

TWO MOSAIC DISEASES OF ANNUAL STOCK¹

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INTRODUCTION

In 1930, a destructive disease of annual stock or gilliflower (*Matthiola incana* R. Br. var. *annua* Voss) was observed by growers in field plantings at Montara, Calif. Of unknown cause and origin, the disease induced a conspicuous variegation or flower breaking in all but the white- and yellow-flowering types which rendered them unmarketable as cut flowers. A study of this disease was undertaken in 1932, and in 1934 a preliminary report was published (9),³ in which the cause of the disease was attributed to virus infection. This disease has since been designated as "mild mosaic." Later, in 1935, a similar but more striking mosaic disease of annual stock was found near San Pablo by H. H. P. Severin, Division of Entomology and Parasitology, who kindly supplied material. To the latter disease the name "severe mosaic" has been given. This paper presents the results of studies on symptomatology, transmission, host range, and properties of the two mosaic viruses involved.

REVIEW OF LITERATURE

Perhaps the first authentic record of the occurrence of flower breaking of annual stock was presented in 1867 by Chaté (1). He mentioned that French growers had observed the disease as early as 1862, and probably earlier. They called it "panache."

Saunders⁴ stated that in her cross-breeding experiments with annual stock, covering a period of 30 years or more, the disease occurred every year, appearing invariably in late summer or in the autumn, and occasionally in very early outdoor plantings. The plants were never attacked by aphids, but thrips were present.

According to Noble et al (5), a mosaic disease of stock (*Matthiola* sp.) was observed in Australia in 1926.

A preliminary note on the occurrence of a mosaic disease of annual stock in California was published in 1934 by Tompkins (9) and constitutes the first report of the disease in the United States.

In a letter to the writer, Noble⁵ stated: "Stock mosaic is common in most plantings and causes complete or partial colour breaking of blooms, apparently in all varieties."

Smith (7, 8) discussed the prevalence in England of a virus disease of annual stock, Brompton stock (*Matthiola incana*), wallflower (*Cheiranthus cheiri* L.), *Arabis* sp., and dames violet (*Hesperis matronalis* L.) which he referred to in one paper (8) as "cabbage mosaic." The

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² The writer is indebted to Profs. Ralph E. Smith and M. W. Gardner for advice and assistance and to Prof. B. A. Madson and W. W. Mackie for greenhouse space and facilities. Valuable assistance in the greenhouse work was rendered by employees of the Federal Works Progress Administration.

³ Italic numbers in parentheses refer to Literature Cited, p. 76.

⁴ Letter dated July 10, 1934, from Dr. E. R. Saunders, Botany School, The Museums, Cambridge, England.

⁵ Letter dated September 11, 1935, from R. J. Noble, Department of Agriculture, Sydney, New South Wales, Australia.

insect vector proved to be the green peach aphid (*Myzus persicae* (Sulzer)). Later Smith⁶ advised the writer that "a virus from stocks, *Matthiola*, produces no local lesions in cabbage but gives rise to a mild mosaic mottling, no necrosis. This virus also produces local lesions on tobacco."

In 1936, Gigante (3) described a mosaic disease of annual stock, first observed at Rome, Italy, in the summer of 1931. Transmission of the disease was obtained by juice inoculations and grafting, but the identity of the insect vector had not been determined.

Chamberlain⁷ found that breaking of annual stock in New Zealand is caused by a turnip mosaic virus. Wallflowers and a number of common cruciferous weeds were also susceptible to infection.

DISTRIBUTION AND ECONOMIC IMPORTANCE OF THE DISEASES

Natural infection of annual stock is of common occurrence in the cool coastal valleys of central California. The two diseases have been found in commercial plantings and home gardens in the San Francisco Bay section, and in the Salinas, Santa Clara, and Santa Maria Valleys.

At Colma and Montara, as well as in other localities on the San Francisco Peninsula, annual stock is grown largely for cut flowers. Because "broken" flowers are unmarketable, heavy losses have at times been sustained by growers. Field infection was especially severe at Montara in 1931 to 1934 inclusive, resulting in more or less of a complete crop failure. The amount of infection varies from season to season and sometimes is of minor consequence; isolated sections, in which no other cultivated or wild crucifers occur, are relatively free from the disease.

The disease occurs in the seed-producing districts of the San Juan and Santa Maria Valleys. It tends to reduce the number and size of the seed pods and is, therefore, of importance to seed growers.

SYMPTOMS OF THE DISEASES

The symptoms produced by the two mosaic viruses on different varieties of annual stock were studied in considerable detail in the field at intervals throughout the year and in the greenhouse on young plants of the variety Fiery Blood Red which were subjected to mechanical inoculation in the four- to six-leaf stage.

