RING NECROSIS OF CABBAGE

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INTRODUCTION

In 1935 Smith (4) described a virus disease of cabbage and brussels sprouts in England, which he designated as “ring spot” because of the characteristic deeply sunken lesions surrounded by almost black necrotic rings. When leaves of young cabbage plants were inoculated, necrosis usually developed on the inoculated leaves and a mosaic mottling without preliminary vein clearing developed in the younger systemically infected leaves. Necrotic and occasionally chlorotic rings followed. In 1938 Tompkins et al. (9) described a virosis of cabbage from California under the name of “black ring.” The early symptoms on inoculated cabbage (no reaction on the inoculated leaves themselves was recorded) consisted of numerous small chlorotic lesions in which necrotic margins developed commonly after 2 or 3 weeks. Under field conditions the necrotic rings were most conspicuous on the under surface of the older, outer head leaves. It is to be noted that neither mosaic mottling nor vein clearing was described in connection with this disease on cabbage.

In 1937, at Madison, Wis., the writers noted in a plot of cabbage infected with a mosaic disease described elsewhere (2) necrotic ring lesions on many mature plants, particularly on the outer head leaves. From such plants a virus was obtained that produced various degrees of chlorosis and necrosis on cabbage. Although it had certain points in common with the diseases noted above, it was sufficiently distinct to warrant the present description. In order to distinguish the disease from others it is designated herein as “ring necrosis” of cabbage. A preliminary report has been published (3).

SYMPTOMS AND HOST RANGE

One of the major points of difference between ring necrosis and black ring is the fact that ring necrosis is masked in the greenhouse at 13° to 19°C. The symptoms herein described were observed on plants growing at 22° to 25°.

CRUCIFEROUS HOSTS

The following crucifers were inoculated mechanically with ring necrosis virus, according to methods described in the section on trans-
mission of the virus, and all were found to be susceptible and to exhibit systemic symptoms.

*Brassica oleracea* var. *capitata* L. (cabbage, vars. Jersey Queen, Marion Market, Wisconsin All Seasons, Wisconsin Hollander).

*Brassica oleracea* var. *botrytis* L. (cauliflower, var. Snowball; sprouting broccoli, var. Green Sprouting).

*Brassica oleracea* var. *gongylodes* L. (kohlrabi, var. Early White Vienna).

**Figure 1**—Young cabbage plant infected with the ring necrosis virus, showing small chlorotic lesions on younger leaves and necrotic ring development on the more mature leaves.

*Brassica oleracea* var. *gemmifera* Zenker (brussels sprouts, var. Long Island Improved).

*Brassica oleracea* var. *viridis* L. (kale, var. Dwarf Green Curled).

*Brassica campestris* var. *napobrassica* DC. (rutabaga, var. American Purple Top).

*Brassica napus* L. (rape, var. Dwarf Essex).

*Brassica rapa* L. (turnip, var. Purple Top White Globe).

*Brassica juncea* (L.) Coss. (leaf mustard, var. Tender Green).

*Brassica pekinensis* (Lour.) Rupr. (Chinese cabbage, var Chihli).

*Brassica hirta* Moench (*B. alba* (L.) Boiss, white mustard).

*Brassica nigra* (L.) Koch (black mustard).

*Cheiranthus allionii* Bailey (Siberian wallflower).
Mathiola incana var. annua (L.) Voss (annual stock, var. Dwarf Ten Weeks).
Hesperis matronalis L. (dames rocket).
Raphanus sativus L. (radish, var. French Breakfast).
Berteroa incana DC. (hoary alyssum).
Lepidium virginicum L. (wild peppergrass).
Lepidium sativum L. (garden cress).
Thlaspi arvense L. (pennycress).
Neslia paniculata (L.) Desv. (ballmustard).
Sisymbrium officinale (L.) Scop. (hedgemustard).
Sisymbrium altissimum L. (tumblemustard).

The symptoms on some of these hosts will be described.

CABBAGE

No symptoms appear on inoculated leaves of cabbage (Brassica oleracea var. capitata), but 17 to 21 days after inoculation small con-

spicuous yellow lesions appear in the parenchyma of the fourth or fifth unfolded leaf, at the distal portion from the growing tip (fig. 1). The more intense chlorosis at the outer margin of the lesions gives the appearance of a halo. Since the lesions are usually numerous they
may impart collectively the effect of mottling, but there is neither true interveinal mosaic nor systemic vein clearing. The lesions gradually increase in size and number over the entire leaf blade.

