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CHARACTERS, DISTRIBUTION, AND FOOD PLANTS OF LEAFHOPPER SPECIES IN THAMNOTETTIX GROUP

DWIGHT M. DELONG and HENRY H. P. SEVERIN

TRANSMISSION OF CALIFORNIA ASTER-YELLOWS VIRUS BY LEAFHOPPER SPECIES IN THAMNOTETTIX GROUP

HENRY H. P. SEVERIN

UNIVERSITY OF CALIFORNIA · BERKELEY, CALIFORNIA

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HENRY H. P. SEVERIN[2]

INTRODUCTION

ACCORDING to Ball (1936),[3] the tree- and shrub-inhabiting leafhoppers have been referred in the past to the genus *Thamnotettix,* but are widely separated from the type of the genus and belong to a number of distinct genera. He divided the genus into nine genera.

Some years ago three leafhopper species (Severin, 1929, 1934) and a biological race (Severin, 1940) of one of these species were reported to transmit California aster-yellows virus. In recent papers (Severin, 1945, 1946, 1947*a*, 1947*b*) thirteen more species have been added to the list of vectors of this virus. The present paper deals with nine species and one variety of leafhoppers in the *Thamnotettix* group, two of which have been previously recorded in the literature (Severin, 1934). All were tested for transmission of California aster-yellows virus and some for transmission of the viruses of curly top and Pierce's disease of the grapevine. The companion paper in this issue (DeLong and Severin, 1948) discusses the characters, distribution, and food plants of eight of these leafhopper species.

METHODS

The cages used and the methods of transferring leafhoppers in a dark chamber were the same as in previous investigations (Severin, 1930, 1931).

The food plants used in maintaining large populations of the geminate leafhopper, *Colladonus geminatus* (Van Duzee), and the mountain leafhopper, *C. montanus* (Van Duzee), have been recorded in previous papers (Severin, 1934, 1942). Infective *Idiodonus heidemanni* (Ball) was reared on diseased celery and asters and noninfective leafhoppers on healthy celery and asters. The other six species and the one variety in the *Thamnotettix* group were collected on their natural host plants. They were not reared on celery and asters, and no attempt was made to breed them on their natural host plants.

IDIODONUS HEIDEMANNI (BALL)

Transmission of Virus to Celery. To determine the efficiency of *Idiodonus heidemanni* (Ball) (= *Thamnotettix heidemanni* Ball) in transmitting California aster-yellows virus, 50 males and 50 females that had completed the nymphal stages on infected celery were transferred singly to healthy celery plants. As table 1 shows, 12 per cent of the males and 20 per cent of the females caused infections.

A comparison was made of the transmission of the virus by 25 lots each of 5, 10, and 20 males and females which had completed the nymphal stages on

[1] Received for publication May 23, 1947.

[2] Entomologist in the Experiment Station.

[3] See "Literature Cited" for citations, referred to in the text by author and date.

diseased celery. The lots of 5 were kept on the first set of healthy celery plants to which they were transferred. With the lots of 10 and 20 leafhoppers, if symptoms developed on a plant, the lot on that plant was transferred to another healthy celery plant. If there were no symptoms, some lots were kept on the first healthy celery plant during adult life; others were changed monthly to successive healthy plants until the last adult died. These results appear in table 1.

TABLE 1

TRANSMISSION OF VIRUS BY VARYING NUMBERS OF *Idiodonus heidemanni* TO SUCCESSIVE HEALTHY CELERY PLANTS

Number of adults in each lot	Number of lots	First set of celery			Second set of celery			Third set of celery		
		Plants inoculated	Plants infected	Per cent infected	Plants inoculated	Plants infected	Per cent infected	Plants inoculated	Plants infected	Per cent infected
1 male	50	50	6	12	..	..	..	..	..	..
1 female	50	50	10	20	..	..	..	..	..	..
5 males	25	25	5	20	..	..	..	..	..	..
5 females	25	25	8	32	..	..	..	..	..	..
10 males	25	25	18	72	13	4	31	2	1	50
10 females	25	25	16	64	16	10	63	6	3	50
20 males	25	25	19	76	22	12	55	10	4	40
20 females	25	25	16	64	20	17	85	14	5	36