MILD MOSAIC

Generally the first symptoms appear on the leaves 2 to 3 weeks after inoculation, as a pronounced, systemic clearing of the veins (fig. 1, A). Of relatively short duration, these symptoms gradually change into a diffuse, somewhat coarse mottle consisting of irregular-shaped, nonraised, light- and dark-green areas (fig. 1, B), in marked contrast to healthy leaves (fig. 1, C). Leaf symptoms have been observed but rarely on naturally infected plants. Occasionally infected plants show marked distortion, curling, and puckering of the leaves, with pronounced shortening of the internodes (fig. 2, A) 3 to 4 weeks after inoculation. On the young flower racemes, breaking of the flowers is first observed when the anthocyanin pigments appear in the petals of the unopened buds. The outer petals and the protruding tips of some petals within the bud show still more conspicuous

⁶ Letter dated January 20, 1937, from Kenneth M. Smith, University of Cambridge, Cambridge, England.

⁷ Letter dated July 2, 1937, from E. E. Chamberlain, Department of Scientific and Industrial Research, Plant Research Bureau, Palmerston North, New Zealand.

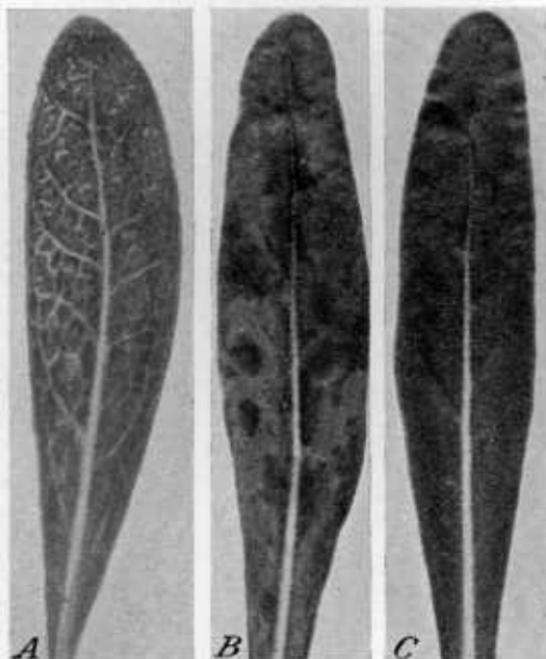


FIGURE 1.—Symptoms produced by the mild mosaic virus of annual stock on young leaves of annual stock, variety Fiery Blood Red, by mechanical inoculation in the greenhouse at 13° to 19° C.: *A*, Vein clearing; *B*, mottling; *C*, noninoculated control.



FIGURE 2.—Symptoms produced occasionally by the mild mosaic virus of annual stock on young annual stock plants, variety Fiery Blood Red, by mechanical inoculation in the greenhouse at 13° to 19° C.: *A*, Infected plant showing distortion of the leaves and shortening of the internodes; *B*, noninoculated control.

symptoms of flower breaking as the buds open. Flower breaking consists of a marked change in, or disarrangement of, the normal pigmentation of self-colored flowers, which results in a variegated effect. The ground color of individual petals from infected plants may be modified to show many white, irregular-shaped islands (fig. 3, *A*) or less frequently circular lesions (fig. 3, *B*), or both. In the greenhouse, all single- or double-flowered racemes on artificially infected plants have consistently shown a fine type of flower breaking (fig. 4, *A*, *B*). In the field, however, sectorial breaking is not uncommon, in which one or several apparently healthy, single- or double-flowered racemes appear on the same plant with racemes showing



FIGURE 3.—Symptoms produced by the mild mosaic virus of annual stock on petals of annual stock plants, variety Fiery Blood Red, by mechanical inoculation in the greenhouse at 13° to 19° C.: *A*, Individual petals from infected flowers showing typical white, irregular-shaped islands; *B*, individual petals from infected flowers showing circular lesions; *C*, a petal from a healthy flower.

flower breaking. Sectorial breaking of individual racemes has never been observed. This disease also causes considerable reduction in the size of seed pods.

SEVERE MOSAIC

The severe mosaic virus causes much more prominent and striking symptoms on annual stock plants than the mild mosaic virus. Leaf symptoms, consisting of a very conspicuous, coarse mottle, are usually visible within 2 to 3 weeks after inoculation and continue unchanged (fig. 5). Flower breaking is also of a coarser type (fig. 6, *A*, *B*). Considered as to symptoms, the mild and severe mosaic diseases may readily be differentiated, although, as will later be shown, they have certain characteristics in common.

MATERIALS AND METHODS

Specimens of the mild mosaic disease of annual stock, variety American Beauty, were collected at Montara, Calif. This variety was known to be highly susceptible to infection throughout the year.

Transfers were made to healthy Fiery Blood Red annual stock seedlings by mechanical inoculation in the greenhouse. Specimens of the severe mosaic disease from San Pablo, contributed by H. H. P. Severin, were similarly treated. The virulence of, and the symptoms produced by, these viruses have remained unaltered through successive monthly transfers during the past 4 years. Fiery Blood Red annual stock seedlings were used as the standard test plant for recovery of the virus from infected plants and for property studies.

