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CONTENTS

THE SUSCEPTIBILITY OF PERENNIAL DELPHINIUMS TO SIX VIRUSES

HENRY H. P. SEVERIN

LEAF VARIEGATIONS OF PERENNIAL DELPHINIUMS

HENRY H. P. SEVERIN

VIROSES OF ANNUAL LARKSPURS

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THE SUSCEPTIBILITY OF PERENNIAL DELPHINIUMS TO SIX VIRUSES¹

HENRY H. P. SEVERIN²

PERENNIAL DELPHINIUMS (hybrid and horticultural varieties of several species of *Delphinium*) have been found to be naturally infected with several virus diseases. Three such diseases—California aster yellows, celery calico, and delphinium ringspot—have been reported in previous papers (5, 6, 7).³ A fourth—tomato spotted wilt—is reported in this paper. Also, included herein are the results of experimental infection of delphiniums with five other viruses—common cucumber mosaic,⁴ western cucumber mosaic, tobacco ringspot, ordinary tobacco mosaic, and curly top. None of these five has been found on delphinium in California under natural conditions up to the present time, but the first has been reported by other investigators to occur naturally on this host plant in England.

TOMATO SPOTTED WILT

Spotted wilt on perennial delphinium has been reported in California by Gardner, Tompkins, and Whipple (2). Smith (8, 9) reported that considerable damage may be caused to delphinium by the spotted-wilt virus in England and he described the symptoms of the disease as follows: black rings, or numerous double concentric rings, or patches of dead tissue appear on the older leaves. The younger leaves are malformed with edges yellow, necrotic, and inwardly curled. Necrotic patches may develop on the stems and older leaves.

Spotted wilt ranks next to aster yellows (6) in seriousness as a disease of delphinium in the coastal regions of California. Entire fields of delphiniums have been observed to be infected with spotted wilt near San Leandro, San Bruno, and Berkeley.

¹ Received for publication June 24, 1941.

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

⁴ Common-cucumber-mosaic, tobacco-ringspot, and ordinary-tobacco-mosaic viruses were kindly sent to me by James Johnson, University of Wisconsin.

Numerous efforts have been made to infect experimentally by mechanical inoculation (4) varieties of delphinium seedlings and two-year-old delphiniums with the spotted-wilt virus; but all attempts using naturally infected tomatoes, garden nasturtium (*Tropaeolum majus*), and bull mallow (*Malva nicæensis*) as a source of virus were failures. On the other hand, when the virus extract from calla (*Zantedeschia æthiopica*) was inoculated in delphiniums, infections were occasionally obtained.

The early symptoms of spotted wilt on delphinium are variable and are often difficult to distinguish from delphinium calico, but the late symptoms of the disease are constant and reliable. The first symptom that appears on the leaves of experimentally infected delphiniums is pale green, circular, elliptical, or irregular areas (plate 1, *A*), which later may become surrounded by chlorotic rings (plate 1, *B*). Some leaves may show numerous, double, concentric rings of various sizes, each composed of an outer green and inner chlorotic ring (plate 1, *C*) or a chlorotic ring (plate 1, *D*) surrounding a green center. Sometimes both rings are so small that the inner ring encloses a pinpoint green center. Large lemon-yellow blotches with or without rings sometimes extend into the lobes of the leaves or pale-green areas are embedded in the yellow tissue. Sometimes within the yellow areas, green or chlorotic banding of the veins occurs (plate 1, *E*). The margin of the leaves may be lemon yellow, and often irregular, chlorotic areas extend toward the base of the lobes (plate 1, *F*).

In the later stages of the disease, black rings of various sizes, often irregular in shape, surround chlorotic tissue (plate 2, *A*) which later becomes black on the lower leaves (plate 2, *B*). Black patches often spread over most of the lobes of the leaves (plate 2, *C, D*), and the petioles and veins may become necrotic (plate 2, *E*). The lower leaves turn brown and become dry (plate 2, *F*) with the blackened areas still conspicuous. As the disease progresses, the intermediate and upper leaves develop the ring, the chlorotic, and later the black pattern. The flowers on infected plants were normal.

During the early spring the ring, the chlorotic, and the black patterns appeared on the lower leaves of the new shoots after attaining a height of from 1 to 2 feet and progressively on the intermediate and upper leaves. After the old stock was cut off, the successive symptoms of the disease again appeared on the new shoots during the summer. No symptoms appeared on the leaves of marked infected delphiniums during the past mild winter (1941-42). These observations were made on two- and three-year-old Pacific-strain delphiniums grown in my home garden during 1939 to 1941.

Numerous attempts have been made to recover the spotted-wilt virus from naturally infected delphiniums and transfer it by mechanical inoculation to healthy delphiniums, Marglobe tomatoes, *Nicotiana glutinosa*, Turkish tobacco, Jimsonweed (*Datura Stramonium*) and asters, without results. If the onion thrips (*Thrips tabaci* Lindeman) or *Frankliniella occidentalis* (Perg.) had been used as vectors of the virus, instead of mechanical inoculation, the virus might have been recovered from naturally infected delphiniums.

Celery calico (5) was sometimes recovered from delphiniums infected with spotted wilt.

COMMON CUCUMBER MOSAIC

On Delphiniums.—According to Smith (8, 9), delphinium is very susceptible to and frequently infected with cucumber-mosaic virus in England; he describes the symptoms as follows: "Affected plants present a yellowish (chlorotic) appearance and there are pale areas on the leaves following the veins. A rather faint green mosaic mottle is usually present. As a rule diseased plants are stunted in comparison with healthy plants and the flowers are poor and few in number."