Number of adults in each lot	Number of lots	Fourth set of celery			Fifth set of celery			Total		
		Plants inoculated	Plants infected	Per cent infected	Plants inoculated	Plants infected	Per cent infected	Plants inoculated	Plants infected	Per cent infected
1 male	50	..	..	..	..	..	..	50	6	12
1 female	50	..	..	..	..	..	..	50	10	20
5 males	25	..	..	..	..	..	..	25	5	20
5 females	25	..	..	..	..	..	..	25	8	32
10 males	25	1	0	0	..	..	..	41	23	56
10 females	25	2	0	0	..	..	..	49	29	59
20 males	25	1	0	0	1	0	0	59	35	59
20 females	25	8	5	63	4	1	25	71	44	62

Table 1 shows that the relation between the percentages of infection caused by males and females, and by lots of 10 and 20, was not constant in the first four sets of celery plants. But the total percentages of infections caused by single males, and by lots of 5, 10, and 20 males, were lower than those of the females. In the lots of 10 and 20, the females inoculated more plants and lived longer than the males. There was a progressive increase in the total percentages of infections with lots of 5, 10, and 20 adults. Thus the number of leafhoppers plays an important role in the transmission of the virus to celery plants.

Transmission of Virus to Asters. Fifty infective male and 75 female *Idiodonus heidemanni* were kept singly on healthy asters until symptoms developed, or during adult life if no symptoms appeared. Fourteen per cent of the males and 8 per cent of the females (table 2), an average of 13 per cent, transmitted the virus to asters, as compared with an average of 16 per cent to celery (table 1).

An experiment was conducted with lots of 5, 10, and 20 males and females to determine the percentages of transmission of the virus to successive sets of healthy asters. Each lot of infective adults was kept on a healthy aster until symptoms of the disease appeared and then was transferred to another healthy aster. If no symptoms developed, the surviving adults were changed to successive asters at irregular intervals until the last adult died. The results obtained appear in table 2.

TABLE 2

TRANSMISSION OF VIRUS BY VARYING NUMBERS OF *Idiodonus heidemanni* TO SUCCESSIVE HEALTHY ASTERS

Number of adults in each lot	Number of lots	First set of asters			Second set of asters		
		Plants inoculated	Plants infected	Per cent infected	Plants inoculated	Plants infected	Per cent infected
1 male	50	50	7	14	..	..	..
1 female	75	75	6	8	..	..	..
5 males	20	20	1	5	..	..	..
5 females	20	20	15	75	14	3	21
10 males	10	10	4	40	6	0	0
10 females	10	10	9	90	10	5	50
20 males	20	20	6	30	4	1	25
20 females	23	23	11	48	16	3	19

Number of adults in each lot	Number of lots	Third set of asters			Total		
		Plants inoculated	Plants infected	Per cent infected	Plants inoculated	Plants infected	Per cent infected
1 male	50	..	..	..	50	7	14
1 female	75	..	..	..	75	6	8
5 males	20	..	..	..	20	1	5
5 females	20	4	2	50	38	20	53
10 males	10	4	0	0	20	4	20
10 females	10	7	1	14	27	15	56
20 males	20	1	1	100	25	8	32
20 females	23	4	2	50	43	16	37

As table 2 shows, the total percentages of infections of the three sets of asters did not increase progressively with lots of 5, 10, and 20 adults: higher percentages of infections were obtained with lots of 5 and 10 adults than with lots of 20 adults. The total percentages of infections were higher with lots of 5, 10, and 20 females than with the males.

Transmission of Virus to Two Host Plants. Transmission of California aster-yellows virus to celery alternating with aster, and to asters alternating with celery, by lots of 20 and 40 male *Idiodonus heidemanni*, was compared. The first and second sets of plants were each exposed to the leafhoppers for a period of 3 days and the third plant during adult life of the insects.

Table 3 shows that when the first sets of celery and asters were exposed to lots of 20 and 40 males for three days, 4 of 20 celery plants and 2 of 20 asters were infected. When the second set of celery plants was exposed to the same number of leafhoppers during adult life, 17 of 20 plants were infected. When

asters alternated with celery, it is evident from table 3, celery was more readily infected than asters.