All inoculations were made in a greenhouse where temperatures ranged from 13° to 19° C. The methods followed were essentially



FIGURE 4.—Symptoms produced by the mild mosaic virus of annual stock on flowers of annual stock plants, variety Fiery Blood Red, by mechanical inoculation in the greenhouse at 13° to 19° C.: A, Breaking of a double-flowered raceme; B, breaking of a single-flowered raceme; C, noninoculated control showing the normal, self-colored flowers.

those described in recent papers (10, 11, 13). Mechanical inoculations were made by dusting the leaves with 600-mesh, powdered carborundum (6) and rubbing lightly with absorbent cotton dipped in juice from a diseased plant.

TRANSMISSION

The annual stock mosaic viruses were readily transmitted to healthy annual stock seedlings by means of the carborundum method (6) or by rubbing the leaves with cotton dipped in extracted juice from a diseased plant without the abrasive. A higher percentage of infection was obtained, however, when powdered carborundum (600-mesh) was used. The incubation period, considered as the elapsed time between the date of inoculation and the date when the first leaf symptoms appeared, ranged from 16 to 22 days for the mild mosaic, with a general average of about 20 days; and about 14 days on the average for the

severe mosaic. Noble⁸ found that annual stock plants which were inoculated in the bud stage showed symptoms of the disease in about 2 weeks.

H. H. P. Severin, who kindly consented to investigate the problem of insect vectors, found viruliferous specimens of the turnip or false cabbage aphid (*Lipaphis pseudobrassicæ* (Davis)) in field collections. This aphid breeds naturally on diseased annual stock as was subsequently proved by successful infection of healthy plants in the greenhouse. Severin also found that two healthy plants in the

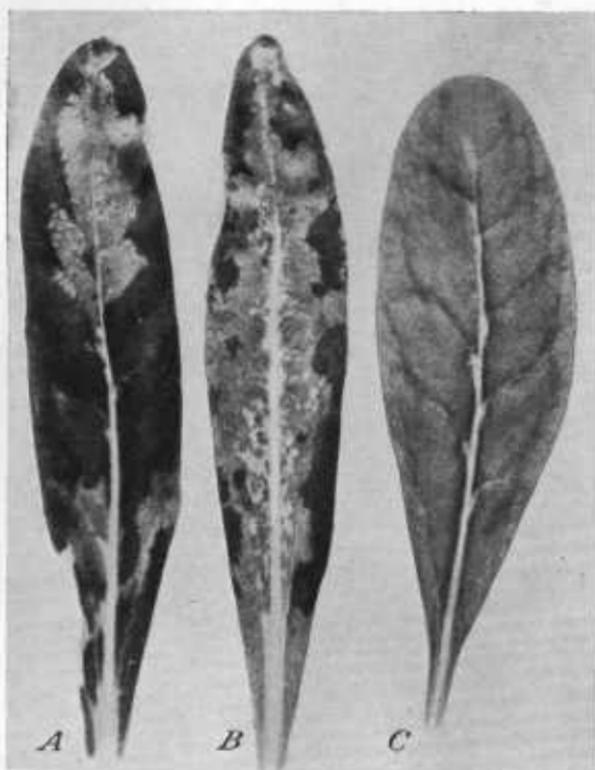


FIGURE 5.—Symptoms produced by the severe mosaic virus of annual stock on young leaves of annual stock, variety Fiery Blood Red, by mechanical inoculation in the greenhouse at 13° to 19° C.: A, B, Coarse mottling; C, noninoculated control.

the cabbage aphid (*Brevicoryne brassicæ* (L.)) and the green peach aphid (*Myzus persicæ* (Sulzer)), which have not been known to breed on annual stock under natural conditions, are capable of acting as vectors. Several lots of seeds were collected from diseased annual stock plants grown out of doors at San Juan Bautista and at the University of California Botanical Garden at Berkeley. These plants became infected under natural conditions with the mild mosaic virus as determined by subsequent inoculations to healthy seedlings in the greenhouse. At San Juan Bautista, seed pods were collected from three lavender and three rose Dwarf Ten Weeks plants; at Berkeley, from eight purple Giant Imperial plants. Seeds were planted in a flat of autoclaved soil in the greenhouse. A total of 1,743 seedlings were counted in the flats planted with seed from San Juan Bautista and 1,815 seedlings from the Berkeley seed. When examined in the six- to eight-leaf stage, all seedlings were healthy, indicating that seed transmission probably does not occur.

HOST RANGE

No extended search has been made for natural hosts of the two mosaic viruses of annual stock. However, one natural host of the mild mosaic virus—honesty (*Lunaria annua* L.)—was found at Montara soon after the disease was originally detected on annual stock.