In perennial delphiniums grown from seeds and experimentally infected with common cucumber mosaic by mechanical inoculation (4), a considerable amount of variation occurred in the development of symptoms of the disease in different varieties and hybrids, and even in different plants of the same variety or hybrid. The first symptom which frequently appeared on some of the younger leaves was circular, chlorotic areas (plate 3, *A*), sometimes distributed along the veins (plate 4, *A*), which coalesced and formed pale-yellow vein banding (plate 4, *B*), and later chlorosis sometimes spread in all of the lobes of the leaf (plate 4, *C*, *D*). A common symptom on some of the lower leaves was green spotting in the chlorotic areas in one or more lobes of a leaf (plate 3, *C*). Green vein banding occurred on some leaves of an infected plant (plate 3, *E*). Sometimes a faint mottling or mosaic pattern (plate 4, *E*) appeared on one or more leaves of a plant. The symptoms described were infrequently accompanied with crinkling, puckering, and distortion (plate 4, *F*). Green blisterlike elevations, which are a common symptom of cucumber mosaic on many host plants, were rare on the leaves of infected delphiniums (plate 4, *F*). The prevailing discoloration, if it occurred, was lemon yellow; but in some delphinium varieties or hybrids, the margin of the leaf was orange, fading to pale yellow within the lobes. All delphiniums observed were kept until the blossoming period; but, without exception, the flowers were normal.

TABLE 1
LIST OF DELPHINIUM VARIETIES AND HYBRID SEEDLINGS EXPERIMENTALLY INFECTED
WITH COMMON CUCUMBER MOSAIC, INCUBATION PERIOD OF
DISEASE, AND RECOVERY OF VIRUS

Delphinium variety or hybrid and date inoculated (1939-40)	Delphiniums inoculated	Delphiniums infected	Incubation period of disease in plants		Recovery of virus from infected delphiniums	
			Range	Mean	Cucumbers inoculated	Cucumbers infected
	number	number	days	days	number	number
Blackmore and Langdon hybrids:						
October 31.....	5	2	28-55	41.5	10	0
Belladonna tall hybrids:						
July 9.....	5	1	7	....	5	0
August 14.....	5	3	43-57	47.7	15	15
Chinese Azure Blue:						
August 31.....	5	1	40	....	5	0
Clivenden Beauty:						
July 8.....	5	2	6-22	11.0	10	0
September 17.....	5	2	54-54	54.0	10	10
<i>Delphinium Parryi</i> var. <i>maritimum</i> :						
November 15.....	2	1	—*	—*	5	1
Dreer's De Luxe Art shades:						
July 9.....	5	1	9	....	5	1
Dreer's De Luxe Dark-Blue shades:						
July 9.....	5	1	8	....	5	2
September 17.....	2	2	45-54	49.5	10	10
Dreer's De Luxe Light-Blue shades:						
July 9.....	1	1	—*	—*	5	5
August 31.....	4	3	25-26	25.7	15	0
English hybrids Deep-Blue shades:						
July 9.....	5	1	22	....	5	5
Burpee's Floradale Giants Deep Blue:						
July 9.....	1	1	—*	—*	5	4
August 31.....	5	1	40	....	5	0
Burpee's Floradale Giants Light Blue:						
July 9.....	1	1	—*	—*	5	5
Burpee's Floradale Giants Mid Blue:						
July 9.....	3	2	22-24	....	10	5
August 31.....	2	2	38-38	38.0	10	10
September 17.....	1	1	34	....	5	5
A. & M. Gold Medal hybrid:						
July 8.....	4	2	7-10	8.5	10	10
Gold Medal hybrids:						
September 17.....	1	1	55	....	5	5
Hardy larkspur (<i>Delphinium formosum</i>):						
September 17.....	5	2	27-53	45.0	10	10
Iceberg:						
August 31.....	5	2	25-26	25.5	10	4
September 17.....	1	1	24	....	5	5
Lemon Gem:						
July 9.....	3	3	—*	—*	15	15
Burpee's Mammoth hybrids:						
July 9.....	5	2	6-7	6.5	10	0
Pacific Giant mixed:						
July 9.....	5	2	6-20	13.0	10	0
September 17.....	1	1	38	....	5	5
Pacific Giant White:						
July 8.....	5	5	—*	—*	25	25
A. & M. Sunbeam hybrids:						
July 9.....	4	4	5-24	11.2	20	12
Total.....	106	54	....	....	270	169
Percentage.....	....	50.9	....	....	....	62.9

* No symptoms, but virus recovered from infected delphiniums.

The type of infection was systemic. The symptoms sometimes appeared on the inoculated leaves of delphinium seedlings, or on a few of the intermediate or upper leaves not inoculated. The virus was recovered and transferred to White Spine cucumber plants, from the inoculated leaves, and also from the intermediate and upper leaves not inoculated.

The delphinium varieties experimentally infected with the virus are listed in table 1. Of a total of 106 delphinium seedlings inoculated, 54, or 50.9 per cent, were infected. The virus was recovered from 39 of 54 infected delphiniums, or 72.2 per cent; the infected plants included 12 symptomless carriers.

On Cucumbers.—The first symptom of common cucumber mosaic on the cotyledons of White Spine cucumber seedlings is chlorotic rings, each enclosing a green area. Sometimes an outer chlorotic ring and an inner green ring surround a chlorotic area. Later the green area becomes chlorotic and a pinpoint necrotic center appears. Cleared veinlets develop on the first leaf when small (plate 5, *A*), later numerous rings appear similar to those on the cotyledons but much smaller. The blade is often cupped inward along the midrib, or the margin is rolled outward and the petiole bent downward (plate 5, *B*). The second leaf is sometimes balled (plate 5, *B*). Blisterlike elevations develop on some of the younger leaves. In a later stage, chlorosis begins at the margin of the first leaf and sometimes progresses until the entire blade becomes yellow. The older leaves are mottled with yellow or orange and green areas. Necrotic streaks which crack later appear on the stem and on some of the petioles, and finally the stem may collapse and the plant die.