Retention of Virus by Single Adults. Virus retention was determined with single adult *Idiodonus heidemanni* that had transmitted the virus to celery

TABLE 3

TRANSMISSION OF VIRUS TO SUCCESSIVE SETS OF TWO HOST PLANTS BY 10 LOTS EACH OF 20 OR 40 MALE *Idiodonus heidemanni*

Test no. and plants tested	20 adults per lot			40 adults per lot		
	Period of inoculation, days	Plants inoculated	Plants infected	Period of inoculation, days	Plants inoculated	Plants infected
Test 1:						
First set of celery	3	10	2	3	10	2
First set of asters	3	10	0	3	10	2
Second set of celery	21-59	10	8	15-60	10	9
Test 2:						
First set of asters	3	10	1	3	10	2
First set of celery	3	10	2	3	10	6
Second set of asters	23-34	10	1	7-18	10	1

TABLE 4

TRANSMISSION OF VIRUS TO CELERY AND ASTERS BY VARYING NUMBERS OF *Idiodonus kirkaldyi*

Plant and number of adults in each lot	Number of lots	Plants inoculated	Plants infected	Per cent infected
Celery:				
1 male	50	50	0	0
1 female	50	50	0	0
4 females	1	7	2	29
5 males	3	3	0	0
5 females	3	3	0	0
10 males	1	1	0	0
10 females	3	1	0	0
20 males	1	1	0	0
25 males	1	5	0	0
Aster:				
1 male	11	11	0	0
1 female	14	14	0	0
5 males	2	2	0	0
5 females	2	2	0	0
10 males	1	1	0	0
10 females	1	1	0	0
20 males	1	1	0	0

in tests of vector efficiency. After a leafhopper had produced the first infection, it was transferred daily to healthy asters during adult life. One male infected the first 2 successive asters, retaining the virus for 11 days after producing the first infection. The incubation period of the disease in the first aster is not included in the retention of the virus, since the adult was able to acquire the virus again. The longevity of the male was 67 days. Two males and 2 females produced only 1 infection in the first aster.

Attempt to Transmit Curly-Top Virus. Because the beet leafhopper, *Eutettix tenellus* (Baker), was originally described in the genus *Thamnotettix,* a large number of tests were made to determine whether *Idiodonus heidemanni,* also formerly placed in the genus *Thamnotettix,* was a victor of the curly-top virus. All attempts to transmit curly-top virus to healthy sugar-beet seedlings were failures.

IDIODONUS KIRKALDYI (BALL)

Idiodonus kirkaldyi (Ball) (= *Thamnotettix kirkaldyi* Ball) (plate 1, *A, B*) is an inefficient vector of California aster-yellows virus. The leafhoppers tested were collected from California sagebrush, *Artemisia californica.* One lot of 4 adults was kept on diseased celery for 66 days and then was transferred every week to successive healthy celery plants until the last adult died. Two of 7 plants inoculated were infected. Fifty males and 50 females tested singly on healthy celery produced no infection. Lots of 5, 10, 20, and 25 males or females which were kept on diseased celery from 10 to 14 days, failed to transmit the virus to healthy celery plants (table 4). The virus was not transmitted from infected to healthy asters by varying numbers of adults (table 4).

GEMINATE LEAFHOPPER, COLLADONUS GEMINATUS (VAN DUZEE)

The geminate leafhopper, *Colladonus geminatus* (Van Duzee) (= *Thamnotettix geminatus* Van Duzee), was previously reported (Severin, 1934) as a vector of the California aster-yellows virus. In a later investigation (Severin, 1942), this leafhopper species was demonstrated to be one of the most important vectors of the virus to perennial delphiniums, and was shown to breed on this host plant under natural conditions.

The number of infections induced by varying numbers of adults has been reported in two previous papers (Severin, 1934, 1942). The transmission of the virus to celery averaged 14 per cent, but no infections were obtained with 182 asters inoculated. Twenty-five lots of 50 males each were used to inoculate asters; and 4 of 50 asters were infected, or 8 per cent (Severin, 1942).

Transmission of Virus to Celery and Asters. To determine the efficiency of the geminate leafhopper in transmitting the California aster-yellows virus to celery, 100 males and 100 females that had completed the nymphal stages on diseased celery were transferred singly to healthy celery plants. Two males and 3 females, or 3 per cent, produced infections.

