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VIROSES OF ANNUAL LARKSPURS

HENRY H. P. SEVERIN

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HENRY H. P. SEVERIN[2]

ANNUAL LARKSPURS are naturally infected with many virus diseases, in a few of which the identity of the virus has been determined. Annual and perennial larkspurs, or delphiniums, both belong to the genus *Delphinium,* and hence in connection with investigations of diseases and leaf variegations of perennial species (*2, 3, 4, 5, 6*)[3] a study was undertaken to determine whether delphinium viroses (*2, 3, 6*) also affect annual species under natural conditions.

In this paper the following virus diseases of annual larkspurs are discussed: California aster yellows, celery calico, curly top, tomato spotted wilt, and western cucumber mosaic.

CALIFORNIA ASTER YELLOWS

Annual larkspur was demonstrated to be naturally infected with California aster yellows. The virus was recovered from naturally infected annual larkspurs grown for the cut-flower trade, in home gardens, and on seed farms. The virus was recovered from naturally infected annual larkspurs and transferred to asters by the short-winged and long-winged forms of aster leafhopper, *Macrosteles divisus* (Uhl.), and was transferred to celery by the mountain leafhopper, *Thamnotettix montanus* Van D., and by the geminate leafhopper, *T. geminatus* Van D.

Since short-winged and long-winged aster leafhoppers were not efficient vectors of the virus to perennial delphiniums and a high mortality occurred within 24 hours, an attempt was made to infect annual larkspurs with these leafhoppers experimentally. Table 1 gives a list of annual larkspurs which were infected with the virus. Both short-winged and long-winged aster leafhoppers infected 19 of the 24 plants inoculated, or 79.2 per cent. The virus was recovered from infected annual larkspurs by these leafhoppers and transferred to asters.

The longevity of short-winged aster leafhoppers on varieties of annual larkspur varied from 9 to 26 days for the males and from 15 to 22 days for the females; that of the long-winged aster leafhoppers varied from 8 to 13 days for the males and from 8 to 21 days for the females. Nymphs of both leafhoppers emerged from eggs deposited in larkspurs but none lived to become adults. The nymphal stages of the mountain and gemi-

[1] Received for publication June 24, 1941.

[2] Associate Entomologist in the Experiment Station.

[3] Italic numbers in parentheses refer to "Literature Cited" at the end of this paper.

nate leafhoppers were completed on the Lilac Supreme, Sky Blue, Daintiness, and Exquisite Pink Improved varieties of annual larkspur.

The first symptom resulting from aster yellows on annual larkspur was a chlorotic appearance of the stem and flower stalk followed by a yellowing of the foliage. Droplets of clear sap sometimes exuded from the petioles and stems of experimentally infected annual larkspurs. Later the droplets turned brown and formed a crust, a symptom which also occurred on naturally infected larkspurs. Phyllody, or the tendency of the floral organs to resemble leafy structures, and virescence, or greening of the flowers, were somewhat similar to those described on perennial delphiniums in a previous paper (*2*). The sepals, petals, carpels, and stamens were often replaced by green leafy structures (plate 1, *B, F*) or the carpels were leaflike and the stamens were apparently normal (plate 1, *A, E*), and sometimes the carpels were replaced by stems bearing variously modified appendages frequently resembling leaves (plate 1, *C*).

The incubation period of the disease varied from 18 to 62 days, with an average of 36.4 days, as indicated in table 1.

CELERY CALICO

Annual larkspur was proved to be infected with celery calico in nature. The virus was recovered from naturally infected larkspurs and transferred by mechanical inoculation (*1*) to celery, Turkish tobacco, and White Spine cucumbers.

The varieties of larkspurs experimentally infected by mechanical inoculation are listed in table 2. A total of 108 annual larkspurs were inoculated, and 101, or 93.5 per cent, became infected, as shown in table 2. The virus was recovered and transferred to White Spine cucumber (table 2).

It is often difficult to detect symptoms of calico on the multifid linear segments of the leaves. Small green areas embedded in yellow portions of the leaves (plate 2, *D*) proved to be a reliable symptom of the disease.

CURLY TOP

Annual larkspurs have been demonstrated to be infected with curly top in the San Joaquin Valley. Previously noninfective beet leafhoppers, *Eutettix tenellus* (Baker), after feeding on the naturally infected plants, were transferred to sugar beets, and typical symptoms of the disease developed.