WESTERN CUCUMBER MOSAIC

The present known distribution of western cucumber mosaic is in the interior regions of California; the disease is common in the Sacramento and San Joaquin valleys, but no infected host plants have been found in the coastal regions of the San Francisco Bay district, Santa Clara Valley, or in the fog belt of the Salinas Valley. The host range, property studies, and vectors of this virus are the subjects of a separate study.

Since western-cucumber-mosaic virus produces fern leaf, filiform leaf, or shoestring leaf on tomato and other host plants, an examination was made of a large number of delphiniums in the central-coastal district that had such malformed leaves (fig. 1) and dwarfed and frequently brown and dried flowers (fig. 2, *A*, *B*). All attempts to recover from these delphiniums a virus producing such symptoms on tomato and other host plants were failures. California-aster-yellows and celery-calico viruses were recovered from delphiniums with malformed leaves and

abnormal flowers, but these viruses do not produce such symptoms on delphinium. No intensive investigation of western cucumber mosaic on delphinium in the interior regions of California has been made.

In perennial delphiniums grown from seeds experimentally infected with western cucumber mosaic by mechanical inoculation (4), the symp-

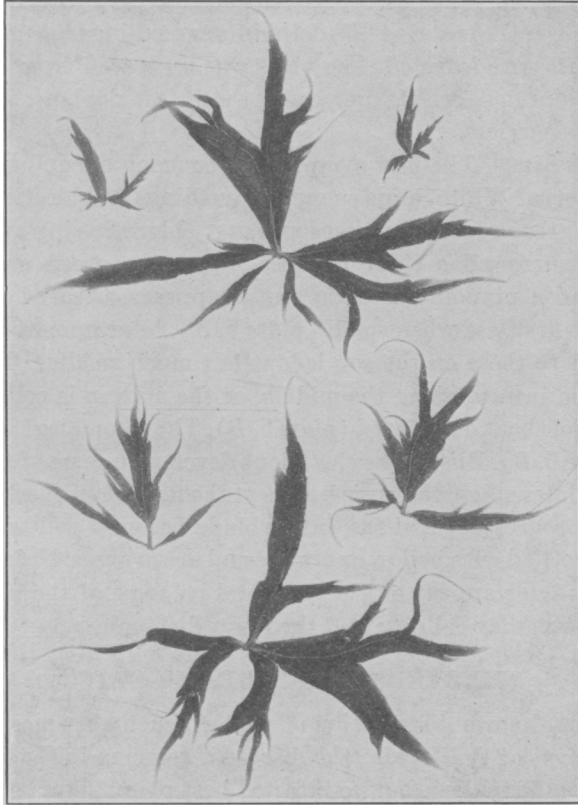


Fig. 1.—Malformed leaves resembling fern leaf, filiform leaf, or shoestring leaf (cause unknown) on Dreer's De Luxe delphinium. The virus of celery calico was recovered from this plant and transferred to cucumbers and Turkish tobacco, but this virus does not produce the symptom. (Mt. Eden, December 22, 1938.)

toms on the leaves are somewhat milder than those of common cucumber mosaic. They are usually not conspicuous and may be limited to one or more inoculated leaves or to a few of the intermediate or upper leaves not inoculated. Some infected delphinium varieties or hybrids show a pale, yellow discoloration of a few leaves. Plate 3 shows a comparison of some of the symptoms caused by common and by western cucumber mosaic:

circular or elongated, chlorotic areas are illustrated in *A, B*; green spotting in chlorotic areas in *C, D*; and green vein banding in *E, F*. The flowers were normal with both viruses.

The type of infection was systemic as determined by the development of symptoms of the disease and recovery of the virus as described for common cucumber mosaic.



Fig. 2.—Spikes of Dreer's De Luxe delphinium showing fern leaf, fliform leaf, or shoestring leaf (cause unknown): *A*, spike showing dwarfed flowers and seed pods; *B*, spike showing brown and dried flowers. (Mt. Eden, December 27, 1938.)

The delphinium varieties and hybrids experimentally infected with the virus are listed in table 2. Of a total of 197 delphiniums inoculated, 127, or 64.0 per cent, were infected. The virus was recovered from 125 of 127 infected delphiniums, or 98.4 per cent; the infected plants included 75 symptomless carriers.

The incubation period of the disease varied from 6 to 55 days, as shown in table 2.

The virus was recovered from experimentally infected delphiniums

TABLE 2
LIST OF DELPHINIUM VARIETIES AND HYBRID SEEDLINGS EXPERIMENTALLY INFECTED
WITH WESTERN CUCUMBER MOSAIC, INCUBATION PERIOD OF
DISEASE, AND RECOVERY OF VIRUS