Twelve lots of 20 males were kept on diseased celery for 5, 10, or 15 days, and then each lot was transferred to 37, 32, or 27 successive healthy celery plants. The average number of infections caused by lots of 20 adults was 2.4, 1.5, and 2.4, with exposures of 5, 10, and 15 days, respectively.

Another experiment was undertaken with asters as the host plant. Three hundred males and 300 females that had completed the nymphal stages on naturally infected asters and on experimentally infected asters and celery, were transferred singly to healthy asters. Not a single infection was obtained.

As reported in a previous paper (Severin, 1934), the geminate leafhopper was collected on asters under natural conditions; but a high mortality occurred on small asters in the greenhouse when the adults were transferred

from large asters in the field. It was found that the adults fed on small healthy asters died within a week. Nymphs lived longer than adults, and sometimes the nymphs acquired the winged stage on large asters.

Latent Period of Virus in Adults. The latent period of California aster-yellows virus in the geminate leafhopper was determined with 8 lots of single previously noninfective males and 11 lots of 100 males. After 1 day on an

TABLE 5

LATENT PERIOD OF VIRUS IN ADULT GEMINATE LEAFHOPPER, *Colladonus geminatus*, WITH CELERY AS THE HOST PLANT

Lot no.	Number of adults	Days on infected celery	Successive plants inoculated	Plants infected	Per cent infected	Days on which successive infections occurred, including initial day on infected celery	Adults alive at end of 42 days
1*	1	1	41	1	3	31	1
9	100	1	41	8	20	18, 26, 31, 34, 36, 39, 41, 42	62
10	100	1	41	12	29	21, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41	75
11	100	1	41	8	20	23, 26, 27, 28, 30, 32, 39, 41	62
12	100	1	41	7	17	24, 25, 26, 27, 28, 29, 30	62
13	100	1	41	2	5	27, 37	37
14	100	1	41	13	32	27, 28, 30. 31, 32, 34, 35, 36, 37, 38, 39, 41, 42	48
15	100	1	41	9	22	31, 32, 34, 35, 36, 37, 38, 39, 42	69
16	100	1	41	5	1	32, 34, 35, 39, 42	15
17	100	1	41	3	7	33, 37, 42	57
18	100	1	41	5	1	36, 37, 38, 39, 41, 42	69
19	100	1	41	6	2	36, 37, 39, 41, 42	48
20	20	5	37	2	6	22, 23	8
21	20	5	37	1	3	22	10
22	20	5	37	1	3	23	9
23	20	5	37	3	8	26, 30, 34	10
24	20	5	37	2	6	27, 31	7
25	20	10	32	1	3	17	7
26	20	10	32	1	3	33	9
27	20	15	27	2	7	20, 29	10
28	20	15	27	2	7	23, 33	11
29	20	15	27	1	4	31	5
30	20	15	27	1	4	33	8
31	20	15	27	1	4	38	20

* Lots 2 to 8 were single-insect tests; no infections were obtained with them.

infected celery plant, the adults were transferred daily to successive healthy celery plants throughout a period of 41 days. The virus latent period in 1 male was 31 days, as appears in table 5. Seven lots of single adults kept on diseased celery plants for 1 day and then transferred daily to healthy celery during 41 days failed to cause infections, but 2 adults kept on healthy celery produced infections after 54 and 90 days (not included in table 5). The minimum latent period in 11 lots of 100 males ranged from 18 to 36 days.

Attempts to Transmit the Viruses of Curly Top and Pierce's Disease of the Grapevine. In discussing the number of leafhopper vectors of the California aster-yellows virus, plant pathologists have asked repeatedly whether any of these leafhoppers transmit the viruses of curly top and Pierce's disease of the grapevine. All efforts to transmit the curly-top virus by means of the geminate leafhopper were failures. The geminate leafhopper also failed to

transmit the virus of Pierce's disease to healthy wild grapevine seedlings and to California common or Chilean alfalfa; and from alfalfa dwarf to healthy wild grapevine seedlings and healthy alfalfa.

MOUNTAIN LEAFHOPPER, COLLADONUS MONTANUS (VAN DUZEE)

The mountain leafhopper, *Colladonus montanus* (Van Duzee) (= *Thamnotettix montanus* Van Duzee), has been previously reported as a vector of the California aster-yellows virus (Severin, 1934). This leafhopper is an efficient vector of the virus to perennial delphinium and breeds on this host plant under natural conditions (Severin, 1942).