⁸NOBLE, R. J. See footnote 5.

grown out of doors at San Juan Bautista and at the University of California Botanical Garden at Berkeley. These plants became infected under natural conditions with the mild mosaic virus as determined by subsequent inoculations to healthy

Representative varieties of six commercial types or classes of annual stock were tested for susceptibility to infection by artificial inoculation in the greenhouse. Plants of each variety were inoculated simultaneously with the mild and severe mosaic viruses, and a suitable number of controls was used. Records were taken on both leaf and flower symptoms. Most of the tested varieties were found to be highly susceptible to infection by each virus as indicated by mottled leaves and flower breaking. Although all infected plants had mottled leaves, irrespective of variety, it was observed that the white- and yellow-flowered varieties did not show flower breaking. No flower breaking



FIGURE 6.—Symptoms produced by the severe mosaic virus of annual stock on flowers of annual stock plants, variety Fiery Blood Red, by mechanical inoculation in the greenhouse at 13° to 19° C.: A, Unopened buds showing a coarse breaking of the outer petals; B, coarse breaking of a double-flowered raceme; C, noninoculated control.

was observed on the following varieties: Beauty of Nice (canary yellow),⁹ Giant Imperial (golden ball and white), Perpetual Branching (snowdrift, white, and yellow).

When the varieties Early Giant Imperial (chamois) and Giant Imperial (chamois) were inoculated with each of the viruses, only the severe mosaic virus induced flower breaking.

Under greenhouse conditions, the following varieties were tested with the two viruses and found to be highly susceptible as indicated by leaf and flower symptoms: Beauty of Nice (crimson, lavender, and purple), Dwarf Ten Weeks (crimson, lavender, and purple), Early Giant Imperial (elk's pride, flesh, lavender, and rose), Giant Imperial (antique copper, apple blossom, chamois rose, crimson, flesh, fiery blood red, golden rose, lavender, mauve, purple, rose pink), Giant Perfection (crimson, pale blue, and pink), Perpetual Branching (brilliant blood red, crimson), Empress Augusta Victoria (lavender), Heatham Beauty (rose pink), May Queen (mauve, pansy violet,

⁹ Descriptive color terms in parentheses are those used by seedsmen in their catalogues.

purple, and rose pink), and Harbinger, a cross between annual and Brompton stock.

Symptoms produced experimentally by the mild mosaic virus of annual stock on certain cruciferous and other hosts are given in table 1; some of them are illustrated in figure 7. The mild mosaic virus was recovered from all infected plants except from sowbane, white mustard, and mignonette. No infection was obtained on spinach (*Spinacea*

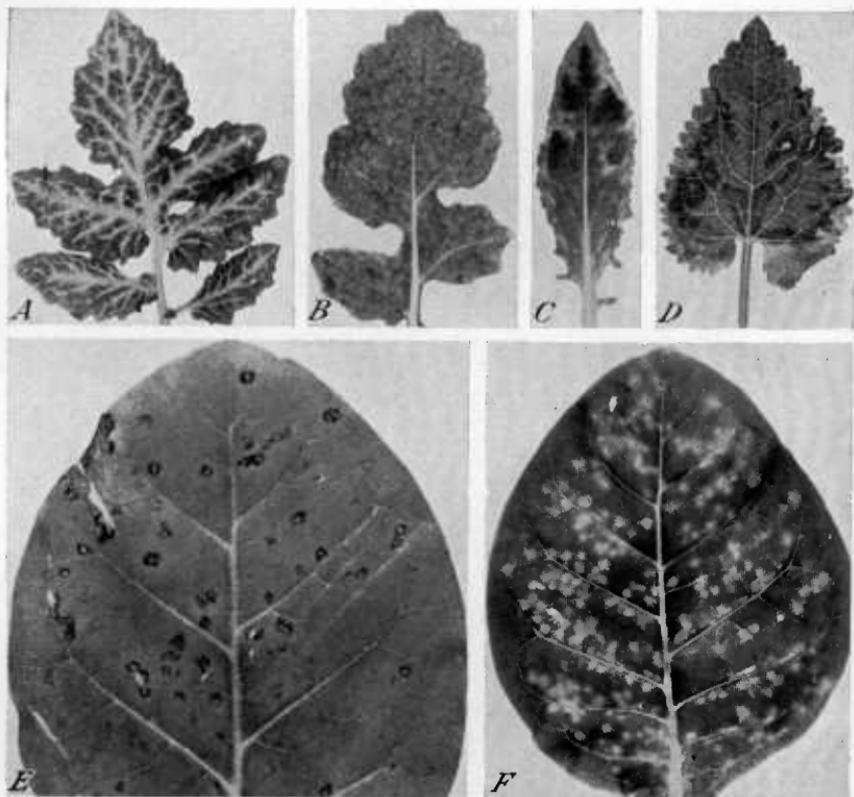


FIGURE 7.—Symptoms produced by the mild mosaic virus of annual stock on leaves of young plants by mechanical inoculation in the greenhouse at 13° to 19° C.: A, Vein clearing on white mustard; B, mottling on turnip; C, mottling on dames violet; D, mottling on honesty; E, local necrotic lesions on Turkish Burley tobacco; F, local necrotic lesions surrounded by chlorotic halos, on White Burley tobacco.

oleracea L.) var. Bloomsdale, lambsquarters (*Chenopodium album* L.), or petunia (*Petunia hybrida* Hort.).