Delphinium variety or hybrid and date inoculated (1939-40)	Del- phiniums inocu- lated	Del- phiniums infected	Incubation period of disease in plants		Recovery of virus from infected delphiniums	
			Range	Mean	Cucumbers inoculated	Cucumbers infected
	number	number	days	days	number	number
Blackmore and Langdon Giants:						
June 28.....	1	1	15	....	5	0
January 16.....	3	3	—*	—*	15	15
Belladonna tall hybrids:						
June 28.....	5	1	13	....	5	0
Chinese Azure Blue:						
July 8.....	3	3	—*	—*	15	15
Chinese Dark Blue:						
June 25.....	5	1	19	....	5	5
December 20.....	3	3	—*	—*	15	9
October 1.....	1	1	—*	—*	5	5
December 20.....	3	1	—*	—*	5	3
Clivenden Beauty:						
November 20.....	5	5	—*	—*	25	25
A. & M. Clivenden Beauty:						
June 25.....	5	4	11-12	11.5	20	20
<i>Delphinium cardinale</i> :						
June 2.....	3	3	—*	—*	15	9
<i>Delphinium grandiflorum</i> var. <i>album</i> :						
June 25.....	5	3	19-34	24.0	15	15
<i>Delphinium Zazil</i> :						
March 14.....	1	1	—*	—*	5	5
Dreer's De Luxe Art shades:						
June 28.....	5	4	8-17	14.0	20	20
Dreer's De Luxe Dark-Blue shades:						
June 28.....	5	2	14-16	15.0	10	10
November 19.....	4	4	—*	—*	20	20
Dreer's De Luxe Light-Blue shades:						
July 8.....	1	1	—*	—*	5	1
Dreer's De Luxe Mid-Blue shades:						
June 28.....	5	3	8-15	11.0	15	15
November 19.....	5	1	—*	—*	5	5
Dwarf Chinese Blue Butterfly:						
June 28.....	5	2	15-39	27.0	10	10
English Hybrids Deep-Blueshades:						
June 28.....	5	1	14	....	5	4
English Hybrids Light-Blue shades:						
July 8.....	1	1	9	....	5	2
English Hybrids Mid-Blue shades:						
June 25.....	5	3	18-20	19.0	15	15
November 19.....	5	1	—*	—*	5	5
English Hybrids Pastel shades:						
July 8.....	2	2	—*	—*	10	10
August 31.....	5	1	55	....	5	5
Burpee's Floradale Giants Deep Blue:						
July 8.....	1	1	—*	—*	5	5
<i>Carried forward</i>	97	57	....	....	285	253

* No symptoms, but virus recovered from infected delphiniums.

TABLE 2—*Concluded*

Delphinium variety or hybrid and date inoculated (1939-40)	Delphiniums inoculated	Delphiniums infected	Incubation period of disease in plants		Recovery of virus from infected delphiniums	
			Range	Mean	Cucumbers inoculated	Cucumbers infected
	number	number	days	days	number	number
<i>Brought forward</i>	97	57	....	....	285	253
Burpee's Floradale Giants Light Blue:						
July 8.....	2	2	—*	—*	10	2
August 31.....	1	1	35	....	5	5
Burpee's Floradale Giants Mid Blue:						
August 31.....	5	3	35-35	35.0	15	15
Giant Single and Double hybrids:						
July 8.....	4	4	—*	—*	20	8
A. & M. Gold Medal hybrids:						
June 25.....	5	2	15-19	17.0	10	10
Gold Medal hybrids:						
July 8.....	3	3	—*	—*	15	15
Hardy larkspur (<i>Delphinium formosum</i>):						
June 25.....	5	4	11-11	11.0	20	20
October 1.....	5	5	—*	—*	25	25
Hybrida mixed:						
June 25.....	5	4	11-22	16.2	20	20
November 20.....	5	4	—*	—*	20	20
Iceberg:						
June 28.....	5	1	9	....	5	5
August 31.....	5	3	35-35	35.0	15	15
Improved Belladonna:						
November 19.....	5	5	—*	—*	25	16
Improved English hybrids mixed:						
July 8.....	1	1	—*	—*	5	5
Lady Guinevere:						
November 20.....	5	5	—*	—*	25	25
Lemon Gem:						
November 20.....	5	5	—*	—*	25	25
Burpee's Mammoth hybrids:						
July 8.....	4	1	6	....	5	5
July 8.....	2	2	—*	—*	10	10
October 1.....	1	1	—*	—*	5	5
New Hollyhock strain:						
November 20.....	5	5	—*	—*	25	25
Pacific Giant mixed:						
June 28.....	5	3	15-17	12.3	15	9
Pacific Giant White:						
June 25.....	5	2	15-18	16.5	10	10
A. & M. Sunbeam hybrids:						
July 8.....	5	1	7	....	5	5
July 8.....	2	2	—*	—*	10	8
Wrexham Hollyhock strain:						
October 1.....	5	1	—*	—*	5	5
Total.....	197	127	....	....	665	550
Percentage.....	....	64.0	....	....	...	82.7

* No symptoms, but virus recovered from infected delphiniums.

and transferred to White Spine cucumber by mechanical inoculation. The first symptom of western cucumber mosaic on the cotyledons of cucumber seedlings is chlorotic rings, each surrounding a green area, which later becomes necrotic. The first leaf is often cupped inward along the midrib and with the margin rolled inward, but later the blade may expand normally. Numerous, small, circular, chlorotic areas appear on the first leaf (plate 5, *C*) and these coalesce later (plate 5, *D*). Necrosis of the circular, chlorotic areas may occur about 1 month after inoculation. Some of the younger leaves may show blisterlike elevations. The older leaves are sometimes malformed and become mottled with yellow and green areas. No necrosis of the stem and petioles occurs, western cucumber mosaic differing in this respect from ordinary cucumber mosaic.

TOBACCO RINGSPOT

Wingard (10) experimentally infected 62 species of plants belonging to 38 genera in 17 families with tobacco-ringspot virus but made no attempt to infect any species of the family Ranunculaceae, to which delphinium belongs.

Twenty-five perennial delphinium seedlings were mechanically inoculated (4) with tobacco-ringspot virus, and 4 plants developed symptoms of the disease. Five Pacific-strain two-year-old delphiniums were inoculated and reinoculated with the virus but failed to show symptoms.

The ringspots were composed of alternating, concentric, chlorotic and green rings surrounding green or chlorotic tissue in the center (plate 6, *A*). The ringspots varied considerably in number and size on the leaves (plate 6, *B*).