The number of infections produced by lots of 5, 10, and 20 adults has been published in a previous paper (Severin, 1934). A total of 464 celery plants and 412 asters were inoculated; 121 celery plants and 12 asters were infected, or 26 and 3 per cent, respectively.

Transmission of Virus to Celery and Asters. Fifty males and 50 females that had completed the nymphal stages on diseased celery were tested singly on healthy celery plants to determine the efficiency of the mountain leafhopper in transmitting the California aster-yellows virus. Three males and 8 females, or 11 per cent, caused infections.

Thirteen lots of 20 males kept on infected celery for 1 day and then transferred to healthy celery for 41 days caused no infections. With exposures of 5, 10, and 15 days to infected celery, the average number of infections produced by 13 lots of 20 adults was 4, 1.3, and 3, respectively. One lot of 20 adults kept on diseased celery for 5 days and 2 lots for 10 days failed to transmit the virus to healthy celery plants.

The first experiment was repeated with asters as a host plant. Fifty males and 50 females reared during all nymphal stages on naturally infected asters, and on experimentally infected asters and celery, were transferred singly to healthy asters. No infections were produced. The longevity of the adults on asters ranged from 2 to 15 days, with an average of 4.3 days.

Latent Period of Virus in Adults. The latent period of the California aster-yellows virus in the mountain leafhopper was determined with 8 lots of single previously noninfective males and 10 lots of 100 males. All lots were kept on diseased celery plants for 1 day and then were transferred daily to successive healthy celery plants for 41 days. As shown in table 6, the latent periods of the virus in 2 single males were 23 and 31 days. Six lots of single males failed to transmit the virus. The minimum latent period of the virus in 10 lots of 100 males ranged from 8 to 40 days. The number of infections produced by each lot and the number of adults alive at the end of 42 days appear in table 6.

Retention of Virus. The retention of the California aster-yellows virus in the mountain leafhopper was determined with single males and females that had transmitted the virus in testing the efficiency of virus transmission by this vector. Each leafhopper was kept on a healthy celery plant until the latter showed symptoms, then the insect was transferred to successive healthy celery plants throughout its adult life. Two males and 1 female produced only the initial infection.

TABLE 6

LATENT PERIOD OF VIRUS IN ADULT MOUNTAIN LEAFHOPPER, *Colladonus montanus*, WITH CELERY AS THE HOST PLANT

Lot no.	Number of adults	Days on infected celery	Successive plants inoculated	Plants infected	Per cent infected	*Days on which successive infections occurred	Adults alive at end of 42 days
1	1	1	41	1	3	23	1
2	1	1	41	1	3	31	1
3	100	1	41	7	17	8, 11, 18, 28, 37, 39, 41	42
4	100	1	47	11	27	15, 16, 17, 20, 22, 26, 27, 29, 32, 35, 41	57
5	100	1	47	8	20	20, 35, 36, 37, 38, 40, 41, 42	45
6	100	1	41	3	7	20, 29, 32	40
7	100	1	41	9	22	23, 25, 26, 28, 30, 33, 35, 36, 41	78
8	100	1	41	13	32	24, 26, 27, 28, 29, 30, 31, 32, 34, 35, 37, 38, 42	61
9	100	1	41	11	27	26, 29, 30, 31, 32, 33, 34, 35, 38, 40, 42	60
10	100	1	41	3	7	30, 32, 35	15
11	100	1	41	1	3	30	4
12	100	1	41	2	5	40, 42	73
13	20	5	37	3	8	22, 32	17
14	20	5	37	9	3	23, 27, 29, 34, 35, 36, 38, 40, 42	6
15	20	5	37	2	6	23, 24	14
16	20	5	37	2	6	33, 36	8
17	20	10	32	1	3	19	15
18	20	10	32	1	3	27	19
19	20	10	32	1	3	32, 35	14
20	20	15	27	3	1	19, 30, 36	17
21	20	15	27	3	1	28, 38, 42	16
22	20	15	27	4	2	29, 30, 34, 37	20
23	20	15	27	4	2	29, 32, 35, 36	17
24	20	15	27	3	1	29, 39, 41	14
25	20	15	27	1	3	38	20

* Days are numbered from the initial day on infected celery.