Symptoms produced experimentally on certain cruciferous and other hosts by the severe mosaic virus are also listed in table 1. The severe mosaic virus was recovered from all infected plants except from lambsquarters, spinach, and mignonette. Using the insect vectors reported for this disease, H. H. P. Severin was unable to recover the severe mosaic virus from artificially infected spinach plants. No infection was obtained on Chinese or leaf mustard, pe-tsai, Virginian stock, honesty, sweet alyssum, radish, wallflower, Chinese radish, *Brassica adpressa*, sowbane, *Nicotiana langsdorffii*, or *N. glutinosa*.

TABLE 1.—Plants susceptible to the mild and severe mosaic viruses of annual stock, as indicated by mechanical inoculation of greenhouse-grown seedlings, and symptoms characteristic of infection

Family	Species and common name	Symptoms produced by—	
		Mild mosaic virus	Severe mosaic virus
Cruciferae	<i>Brassica rapa</i> L. (turnip-var. Purple Top White Globe).	Systemic infection. Motting.	Systemic infection. Motting.
	<i>B. juncea</i> Coss. (Chinese or leaf mustard).	do	
	<i>B. pe-tsai</i> Bailey (pe-tsai)	do	
	<i>B. nigra</i> Koch (black mustard).	do	Systemic infection. Vein clearing.
	<i>B. alba</i> (L.) Boiss. (white mustard).	do	Systemic infection. Motting.
	<i>Matthiola bicornis</i> DC. (evening scented stock).	do	Do.
	<i>Malcolmia maritima</i> R. Br. (Virginian stock).	do	
	<i>Lunaria annua</i> L. (honesty).	do	
	<i>Alyssum maritimum</i> Lam. (sweet alyssum).	do	
	<i>Raphanus sativus</i> L. (radish-var. White Icicle).	do	
	<i>Cheiranthus cheiri</i> L. (wallflower).	Systemic infection. Motting, distortion, dark-green raised islands, and necrotic lesions on leaves; shortening of internodes.	
	<i>Hesperis matronalis</i> L. (dames violet).	Systemic infection. Motting and necrotic lesions on older leaves.	Systemic infection. Motting.
	<i>R. sativus</i> var. <i>longipinnatus</i> Bailey (Chinese radish).	Systemic infection. Vein clearing.	
	<i>B. arvensis</i> (L.) Ktze. (charlock).	do	Systemic infection. Vein clearing.
	<i>Capsella bursa-pastoris</i> (L.) Medic. (shepherds-purse).	do	Systemic infection. Motting.
<i>B. adpressa</i> Boiss.	Systemic infection. Chlorotic lesions.		
Chenopodiaceae	<i>Chenopodium murale</i> L. (sowbane or nettle-leaf goosefoot).	Local infection. Chlorotic lesions on inoculated leaves.	
	<i>C. album</i> L. (lambquarters or white pigweed).		Systemic infection. Chlorotic lesions.
	<i>Spinacia oleracea</i> L. (spinach).		Do.
Resedaceae	<i>Reseda odorata</i> L. (mignonette).	Systemic infection. Motting.	Systemic infection. Motting.
	<i>Nicotiana langsdorffii</i> Weinm.	Systemic infection. Motting and chlorotic lesions.	
Solanaceae	<i>N. glutinosa</i> L.	Local infection. Necrotic lesions on inoculated leaves.	
	<i>N. tabacum</i> L. (var. Turkish and White Burley).	do	Local infection. Necrotic lesions on inoculated leaves.
	<i>Petunia hybrida</i> Hort. (petunia).		Systemic infection. Chlorotic lesions.

On certain hosts, including black mustard, white mustard, evening scented stock, dames violet, and shepherds-purse, the symptoms produced by the mild mosaic virus were distinctly different from those caused by the severe mosaic virus. The mild mosaic virus produced fewer but larger lesions on Turkish tobacco than did the severe mosaic virus; however, on White Burley tobacco, the lesions were indistinguishable.

In further tests with the two viruses, no infection was obtained by mechanical inoculation in 55 species of plants representing 46 genera in 26 families, as follows:

Begoniaceae:

Fibrous-rooted begonia (*Begonia semperflorens* Link and Otto)

Boraginaceae:

Forget-me-not (*Myosotis alpestris* Schmidt)

Common heliotrope (*Heliotropium peruvianum* L.)