The type of infection was systemic. On delphinium seedlings, ringspots appeared on the newly developing basal leaves that were not inoculated and on the lower leaves of the stalk but appeared only faintly on the intermediate leaves and finally failed to appear on the upper or younger leaves.

The virus was recovered from delphinium leaves showing ringspots and from the upper leaves not showing symptoms when the expressed juice was inoculated in White Spine cucumbers. The first symptom of tobacco ringspot on the cotyledons of cucumber seedlings is numerous, pale, chlorotic rings, each enclosing a green area. The green area gradually becomes smaller, the chlorotic ring widens, until the entire circular area becomes chlorotic. A pinpoint necrotic center appears in the chlorotic area and later enlarges until the entire circular area becomes necrotic.

The sequence of symptoms on the first leaf is somewhat similar to

that on the cotyledons. The chlorotic rings surrounding green areas are smaller and more numerous (plate 5, *E*) than on the cotyledons. Frequently the chlorotic areas are bounded by cleared veinlets (plate 5, *E*). In the later stage a chlorotic ring surrounds necrotic tissue (plate 5, *F*), which sometimes drops out, leaving a hole.

The second leaf is usually cupped inward along the midrib, with rolled margin, and the blade becomes puckered with circular chlorotic areas.

ORDINARY TOBACCO MOSAIC

Grant (3) infected an annual larkspur (*Delphinium Consolida*) with the tobacco-mosaic virus; the symptom expression was stunting of the plants, mottling, yellowing, and necrosis. The type of infection was systemic.

Blackmore and Langdon and Pacific-strain perennial delphiniums experimentally infected with tobacco mosaic by mechanical inoculation (4) frequently showed brown necrotic streaks along the veins of the inoculated leaves (plate 6, *C*) and large intervenal necrotic areas (plate 6, *D*), followed by yellowing and drying of the leaves.

The type of infection was local and not systemic. In twenty-five delphinium seedlings inoculated with the tobacco-mosaic virus, symptoms of the disease developed only on the inoculated leaves. The virus was recovered and transferred to *Nicotiana glutinosa* from the inoculated leaves but not from the newly developing leaves. In another experiment two-year-old Pacific-strain delphiniums were inoculated with the ordinary-tobacco-mosaic virus, a few of the upper or youngest, the intermediate, and the lowest or basal leaves being inoculated on each plant. The inoculated leaves were marked by cutting off the tip of a lobe. The virus was recovered 17 days after inoculation only from the inoculated leaves. The flowers were normal.

The virus was recovered from infected leaves of delphiniums and transferred to *Nicotiana glutinosa*, which developed local lesions (plate 6, *E*); these coalesced to form necrotic areas (plate 6, *F*), and later the inoculated leaves became dry.

CURLY TOP

Orange larkspur (*Delphinium nudicaule*), a native perennial delphinium occurring in California and Oregon, has been experimentally infected with curly top, and the virus was recovered and transferred to healthy sugar beets by previously noninfective beet leafhoppers with the method described by Freitag and Severin (1). Orange larkspur infected

with curly top failed to develop symptoms of the disease under greenhouse conditions.

During the past ten years, inquiries have been received from scientists, seed companies, nurserymen, and growers of delphinium in home gardens, as to whether the virus of curly top transmitted by the beet leafhopper, *Eutettix tenellus* (Baker) causes phyllody and virescence or greening of the flowers in delphinium. An attempt was made to infect one variety of delphinium with the virus of curly top by means of infective male beet leafhoppers. Five healthy Wrexham delphiniums grown from seeds were each exposed to lots of 20 infective leafhoppers. When one lot of insects died, another lot of 20 males was put in the cage, each plant being inoculated with from 2 to 4 lots of leafhoppers. Wrexham delphinium was an unfavorable food plant for the beet leafhopper; the males lived from 4 to 8 days on the seedlings. The five delphiniums were kept under observation for a period of 7 months, but no symptoms developed; and repeated efforts to recover the curly-top virus were failures. It is evident that Wrexham delphinium is immune to the virus of curly top.

During the following spring, five Wrexham delphiniums used as check or control plants were inoculated with the aster-yellows virus by the geminate leafhopper and typical symptoms of this disease developed.

SUMMARY

Perennial delphinium has been proved to be infected with tomato spotted wilt in nature. This disease ranks next to aster yellows as a serious disease in the central-coastal regions of California. Delphinium has been demonstrated to be naturally infected with a virus complex including spotted wilt and celery calico.

Varieties and hybrid delphiniums have been experimentally infected with common cucumber mosaic and western cucumber mosaic. The type of infection was systemic.

Delphiniums were experimentally infected with tobacco ringspot and ordinary tobacco mosaic. The type of infection was systemic with tobacco ringspot and local with ordinary tobacco mosaic.

Orange larkspur (*Delphinium nudicaule*), a native perennial delphinium, has been reported in a previous paper (1) to be a symptomless carrier of curly top. Wrexham delphinium was immune to the virus of curly top.