The following varieties of annual larkspurs were experimentally in-

fected with curly top by means of infective beet leafhoppers: Double mixed, Gloria, Exquisite Pink Improved, Lilac, Pink, and Sky Blue.

The method used to experimentally infect annual larkspurs grown from seeds was to allow 20 infective male beet leafhoppers to feed on

TABLE 1

TRANSMISSION OF CALIFORNIA-ASTER-YELLOW VIRUS BY SHORT-WINGED AND LONG-WINGED ASTER LEAFHOPPERS TO ANNUAL LARKSPURS AND INCUBATION PERIOD OF THE DISEASE

Type and variety of annual larkspur	With short-winged aster leafhopper			With long-winged aster leafhopper			Incubation period of disease in plant, with both insects
	Plants inoculated	Period of inoculation	Plants infected	Plants inoculated	Period of inoculation	Plants infected	
	number	*days*	*number*	*number*	*days*	*number*	*days*
Giant Imperial Double:							
Carmine King	1	1	0	1	1	1	32
Daintiness	2	20, 26	2	2	13, 20	1	....
Double mixed	1	13	1	1	13	1	....
Exquisite Pink Improved	2	10, 15	2	2	2, 8	1	....
Gloria	2	16, 22	2	2	8, 21	1	....
La France	1	2	1	1	2	1	....
Lilac Spire	1	1	1	1	1	1	45, 61
Miss California	1	1	1	1	1	1	35, 35
White King	1	1	0	1	1	1	25
White Spire	1	1	1	1	1	1	34, 34
Tall Double Stock-flowered:							
Bright Rose	1	1	1	1	1	1	28, 28
Bright Violet	1	1	0	1	1	1	30
Dark Blue	1	1	1	1	1	0	47
Lilac	1	1	1	1	1	1	18, 27
Lilac Supreme	2	18, 7	2	2	9, 9	1	....
Lustrous Carmine	1	1	0	1	1	1	62
Pink	1	14	1	1	9	1	....
Sky Blue	2	9, 18	2	2	9, 11	2	....
White	1	1	0	1	1	1	42
Total or average	24	....	19	24	....	19	36.4

each plant for a period varying from 1 to 14 days. Males were used rather than females to avoid egg deposition. The leafhoppers were then removed from the inoculated plants and played no further part in the experiment.

The method used to recover the virus from larkspurs after symptoms appeared was to feed lots of 20 previously noninfective males on each infected plant for a period of 3 days, then healthy sugar beets were exposed to the leafhoppers until symptoms of the disease developed.

Annual larkspurs infected with curly-top virus were stunted with bunched leaves at the apical end of the stem and on the axillary shoots

TABLE 2

LIST OF ANNUAL LARKSPURS EXPERIMENTALLY INFECTED WITH CELERY CALICO AND WESTERN CUCUMBER MOSAIC AND RECOVERY OF VIRUSES

Type and variety of annual larkspur	Celery calico				Western cucumber mosaic			
	Larkspurs inoculated	Larkspurs infected	Recovery of virus from infected larkspurs		Larkspurs inoculated	Larkspurs infected	Recovery of virus from infected larkspurs	
			Cucumbers inoculated	Cucumbers infected			Cucumbers inoculated	Cucumbers infected
	number	*number*	*number*	*number*	*number*	*number*	*number*	*number*
Giant Imperial Double:								
Blue Bell	3	2	10	2	5	3	25	12
Blue Spire	8	8	40	40	8	6	40	26
Carmine King	13	13	65	65	5	5	25	25
Coral King	3	3	15	3	3	3	15	15
Daintiness	6	6	30	30	5	5	25	25
Mixed	3	1	5	1	3	3	15	12
Exquisite Pink Improved	1	1	5	5	4	4	20	20
Exquisite Rose	7	6	30	30	5	5	25	25
Gloria	4	4	20	17	6	6	30	30
Hyacinth	5	5	25	25	5	5	25	25
La France	3	3	15	15	3	3	15	15
Lilac Spire	3	3	15	12	6	6	30	18
Los Angeles Improved	3	3	15	15	3	2	15	2
Miss California	3	3	15	15	3	3	15	3
White King	3	3	15	12	3	3	15	15
White Spire	3	3	15	15	3	3	15	3
Tall Double Stock-flowered:								
Bright Rose	3	3	15	15	3	3	15	3
Bright Violet	3	2	10	4	3	3	15	15
Dark Blue	3	1	5	1	3	3	15	15
Mixed	6	6	30	30	5	5	25	25
Lilac	5	5	25	25	5	5	25	25
Lilac Supreme	1	1	5	5	5	5	25	25
Lustrous Carmine	3	3	15	15	3	3	15	15
Pink	1	1	5	5	3	3	15	15
Rosamond	5	5	25	25	5	5	25	25
Rosy Scarlet	3	3	15	9	3	3	15	15
Sky Blue	1	1	5	5	5	2	25	2
White	3	3	15	15	3	3	15	9
Total	108	101	505	456	116	108	550	460
Percentage	..	*93.5*	..	*90.3*	..	*93.1*	..	*83.6*