TABLE 7

TRANSMISSION OF VIRUS TO CELERY AND ASTERS BY VARYING NUMBERS OF *Colladonus commissus*

Plant and number of adults in each lot	Number of lots	Plants inoculated	Plants infected	Per cent infected
Celery:				
1 male	50	50	14	28
1 female	50	50	24	48
10 males	1	13	9	69
20 males	1	9	2	22
25 males	3	24	6	25
25 females	2	56	16	28
Asters:				
1 male	1	1	0	0
1 female	8	8	0	0
5 females	5	5	1	20

Attempts to Transmit the Viruses of Curly Top and Pierce's Disease of the Grapevine. The mountain leafhopper failed to transmit curly-top virus. It also failed to transmit the virus of Pierce's disease to healthy wild grapevine seedlings and to California common or Chilean alfalfa; and from alfalfa dwarf to healthy wild grapevine seedlings or to healthy alfalfa.

COLLADONUS COMMISSUS (VAN DUZEE)

Colladonus commissus (Van Duzee) (= *Thamnotettix commissus* Van Duzee) (plate 1, *C, D,*) was collected on monkey-flower, *Diplacus aurantiacus.*

Tranmission of Virus to Celery. The efficiency of *Colladonus commissus* in transmitting the California aster-yellows virus was determined with single adults, each transferred from a diseased to a healthy celery plant. Table 7 shows that 14 to 50 males and 24 of 50 females caused infections of celery plants.

TABLE 8

RETENTION OF VIRUS BY SINGLE ADULT *Colladonus commissus* WITH CELERY AS THE HOST PLANT

Days on first plant before symptoms developed	Plants inoculated after first infection	Plants infected after first infection	Per cent infected after first infection	Days after first infection on which successive infections occurred	Longevity of adults, days
23	24	12	50	3, 4, 5, 8, 9, 10, 12, 13, 14, 15, 18, 27	47
21	39	3	8	2, 4, 6	60

Lots of 10 to 25 males or females were transferred from diseased to successive healthy celery plants weekly. Table 7 shows the number of infections produced by each lot of leafhoppers.

To determine whether a longer period of exposure to healthy celery plants is a factor in the transmission of the virus, a male and a female were transferred singly from diseased to successive healthy celery plants every month during adult life. The male infected 2 of 3 plants and the female 3 of 4 plants.

Transmission of Virus to Asters. No infections were obtained with 9 adults tested singly on asters. Five lots of 5 adults transmitted California aster-yellows virus to 1 of 5 asters (table 7).

Retention of Virus by Single Adults. The retention of California aster-yellows virus by *Colladonus commissus* was determined with single adults that had transmitted the virus in tests of vector efficiency. After the first infection of celery, the leafhopper was transferred daily to successive healthy celery plants during adult life. One female retained the virus for 27 days after symptoms developed on the first plant and caused 12 infections, as appears in table 8. Another female retained the virus for 6 days and produced 3 infections. The period on the first plant is not included in the retention of the virus since the adults were able to acquire the virus again. Eleven adults induced only the initial infection.

Attempts to Transmit the Viruses of Curly Top and Pierce's Disease of the Grapevine. Because of the interest in curly top and Pierce's disease of the grapevine, attempts were made to transmit these by means of *Colladonus commissus.*

There was no proof that *Colladonus commissus* could transmit the curly-top virus to healthy sugar-beet seedlings or the virus of Pierce's disease of the grapevine to healthy wild grapevine seedlings. Some of the beet seedlings showed cleared veinlets on a portion of a leaf, a reliable symptom of curly top; but noninfective beet leafhoppers failed to recover the curly-top virus from such plants.

COLLADONUS MENDICUS (BALL)

Colladonus mendicus (Ball) (= *Thamnotettix mendicus* Ball) has not been demonstrated to be a vector of California aster-yellows virus. One lot of 32 adults collected on creek nettle, *Urtica gracilis* var. *holosericea* on October 27, 1942, was kept on diseased celery for 19 days, and then 2 lots of 5 and 15 adults that survived were changed to 2 healthy celery plants, without results. Another lot of 5 adults, captured on California blackberry, *Rubus vitifolius,* was fed on an infected celery plant for 34 days and then transferred to a healthy celery plant, but caused no infection. One lot of 10 adults collected on creek nettle was kept on a diseased aster for 11 days; 4 surviving adults, transferred to a healthy celery plant, caused no infection. The longevity of the adults on healthy celery was only 4 days.