Campanulaceae:

Canterbury-bells (*Campanula medium* L.)

Caryophyllaceae:

Sweet-william (*Dianthus barbatus* L.)

Carnation (*D. caryophyllus* L.)

Babysbreath (*Gypsophila paniculata* L.)

Compositae:

Head lettuce (*Lactuca sativa* L. var. *capitata* Hort.) var. New York and Tom Thumb

Dandelion (*Taraxacum officinale* Weber)

Transvaal daisy (*Gerbera jamesonii* Hook. var. *transvaalensis* Hort.)

Annual marguerite (*Chrysanthemum coronarium* L.)

Shasta daisy (*C. maximum* Ram.)

English daisy (*Bellis perennis* L.)

China-aster (*Callistephus chinensis* Nees) var. Giant Branching White, wilt resistant

African marigold (*Tagetes erecta* L.)

French marigold (*T. patula* L.)

Winter Cape-marigold (*Dimorphotheca aurantiaca* DC.)

Gaillardia pulchella Foug. var. *picta* Gray

Hybrid cineraria (*Senecio cruentus* DC.)

Convolvulaceae:

Morning-glory (*Ipomoea purpurea* Roth)

Cruciferae:

Kale (*Brassica oleracea* L. var. *acephala* DC.)

Brussels sprouts (*B. oleracea* var. *gemmifera* DC.)

Cabbage (*B. oleracea* var. *capitata* L.) var. Winter Colma

Cauliflower (*B. oleracea* var. *botrytis* L.) var. February

Broccoli (*B. oleracea* var. *botrytis*) var. Italian Green Sprouting

Kohlrabi (*B. oleracea* var. *caulorapa* DC.)

Rape (*B. napus* L.)

Rutabaga (*B. compestris* L. var. *napobrassica* DC.)

Rockcress (*Arabis albida* Stev.)

Brompton stock (*Matthiola incana* R. Br.)

Goldentuft (*Alyssum saxatile* L.)

Cucurbitaceae:

Cucumber (*Cucumis sativus* L.)

Dipsacaceae:

Mourning bride or pincushion flower (*Scabiosa atropurpurea* L.)

Euphorbiaceae:

Castor-bean (*Ricinus communis* L.)

Geraniaceae:

Storksbill (*Pelargonium zonale* Willd.)

Gramineae:

Corn (*Zea mays* L.) var. Golden Bantam

Labiatae:

Flowering sage (*Salvia farinacea* Benth.)

Leguminosae:

Garden pea (*Pisum sativum* L.) var. Alderman

Broadbean (*Vicia faba* L.)

Lobeliaceae:

Lobelia hybrida Hort.

Onagraceae:

Clarkia elegans Dougl.

Godetia grandiflora Lindl.

Papaveraceae:

Oriental poppy (*Papaver orientale* L.)

Polygonaceae:

Rhubarb (*Rheum rhaponticum* L.)

Ranunculaceae:

Rocket larkspur (*Delphinium ajacis* L.)

Hybrid delphinium (*D. cultorum* Voss)

Rosaceae:

Geum chiloense Balb.

Scrophulariaceae:

Snapdragon (*Antirrhinum majus* L.)

Pentstemon or beardtongue (*Pentstemon barbatus* Nutt.)

Solanaceae:

Solanum aviculare Forst.Potato (*Solanum tuberosum* L.)Tomato (*Lycopersicum esculentum* Mill. var. *vulgare* Bailey) var. Early Santa Clara CannerCurrant tomato (*Lycopersicum pimpinellifolium* Dunal)*Nicotiana rustica* L. var. *humulis* SchrankJimsonweed (*Datura stramonium* L.)

Tropaeolaceae:

Garden nasturtium (*Tropaeolum majus* L.)

Umbelliferae:

Celery (*Apium graveolens* L.) var. Golden Self Blanching

Verbenaceae:

Garden verbena (*Verbena hybrida* Voss)

Violaceae:

Tufted pansy (*Viola cornuta* L.)Pansy (*V. tricolor* L.)

Subsequent inoculations to annual stock with extracted juice from inoculated plants of the above-mentioned plant species failed to cause infection.

PROPERTIES OF THE TWO MOSAIC VIRUSES

The data on properties of the mild and severe mosaic viruses of annual stock are based on both leaf and flower symptoms. As shown in table 2, the mild mosaic virus retained its infectivity after storage at a constant temperature of 22° C. for 5 days but was inactivated at the end of 6 days; the severe mosaic virus was infectious after 7 days and noninfectious after 8 days. The infectivity of each virus was retained after heating at 58° for 10 minutes, but inactivation occurred after heating at 60°. Therefore, under conditions of these tests, the inactivation temperature for each virus lies between 58° and 60°. When diluted 1:4,000, the mild mosaic virus was infectious but a dilution of 1:5,000 inactivated the virus. Infection resulted from a 1:3,000 dilution of the severe mosaic virus, but it was inactivated when diluted 1:4,000.