arising from the nodes and with the lower and intermediate leaves downwardly curled (plate 2, *C*).

The incubation period of the disease varied from 22 to 33 days.

TOMATO SPOTTED WILT

Annual larkspurs frequently have been observed with black leaves under natural conditions indicating an infection of tomato spotted wilt. No attempt has been made to recover the virus from such plants nor to infect healthy plants experimentally.

WESTERN CUCUMBER MOSAIC

Annual larkspurs have not been found to be infected with western cucumber mosaic in the central-coastal regions of California, but no plants have been tested from the Sacramento and San Joaquin valleys, where the virus is known to occur.

A list of varieties of larkspurs experimentally infected by mechanical inoculation (*1*) is shown in table 2. A total of 116 annual larkspurs were inoculated, and 108, or 93.1 per cent, became infected, as shown in table 2. The virus was recovered from infected plants and transferred to White Spine cucumbers (table 2).

It is often difficult to detect visible symptoms of the disease on the linear segments of the leaves, but under the binocular microscope a mottling appears, consisting of elliptical, circular, or irregular chlorotic areas which coalesce later and form elongated streaks. The multifid segments of the leaves are sometimes malformed (plate 2, *B*). When larkspurs are severely affected by the disease, the plants are stunted and the leaves are bunched around the stem (plate 2, *A*). A cluster of abnormal, dwarfed flowers develops on the apical end of the stem of stunted plants but no breaking in color occurs.

SUMMARY

Annual larkspurs have been demonstrated to be naturally infected with California aster yellows, celery calico, and curly top. They have been experimentally infected with western cucumber mosaic.

