916	6
3	Dec. 1, 1915	Dec. 15, 1915	Dec. 27, 1915	Mar. 10, 1916	6
4	Dec. 1, 1915	Dec. 15, 1915	Dec. 27, 1915	Mar. 29, 1916	6

CONCLUSION

The foregoing experiments show the possibility that common weeds may assist in the perpetuation of the infectious factor which causes the curly-top of sugar beets. That these findings are of the greatest significance can be easily understood. Indeed they introduce a definite field of investigation for the control of this most destructive condition. One fact stands out most prominently from all evidence gathered up to the present time, namely, that the insects must be infected in order to be able to cause the disturbance. From their nature these insects in themselves are unable to produce the disorder. Hence, affected plants are required for reinfection of the insects before a general outbreak can be started. There must be present either some beets affected with curly-top in the fields or weeds which harbor the virulent factor, even in a symbiotic way. Clean cultivation, already extremely desirable from the standpoint of diseases and insect pests, especially during the period that no beets are in the field, is thus necessarily indicated as a means of prevention. Even though all vestiges of affected beets from the previous year have disappeared, and all volunteer beets have been eliminated, there remains the possibility that certain weeds, such as mallow, may harbor the virulent factor during hibernation. After clean cultivation has been put into practice attention must be directed to the surrounding native vegetation. The discovery of the original host plant among this vegetation is the next problem to be considered, and investigations are in progress to determine this point.

SUMMARY

Malva rotundifolia, a common weed in the beet fields, has proved to be at least a symbiotic host of the virulent factor of curly-top of sugar beets.

Individual insects of the curly-top leafhopper (*Eutettix tenella* Baker) known to be non-virulent were placed on sickly-looking mallow

1

2

1, Healthy plant of mallow (*Malva rotundifolia*). (Original.) 2, Sugar beet showing typical curly-top infection. (Original.)

1

2

1, Mallow plant (*Malva rotundifolia*) harboring virulent factor causing curly-top of sugar beets. (Original.)

2, Beet plants showing effect of curly-top infection transferred from mallow plants. (Original.)

plants in the field. They were subsequently placed on healthy beets grown from seed in insect-proof cages. The condition was produced in four experiments.

Insects known to be virulent were placed on healthy seedlings of *Malva rotundifolia*. After a certain lapse of time they were removed and replaced with non-virulent insects which were later transferred to healthy beets. All transfers brought about the disorder.

These discoveries throw considerable light on the nature of the condition of sugar beets called curly-top, and establish beyond doubt the possibility of preventing or limiting injury by this condition through the control of the leafhoppers affecting the beets, and through the establishment of clean cultural methods, by means of which infected plants which act as hosts to the leafhoppers may be removed from the vicinity of beet fields.

RELATION OF THE COMMON ROOT MAGGOT (PEGOMYIA FUSCICEPS ZETT.) TO CERTAIN CROPS IN LOUISIANA

By E. S. TUCKER, *State Agricultural Experiment Station, Baton Rouge, La.*

ATTACKS ON YOUNG TOMATO PLANTS

A number of injured tomato plants ranging from five to six inches in length and a few specimens of a small maggot said to have been found burrowing in the stems of similar growth were brought to the writer for examination on March 3, 1914, by a merchant of Norwood, East Feliciana parish, La. He stated that a gardener of his home town had lost more than 1,000 plants like the samples, from stock grown under culture in a coldframe, all having failed in the short time of about two days. When the bed was covered on Saturday evening, February 28, the growth appeared to be perfectly healthy; but on opening the frames on Monday, March 2, the owner noticed many drooping plants, and by close examination, determined the cause of damage through discovery of some maggots in the stems. Other growers also complained that their beds were likewise being depleted.

The sudden loss of great numbers of plants in such manner naturally excited some alarm among the growers, who feared that the trouble might become more extended and thus restrict their production of a tomato crop for the approaching season. Since none of the gardeners had ever before known an enemy of this kind to do any harm to tomato plants, the question of its identity and life-history, and how to deal with it, presented an entirely new problem. For the benefit of the community, therefore, the merchant hastened on a visit to consult