An analysis of all the data on longevity in vitro, inactivation temperature, and tolerance to dilution shows a definite overlapping of results. The slight variations in data relating to longevity and dilution tests are not considered significantly different. It is concluded, therefore, that the data on properties cannot be used as criteria for differentiation of these viruses.

No data were presented by Smith (7, 8) or Gigante (3) on properties of the viruses with which they worked.

TABLE 2.—Longevity in vitro, inactivation temperature, and tolerance to dilution of the mild and severe mosaic viruses of annual stock¹

[5 trials made with 25 plants each in all instances]

LONGEVITY IN VITRO, 22° C.

Aged (hours)	Plants infected with mild mosaic virus	Plants infected with severe mosaic virus	Aged (hours)	Plants infected with mild mosaic virus	Plants infected with severe mosaic virus	Aged (hours)	Plants infected with mild mosaic virus	Plants infected with severe mosaic virus
	Number	Number		Number	Number		Number	Number
0.....	25	25	96.....	1	16	192.....	0	0
24.....	18	25	120.....	1	8	240.....	0	0
48.....	8	24	144.....	0	7	336.....	0	0
72.....	6	20	168.....	0	3	480.....	0	0

¹ 50 noninoculated control plants for each property test remained healthy.

TABLE 2.—*Longevity in vitro, inactivation temperature, and tolerance to dilution of the mild and severe mosaic viruses of annual stock—Continued*

INACTIVATION TEMPERATURE (10 MINUTES)

Temperature (° C.)	Plants infected with mild mosaic virus	Plants infected with severe mosaic virus	Temperature (° C.)	Plants infected with mild mosaic virus	Plants infected with severe mosaic virus	Temperature (° C.)	Plants infected with mild mosaic virus	Plants infected with severe mosaic virus
Untreated	Number 25	Number 25	55-----	Number 25	Number 22	60-----	Number 0	Number 0
50-----	25	25	58-----	1	10	65-----	0	0

TOLERANCE TO DILUTION

Dilution	Plants infected with mild mosaic virus	Plants infected with severe mosaic virus	Dilution	Plants infected with mild mosaic virus	Plants infected with severe mosaic virus	Dilution	Plants infected with mild mosaic virus	Plants infected with severe mosaic virus
	Number	Number		Number	Number		Number	Number
0-----	25	25	1:1,000-----	5	7	1:3,000-----	1	1
1:10-----	25	23	1:1,500-----	4	0	1:4,000-----	1	0
1:100-----	18	17	1:2,000-----	6	4	1:5,000-----	0	0
1:500-----	6	8						

DESCRIPTION OF THE MILD AND SEVERE MOSAIC VIRUSES OF ANNUAL STOCK

H. H. P. Severin found that the mild and severe mosaic viruses are transmitted in nature by the false cabbage or turnip aphid and experimentally in greenhouse tests by the false cabbage or turnip aphid, the cabbage aphid, and the green peach aphid. These viruses are also transmissible by mechanical inoculation with expressed juice from diseased plants with or without carborundum.

MILD MOSAIC VIRUS

Incubation period about 20 days. Resistance to aging in vitro between 5 and 6 days at 22° C. Inactivation temperature at or near 60° for 10-minute exposure. Tolerance to dilution approximately 1 to 4,000. All varieties of annual stock and numerous other ornamental and vegetable crucifers highly susceptible. On annual stock, symptoms consist of mild form of vein clearing, followed by mottling of leaves and mild form of breaking of flowers of all self-colored varieties. Systemic mottling and chlorotic lesions produced on *Nicotiana langsdorffii* and necrotic local lesions on *N. glutinosa* and Turkish and White Burley tobacco. Hosts of mild mosaic virus which are not infected by severe mosaic virus are: Chinese or leaf mustard, pe-tsai, radish, Chinese radish, Virginian stock, honesty, sweet alyssum, wallflower, *Brassica adpressa*, sowbane or nettle-leaf goosefoot, *N. glutinosa*, and *N. langsdorffii*.

SEVERE MOSAIC VIRUS

Incubation period about 14 days. Resistance to aging in vitro between 7 and 8 days at 22° C. Inactivation temperature at or near 60° for 10-minute exposure. Tolerance to dilution approximately 1 to 3,000. All varieties of annual stock and a few ornamental and vegetable crucifers highly susceptible. On annual stock, symptoms consist of a very conspicuous, coarse mottling of leaves and a very coarse type of flower breaking of all self-colored varieties. Necrotic local lesions produced on Turkish and White Burley tobacco. Hosts of the severe mosaic virus which are not infected by the mild mosaic virus include lambsquarters, spinach, and petunia.