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PLATES

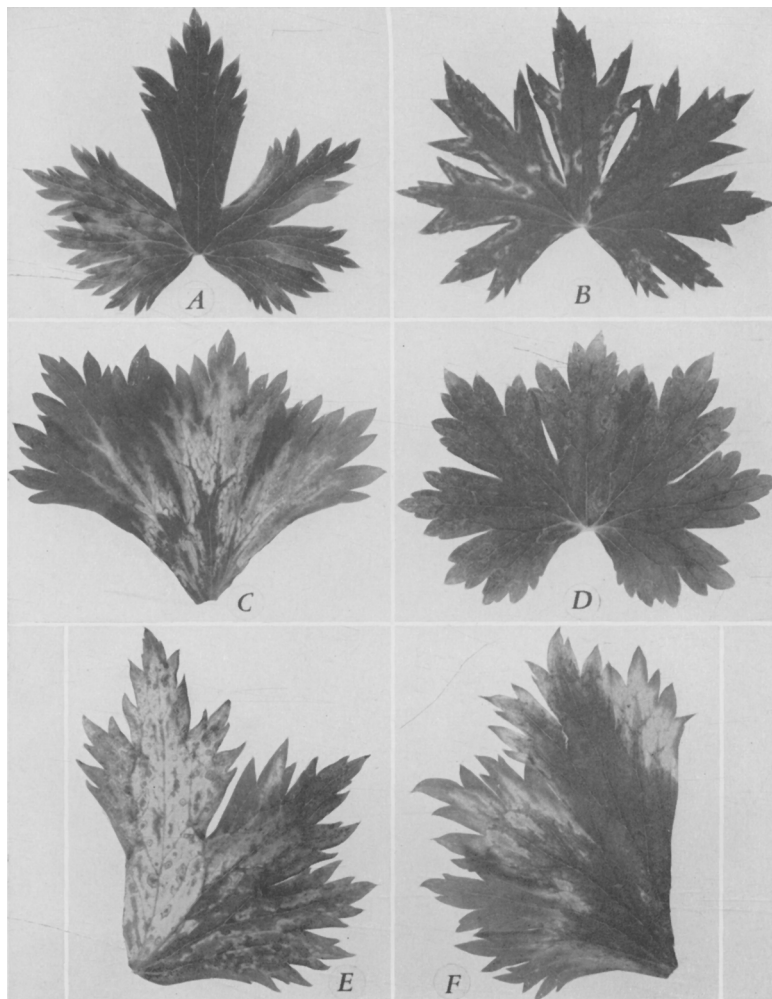


Plate 1.—Early stages of spotted wilt on leaves of delphiniums: *A*, pale-green areas, the first symptom of the disease; *B*, chlorotic rings surrounding green areas and broken, yellow bands along the margin; *C*, green or chlorotic banding of the veins and veinlets; *D*, *E*, double concentric rings of various sizes, each composed of an outer green and inner chlorotic ring, or a chlorotic ring encircling a green center; *F*, lemon-yellow discolorations along the margin and irregular, chlorotic areas.

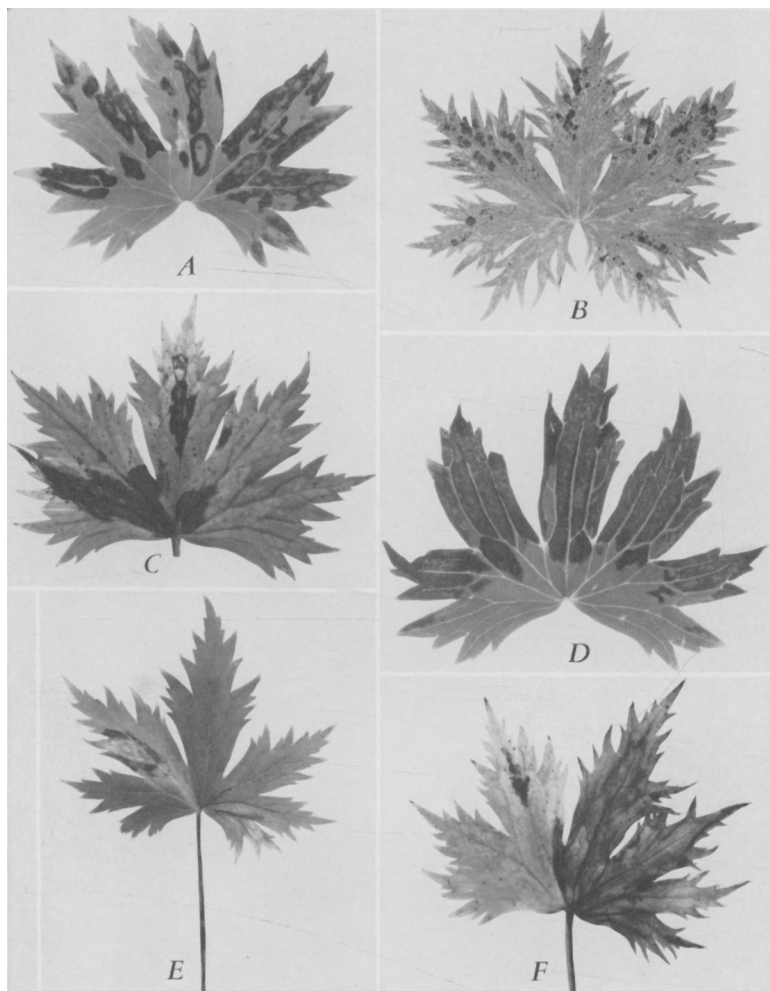


Plate 2.—Late stages of spotted wilt on leaves of delphinium: *A*, black, irregular areas bounding chlorotic tissue; *B*, small pinpoint and large circular or irregular areas which frequently coalesce; *C*, *D*, black areas spreading in lobes; *E*, black region surrounding a ring that encloses a chlorotic center, and necrosis of veins and petioles; *F*, left lobes turning brown and becoming dry, and black areas on other lobes.