Colladonus mendicus was parasitized by a new species of Pipunculidae, described as *Allomethus oleous* Rapp (1943).

COLLADONUS FLAVICAPITATUS (VAN DUZEE)

Colladonus flavicapitatus (Van Duzee) (= *Thamnotettix flavicapitatus* Van Duzee) (plate 1, *E, F*), collected on wild gooseberry, *Ribes* sp., in General Grant Park (DeLong and Severin, 1947) was usually parasitized by a species of Pipunculidae. The parasite was not reared. The leafhoppers were killed by the parasite before the virus incubation period in the insects was completed; this happened with 39 adults collected on September 15, 1944.

The transmission of the virus by this species of leafhopper was limited to three tests. One adult, after 11 days on a diseased celery plant, was changed to 3 successive celery plants at irregular intervals of 11 to 36 days and caused 2 infections. A single male was kept on an infected celery plant for 19 days and then on a healthy celery plant during adult life, but failed to produce an infection. One lot of 10 adults was kept on an infected celery plant for 17 days and then transferred to 5 successive healthy celery plants; 2 infections resulted.

FRISCANANUS INTRICATUS (BALL)

Friscananus intricatus (Ball) (plate 1, *G, H, I*) is rare on the host plants recorded in the companion paper by DeLong and Severin (1948); but although low populations of leafhoppers were used, transmission of the virus to healthy celery was obtained.

Twenty males and females tested singly caused 3 infections (table 9). Two lots of 3 and 4 adults collected during the summers of 1943 and 1944 were kept on diseased celery from 11 to 12 days, and then were transferred to 4 and 13 successive healthy celery plants, respectively; 6 infections resulted—

35 per cent. The longevities of the last surviving adult in the two lots on healthy celery were 67 and 93 days, respectively, or an average of 80 days.

No transmissions from infected to healthy asters were obtained with 3 males and 1 female tested singly (table 9).

TABLE 9

TRANSMISSION OF VIRUS TO CELERY AND ASTERS BY VARYING NUMBERS OF *Friscananus intricatus*

Plant and number of adults in each lot	Number of lots	Plants inoculated	Plants infected	Per cent infected
Celery:				
1 male	6	6	1	17
1 female	14	14	2	14
3 males	1	4	0	0
4 females	1	13	6	46
Aster:				
1 male	3	3	0	0
1 female	1	1	0	0

TABLE 10

TRANSMISSION OF VIRUS TO CELERY AND ASTERS BY VARYING NUMBERS OF *Friscananus rupinatus*

Plant and number of adults in each lot	Number of lots	Plants inoculated	Plants infected	Per cent infected
Celery:				
1 male	50	50	15	30
1 female	50	50	14	28
5 males	3	3	1	33
5 females	2	2	1	50
10 males	1	1	0	0
15 males	1	9	2	22
15 females	1	12	0	0
15 males	3	3	2	67
15 females	6	6	2	33
Asters:				
1 male	8	8	0	0
1 female	25	25	0	0

FRISCANANUS RUPINATUS (BALL)

Nymphs and adults of *Friscananus rupinatus* (Ball) (= *Thamnotettix rupinatus* Ball) (plate 1, *J*, *K*) were collected on bracken, *Pteridium aquilinum* var. *lanuginosum*. Fifty males and 50 females, tested singly on healthy celery plants, produced 15 and 14 infections, respectively (table 10). The transmission of the virus to healthy celery by lots of 5, 10, and 15 adults is shown in table 10. Nine lots of 15 males or females kept on healthy celery plants during adult life transmitted the virus to 4 of 9 plants. During the summer of 1943, 1 lot of 15 males, after feeding on infected celery for 19 days, was transferred to 9 successive celery plants and caused 2 infections. During the summer of 1944, 1 lot of 15 females was kept on diseased celery for 12

days and then was changed to 12 successive healthy celery plants, but no infection resulted. The longevities of the last surviving adult in the two lots on healthy celery were 41 and 110 days, or an average of 76 days.