The mild and severe mosaic viruses of annual stock did not infect kale, Brussels sprouts, cabbage, cauliflower, sprouting broccoli, kohlrabi, and rape. This fact serves as a major difference between these two mosaic viruses of annual stock and certain other crucifer viruses.

RELATION OF THE TWO MOSAIC VIRUSES OF ANNUAL STOCK TO CERTAIN OTHER CRUCIFER VIRUSES

In earlier publications (10, 11, 13), comparisons of certain crucifer viruses were made and attention was called to certain characteristics by means of which they could be differentiated.

The two mosaic viruses of annual stock, although apparently closely related, can easily be separated from the cauliflower mosaic (10), Chinese cabbage mosaic (13), cabbage black ring (12), and turnip mosaic (11) viruses by means of their symptoms, host range, and insect vectors. As has been shown in this paper, no infection of cabbage, cauliflower, kale, Brussels sprouts, sprouting broccoli, kohlrabi, rape, or rutabaga was obtained with either annual stock virus. The annual stock mosaic viruses, as Severin has demonstrated, are disseminated in nature chiefly by the turnip or false cabbage aphid, whereas the principal insect vectors for the other above-mentioned crucifer viruses are the cabbage and green peach aphids. It is believed that these facts are sufficient to differentiate the annual stock mosaic viruses from other crucifer viruses.

It is interesting to note that flower breaking of annual stock is not restricted to the two annual stock mosaic viruses discussed in this paper. The writer has produced typical flower breaking on Fiery Blood Red annual stock plants by inoculation with the Chinese cabbage mosaic virus (13), the cabbage black ring virus (12), the turnip mosaic virus (11), and the horseradish mosaic virus (2). The horseradish virus was obtained through the courtesy of F. P. McWhorter of the Oregon Agricultural Experiment Station. Although the cauliflower mosaic virus (10) causes systemic infection of annual stock plants as evidenced by coarse vein clearing, it does not cause flower breaking. Smith (7, 8) obtained infection and flower breaking of annual stock with a cabbage mosaic virus in England; Chamberlain¹⁰ with a turnip mosaic virus in New Zealand; and recently Larson and Walker (4) with a cabbage mosaic virus in Wisconsin. Recently, through the courtesy of J. F. Adams of Mount Vernon, Wash., the writer received specimens of a virus disease on cabbage in Washington which is similar to the black ring virus disease (12) in California. Inoculated annual stock plants developed conspicuous symptoms of flower breaking. Annual stock (Fiery Blood Red) is immune to at least one crucifer virus, namely, the mosaic virus of cultivated white radish.

SUMMARY

Two mosaic virus diseases of annual stock, designated as mild mosaic and severe mosaic, are described.

These diseases are prevalent in the cool, coastal valleys of California and cause considerable loss in the cut-flower and seed crops.

¹⁰ CHAMBERLAIN, E. E. See footnote 7.

The principal symptoms, common to both diseases, consist of leaf mottling and flower breaking. Severe mosaic shows more conspicuous symptoms.

These viruses are readily transmissible by juice inoculations with carborundum. In nature, transmission is by means of the turnip or false cabbage aphid (*Lipaphis pseudobrassicæ*) which breeds on annual stock. Tests for seed transmission yielded negative results.

All self-colored varieties of annual stock are highly susceptible to infection, as indicated by leaf mottling and flower breaking. Mottling occurred on white- and yellow-flowered varieties, but no flower breaking.

Hosts which are susceptible to infection with both the mild and severe mosaic viruses of annual stock include turnip, black mustard, white mustard, dames violet, evening scented stock, charlock, shepherds-purse, mignonette, and Turkish and White Burley tobacco.

The fact that no infection of cabbage, cauliflower, kale, Brussels sprouts, sprouting broccoli, kohlrabi, rape, or rutabaga was obtained with the two mosaic viruses of annual stock serves to differentiate them from certain other crucifer viruses.

Differential hosts serve as one means of differentiating the two mosaic viruses of annual stock. Susceptible to infection with the mild mosaic virus only are Chinese or leaf mustard, pe-tsai, radish, Chinese radish, Virginian stock, honesty, sweet alyssum, wallflower, *Brassica adpressa*, sowbane or nettle-leaf goosefoot, *Nicotiana glutinosa*, and *N. langsdorffii*. Infection of lambsquarters, spinach, and petunia was obtained only with the severe mosaic virus.

Studies on the properties of the two mosaic viruses indicated that the mild mosaic virus was infectious for 5 days after storage at 22° C. and the severe mosaic virus for 7 days. The inactivation temperature for each virus lies between 58° and 60°. The mild mosaic virus caused infection when diluted up to 1 to 4,000 and the severe mosaic virus up to 1 to 3,000.

Flower breaking of annual stock may also be induced by the Chinese cabbage, turnip, horseradish, and cabbage mosaic viruses and the cabbage black-ring virus.

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