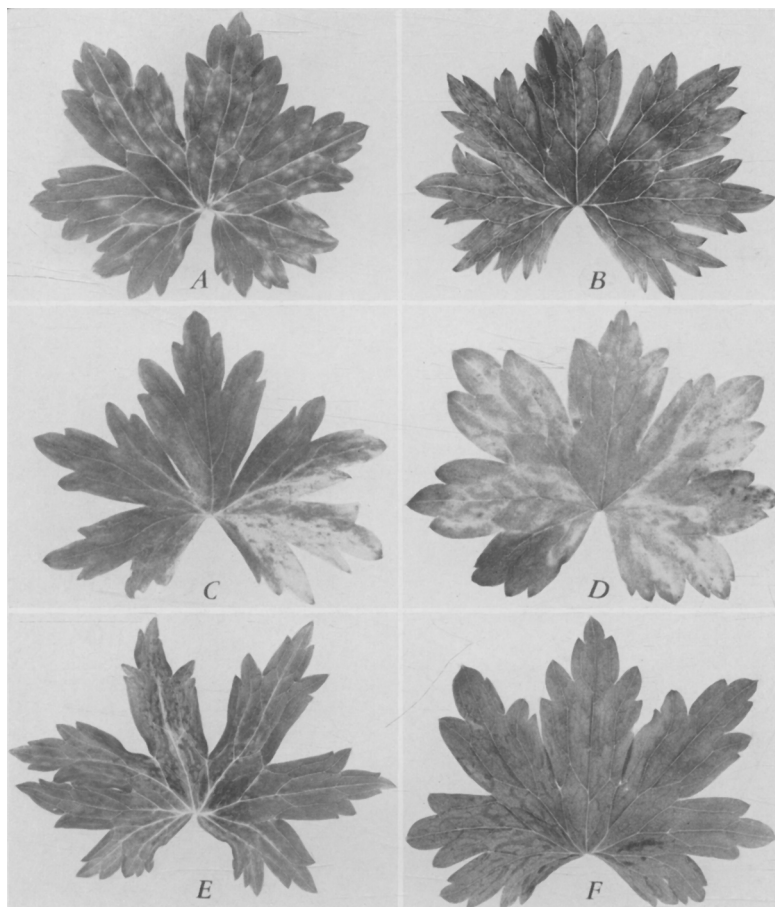


Plate 3.—Comparison of symptoms on the leaves of delphiniums infected with common cucumber mosaic (*A, C, E*) and with western cucumber mosaic (*B, D, F*): *A, B*, circular or elongated, chlorotic areas; *C, D*, green spotting in chlorotic areas; *E, F*, green vein banding.

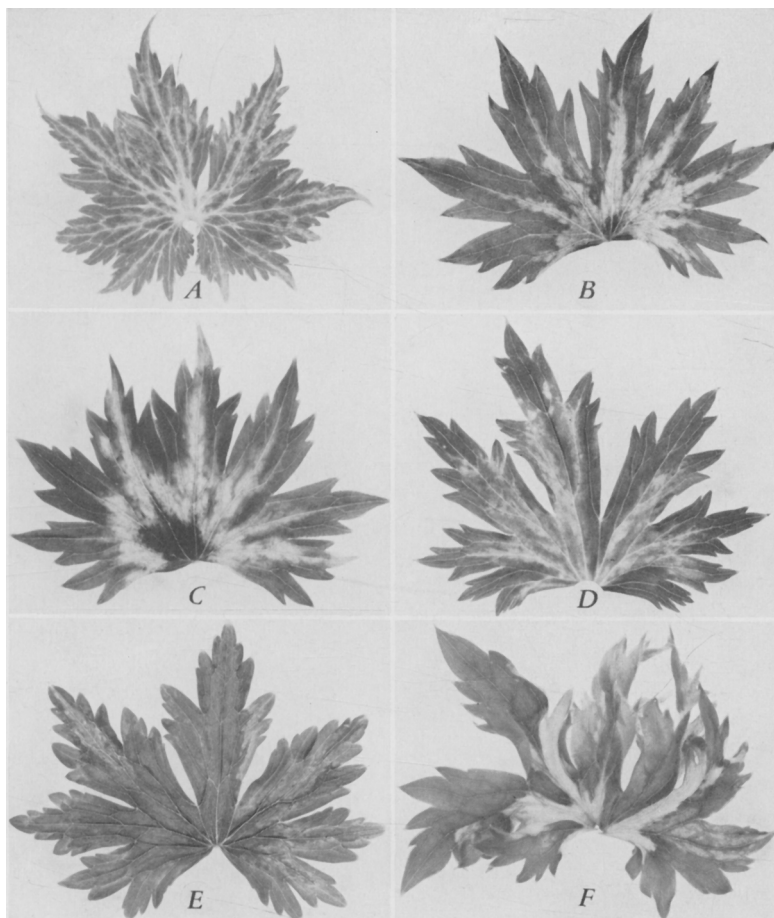


Plate 4.—Common-cucumber-mosaic symptoms on leaves of delphiniums: *A*, circular chlorotic areas distributed along the veins; *B*, pale-yellow vein banding; *C*, *D*, chlorosis spreading in all lobes; *E*, faint mottling or mosaic pattern; *F*, distortion, chlorosis, and blisterlike elevations.