As the leaves become older necrosis appears as spots in the center of the lesion and a little later as concentric rings at the outer margin, giving in the final stage a "bull's-eye" spot in which the dead tissue is brown or blue black (fig. 2). As the disease progresses the tissue

Figure 3.—Outer leaf of diseased mature cabbage plant showing necrotic rings, vein necrosis, and chlorotic bleaching.
between the initial lesions bleaches and finally becomes dry and brittle (fig. 3). At this stage the leaves drop prematurely, but leaf drop is generally less extensive than in cabbage mosaic (2). Affected leaves occasionally develop asymmetrically. Curling or crinkling of the lamina of the leaf is accentuated only in the later stages of the disease. Necrosis may occur on or along the veins after the necrotic rings in the leaf parenchyma have formed. Neither Smith (4) nor Tompkins et al. (9) mentioned stem necrosis, which in the present disease commonly occurs in the form of irregular, dark blue to black, slightly sunken areas. The lesions may be small and linear or they may extend irregularly for some distance, usually not involving the leaf scars (fig. 4).
Figure 5.—Leaf symptoms of ring necrosis on subspecies of *Brassica oleracea*. 
A, B, Kohlrabi: A, Diseased; B, uninoculated control; C, Sprouting broccoli; D, brussels sprouts.
Field symptoms vary considerably. Plant growth may be stunted without any sign of chlorosis or necrosis except on the outer head leaves. Outer leaves show varied effects, including chlorosis, unilateral distortion, necrotic rings in interveinal tissue, and linear necrotic lesions on or along the veins. Bleaching of older infected leaves and stem necrosis may occur. Leaf drop is not common as in mosaic, and the internal necrosis of cabbage heads noted in the latter disease (2) has not been observed.

Other Members of Brassica oleracea

In kale (Brassica oleracea var. viridis), brussels sprouts (B. oleracea var. gemmifera), cauliflower (B. oleracea var. botrytis), sprouting broccoli (B. oleracea var. botrytis), and kohlrabi (B. oleracea var. gongylodes), the first symptoms, as in cabbage, appear as small halolike chlorotic lesions, which develop necrotic rings (fig. 5). Conspicuous linear necrotic lesions appear on veins, petioles, and stems.

Chinese Cabbage

Chinese cabbage (Brassica pekinensis) is very susceptible and exhibits somewhat erratic systemic symptoms. The first evidence of infection is the appearance of numerous dark specks in the interveinal tissue with slight necrotic streaking on the veins. The lesions may be scattered irregularly but are often confined to one side of the

Figure 6.—Leaf symptoms produced by systemic infection of Chinese cabbage with ring necrosis virus: A, Leaf distortion, vein necrosis, and necrotic streaking of petiole; B, uninoculated control.
leaf blade; later when necrotic vein streaking increases and involves the petiole, the symptoms (fig. 6) resemble somewhat those of systemic infection by the black-rot organism, *Bacterium campestris* (Pammel) E. F. Smith (*Phytomonas campestris* (Pammel) Bergey et al.). Well-marked progressive necrotic streaking, severe malformation, and stunting are evident in older infected leaves. The tissues gradually become dry and brittle, and the leaves die prematurely. The virus is occasionally lethal. In contrast to these disease manifestations, Tompkins et al. (9) described only chlorotic rings, some of which became necrotic, on Chinese cabbage infected with black ring.

**White Mustard**

Plants of white mustard (*Brassica hirta*) infected with the ring necrosis virus show slight chlorotic lesions on systemically infected leaves, but before ring symptoms fully develop the plants usually die. Tompkins et al. (9) report that black ring disease on this host produces chlorotic rings confined to inoculated leaves with vein clearing on new inner leaves.

**Annual Stock**

In systemically infected leaves of annual stock (*Mathiola incana var. annua*), chlorotic mottling and vein banding develop, followed by bleaching and necrosis. The plants are usually stunted. The flowers show breaking in the form of light flecks or streaks. In black ring on this host (9), mottling and bleaching of the leaves and breaking of flowers occur.

**Dames Rocket and Siberian Wallflower**

In dames rocket (*Hesperis matronalis*) and Siberian wallflower (*Cheiranthus allionii*), systemic infection results in stunting, conspicuous mottling, and some malformation (fig. 7). The symptoms on these hosts are not unlike those caused by the cabbage mosaic virus (2).

**Rape, Turnip, Rutabaga, and Radish**

In rape (*Brassica napus*), turnip (*B. rapa*), rutabaga (*B. campestris var. napobrassica*), and radish (*Raphanus sativus*), the early lesions on systemically infected leaves are chlorotic at first, and, as in cabbage, necrotic rings develop later. Various degrees of leaf distortion and stunting occur. It is to be noted that the black ring virus did not infect radish (9).

**Shepherd's-Purse, Garden Cress, Pennycress, and Hoary Alyssum**

Shepherd's-purse (*Capsella bursa-pastoris*), garden cress (*Lepidium sativum*), pennycress (*Thlaspi arvense*), and hoary alyssum (*Berteroa incana*) exhibit slight vein clearing with dwarfing of new growth and chlorosis. In 10 to 15 days after inoculation, early symptoms on older leaves appear as chlorosis of the interveinal areas with a downward curling of the leaf and slight mottling followed by necrosis and defoliation. The younger leaves are malformed and curled, giving the appearance of rosette disease (fig. 8, A).
Tompkins et al. (9) secured systemic infection with the black ring virus in lambsquarters (*Chenopodium album* L.), sowbanc (*C. murale* L.), and spinach (*Spinacia oleracea* L.), although they failed to recover the virus from infected plants. No infection was obtained in sugar beet (*Beta vulgaris* L.) nor Swiss chard (*B. vulgaris var. cicla* L.). The writers secured infection in sugar beet, mangel, Swiss chard, and spinach with the ring necrosis virus. On the first three of these, numerous small dark local spots appeared at the distal portion of the systemically infected leaf without mottling or vein clearing. The spots increased in size and number, and the entire leaf gradually became dry and brittle. Infected spinach leaves (var. Bloomsdale) showed vein clearing and a conspicuous progressively chlorotic mottling. The growing point was stunted and the plant formed a
pathological rosette, while the leaves became distorted and died prematurely (fig. 8, C). No infection occurred on lambsquarters.