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PLATES

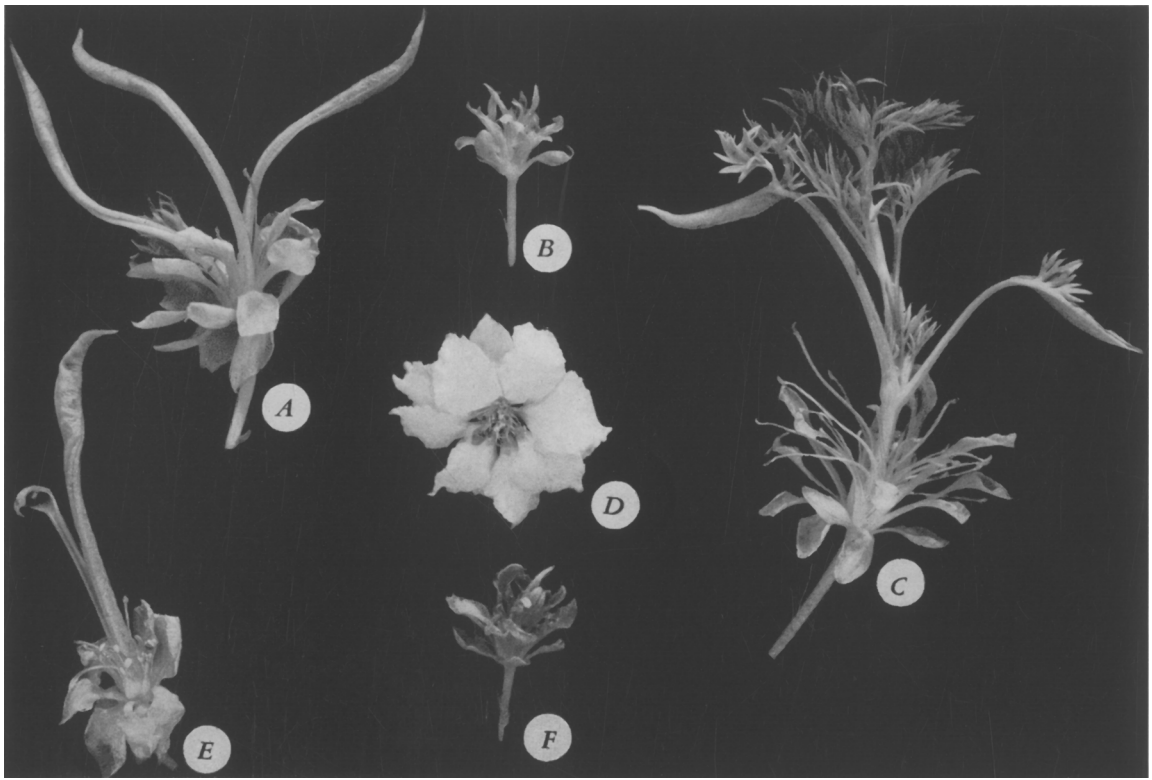

Plate 1.—Center, *D*, flower from healthy annual larkspur, others from plants infected with California aster yellows, showing phyllody and virescence; *A*, *E*, carpels leaflike, stamens apparently normal; *B*, *F*, sepals, petals, carpels, and stamens replaced by green leafy structures; *C*, carpels replaced by stems bearing variously modified appendages resembling leaves.

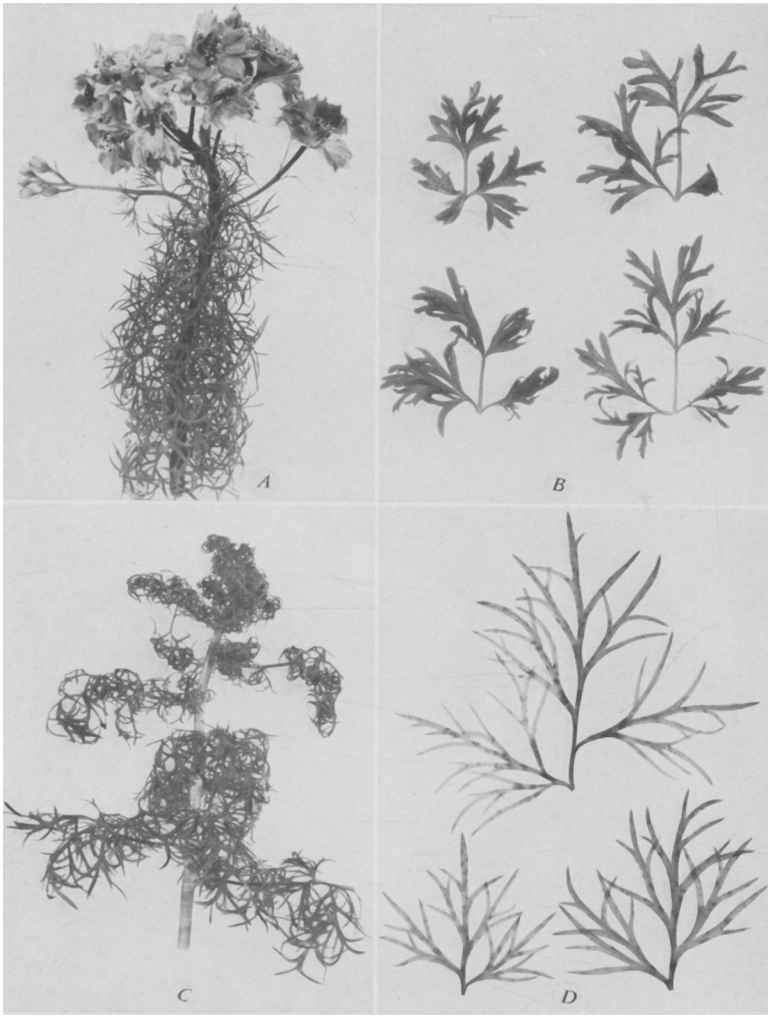

Plate 2.—*A*, *B*, Annual larkspur experimentally infected with western cucumber mosaic: *A*, entire plant stunted, with leaves bunched around the stem; *B*, malformed leaves. *C*, Annual larkspur experimentally infected with curly top showing dwarfing of entire plant with bunched leaves at the apical end of the stem and on the axillary shoots arising from the nodes, and with lower and intermediate leaves downwardly curled. *D*, Leaves from annual larkspur experimentally infected with celery calico showing green areas embedded in the yellow portions of the blades.