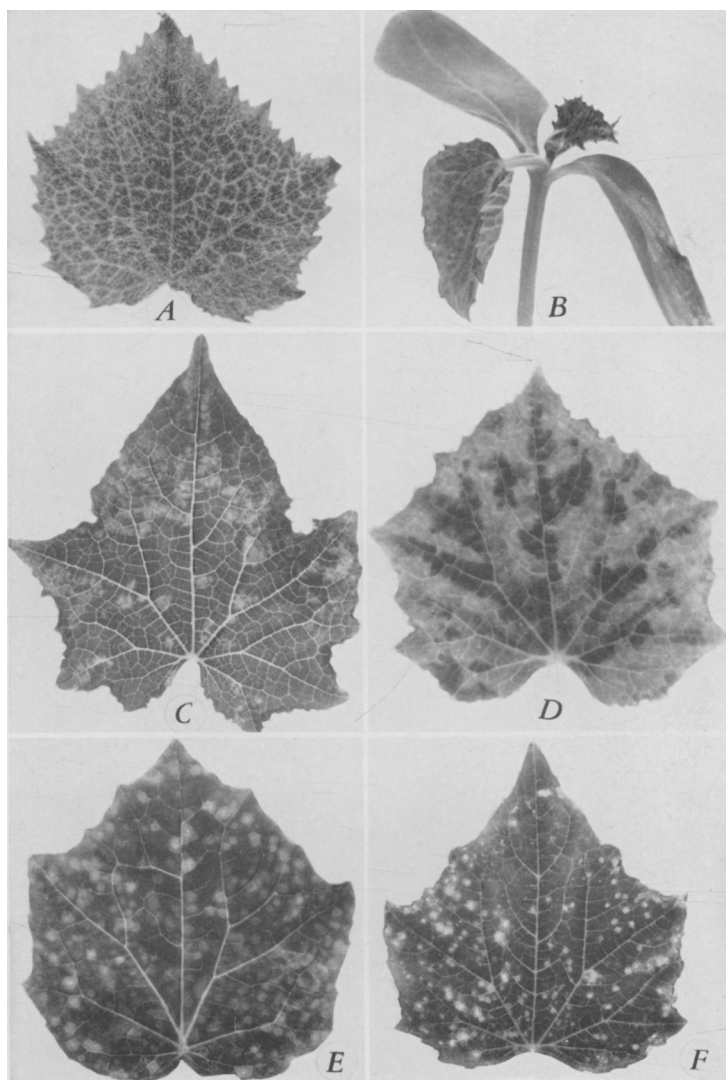


Plate 5.—Symptoms on leaves of White Spine cucumber (*Cucumis sativus*) produced by three viruses recovered from infected delphiniums: A, B, from seedlings infected with common cucumber mosaic, A showing cleared veinlets, and B, drooping of petiole and rolled margin of the first leaf and the balled second leaf; C, D, from plants infected with western cucumber mosaic, C showing small, circular, chlorotic areas on the first leaf, and D, chlorotic and green tissue forming a mottling; E, F, from plants infected with tobacco ringspot, E showing numerous, small, chlorotic areas, some bounded by cleared veinlets, and F, chlorotic rings with necrotic centers.

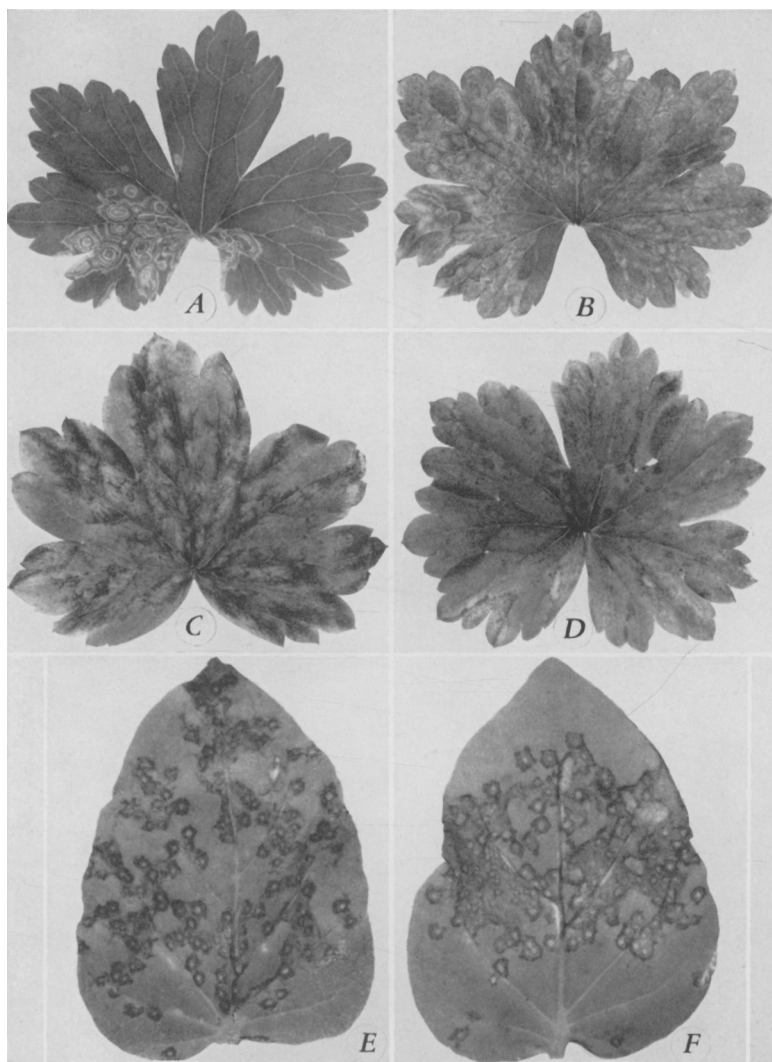


Plate 6.—*A, B*, Tobacco-ringspot symptoms on the leaves of delphinium seedlings: *A*, ringspots 5 weeks after inoculation, consisting of alternating concentric, chlorotic, and green rings surrounding either green or chlorotic tissue in the center; *B*, ringspots 8 weeks after inoculation, showing variation in size. *C, D*, Symptoms of ordinary tobacco mosaic on leaves of delphinium seedlings: *C*, brown necrotic streaks frequently on the veins of the inoculated leaf; *D*, interveinal, necrotic areas. *E, F*, Leaves of *Nicotiana glutinosa*: *E*, local lesions of ordinary-tobacco-mosaic virus which was recovered from infected delphiniums; *F*, local lesions coalescing to form necrotic areas.