Eight males and 25 females, after feeding on infected asters 10 days or longer, were transferred to healthy asters and kept on them during adult life; but no infection occurred (table 10).

An attempt was made to transmit the curly-top virus by means of *Friscananus rupinatus*. Ten lots of 5 or 10 males or females were exposed to curly-top beets for a few days and then each lot was transferred to a healthy beet. All beets remained healthy.

FRISCANANUS RUPINATUS VAR. BRUNNEUS DE LONG AND SEVERIN

Friscananus rupinatus var. *brunneus* DeLong and Severin (plate 1, *L*) was collected on bracken. Its efficiency in transmitting California aster-yellows virus was determined with single adults, each transferred from a diseased to a healthy celery plant. Infections were produced by 3 of 10 males, or 30 per cent; and by 11 of 50 females, or 22 per cent. As compared with these percentages, 50 males and 50 females of *Friscananus rupinatus* kept singly on healthy celery infected 30 and 28 per cent, respectively (table 10).

SUMMARY

Evidence is presented in this paper that the following leafhoppers in the *Thamnotettix* group are vectors of the California aster-yellows virus:

Idiodonus heidemanni (Ball)
Idiodonus kirkaldyi (Ball)
Geminate leafhopper, *Colladonus geminatus* (Van Duzee)
Mountain leafhopper, *Colladonus montanus* (Van Duzee)
Colladonus commissus (Van Duzee)
Colladonus flavocapitatus (Van Duzee)
Friscananus intricatus (Ball)
Friscananus rupinatus (Ball)
Friscananus rupinatus var. *brunneus* DeLong and Severin

TABLE 11

SUMMARY OF RESULTS ON EFFICIENCY OF LEAFHOPPER SPECIES IN TRANSMITTING VIRUS, EACH VECTOR TESTED SINGLY ON HEALTHY CELERY OR ASTERS

Species of leafhopper	Number of lots	Celery			Asters		
		Plants inoculated	Plants infected	Per cent infected	Plants inoculated	Plants infected	Per cent infected
Idiodonus heidemanni	100	100	16	16	125	13	13
*Idiodonus kirkaldyi**	100	100	0	0	25	0	0
Colladonus geminatus	200	200	5	3	300	0	0
Colladonus montanus	100	100	11	11	100	0	0
Colladonus commissus	100	100	38	38	9	0	0
Colladonus flavicapitatus	2	4	3	75	..	..	..
Friscananus intricatus	20	20	3	15	4	0	0
Friscananus rupinatus	100	100	29	29	33	0	0
Friscananus rupinatus var. *brunneus*	60	60	14	23	..	..	..

* Infection was obtained with multiple lots.

A summary of results on the efficiency of each leafhopper species in transmitting the virus when tested singly on healthy celery or asters is given in table 11.

Celery is more readily infected than asters. The number of leafhoppers and the period of exposure to healthy plants plays an important role in the transmission of the virus to celery plants.

The latent period of the virus in 1 male of the geminate leafhopper, *Colladonus geminatus,* was 31 days. The minimum latent period in 11 lots of 100 males ranged from 11 to 36 days. In the mountain leafhopper, *C. montanus,* the minimum latent period in 10 lots of 100 adults ranged from 8 to 40 days.

The retention of the virus by 1 male *Idiodonus heidemanni* was 11 days after producing the initial infection; 2 males and 2 females each caused infection only in the first celery or aster. In tests on the retention of the virus with the mountain leafhopper, *Colladonus montanus,* 2 males and 1 female produced only the initial infection. One female of *C. commissus* retained the virus for 6 days and produced 3 infections. Eleven adults induced only the initial infection.

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Plate 1.—Color patterns which usually distinguish species of leafhoppers in *Thamnotettix* group, vectors of California aster-yellows virus: *A*, male, and *B*, female, *Idiodonus kirkaldyi* (Ball); *C*, male, and *D*, female, *Colladonus commissus* (Van Duzee); *E*, male, and *F*, female, *C. flavocapitatus* (Van Duzee); *G*, male, and *H*, *I*, females, *Friscananus intricatus* (Ball); *J*, male, and *K*, female, *F. rupinatus* (Ball); *L*, *F. rupinatus* var. *brunneus* DeLong and Severin.

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