Most crucifer viruses are infectious to various members of *Nicotiana*. Smith (4) reported that the ring spot virus caused necrotic lesions on inoculated leaves of tobacco (*N. tabacum* L.) in 7 to 10 days. On *N. langsdorffii* Schrank, local lesions and systemic mottling occurred. On *N. glutinosa* L., large local necrotic lesions appeared on inoculated leaves, and a mottling of light-green and yellow specks appeared on younger leaves. This disease was commonly fatal to young plants. Rather similar reactions of these three species to the black ring virus are reported (9).

In the case of the ring necrosis virus, necrotic lesions appeared in 3 to 4 days on tobacco (var. Connecticut Havana No. 38). They enlarged rapidly up to 3 mm. or more in diameter, the necrotic tissue forming concentric rings around a reddish center with a darker band

![Figure 8](image-url)

**Figure 8.**—*A, B, Shepherds-purse:* A, Symptoms of systemic infection by ring necrosis virus, showing chlorosis, leaf curl, and dwarfing; *B*, healthy control. C, D, *Spinach:* C, Virus-infected plant showing systemic chlorotic mottling and stunting of terminal bud leaves; *D*, healthy control.
at the margin (fig. 9). No systemic infection occurred. In *Nicotiana glutinosa* no local lesions occurred. The early systemic symptoms are small diffuse chlorotic lesions that become more conspicuous as slight necrosis develops at the margins. Necrosis gradually involves the entire leaf, but the virus is not fatal to the plant (fig. 10, A). In *N. langsdorffii* as well as in *N. rustica* L. and *N. repanda* Lehm., there

Figure 9.—Necrotic local lesions produced on leaf of *Nicotiana tabacum* by ring necrosis virus.
Figure 10.—A, Systemic infection of *Nicotiana glutinosa*, showing conspicuous chlorotic lesions on younger leaves and necrotic areas on older infected leaves. B, Numerous small scattered chlorotic lesions on systemically infected leaf of cucumber; no symptoms appear on the inoculated leaves. C, Leaf from healthy cucumber plant (uninoculated control).
are likewise no local lesions. The systemic symptoms, like those of the cabbage mosaic virus (2), are chlorosis and pronounced mottling (fig. 11).

In petunia (× Petunia hybrida Vilm.) the black ring virus caused chlorotic rings, curling and puckering of leaves, and stunting. Infection of this plant (var. Summer Pink) with ring necrosis virus is characterized by slight vein clearing and small irregular scattered chlorotic lesions with little or no necrosis. Bleaching and dropping of leaves follow, and there is considerable stunting. Sectorial breaking

Figure 11.—Symptoms produced on leaves of Nicotiana langsdorffii by systemic infection with ring necrosis virus: A, Systemically infected leaf showing conspicuous, irregular chlorotic lesions; B, leaf from uninoculated control.

in the form of streaks results in malformed and undersized flowers (fig. 12, A and C).

Zinnia (Zinnia elegans Jacq., var. Fantasy Yellow) when infected shows vein clearing and slight mottling followed by leaf twisting and severe stunting. In calendula (Calendula officinalis L., var. Ball’s Orange) the first symptoms appear as vein clearing and are followed by chlorosis and stunting.

The black ring virus did not infect cucumber (Cucumis sativus L.). When the ring necrosis virus was inoculated in the Chicago Pickling
Figure 12.—Symptoms produced by ring necrosis virus on petunia: A, Vein clearing and scattered chlorotic lesions of leaves on normal green background; B, uninoculated control; C, sectorial breaking of flower, accompanied by distortion and stunting; D, uninoculated control.
variety systemic symptoms appeared as numerous small chlorotic lesions (fig. 10, B).

Infection was not obtained on the following species in attempts to inoculate them by the abrasive method or by the transfer of aphids known to be vectors of the ring necrosis virus: Lambsquarters (Chenopodium album L.); broadbean (Vicia faba L.); nasturtium (Tropaeolum majus L.), var. Golden Gleam; pansy (Viola tricolor L.), var. Black King; celery (Apium graveolens L.), var. Golden Self-Blanching; tomato (Lycopersicon esculentum Mill.), var. Globe; currant tomato (L. pimpinellifolium (Jusl.) Mill.); potato (Solanum tuberosum L.), var. Irish Cobbler and Rural New Yorker; nightshade (S. nigrum L.); eggplant (S. melongena L.), var. Black Beauty; Nicotiana sanderae Bailey; N. longiflora Cav.; N. nudicaulis S. Wats.; jimsonweed (Datura stramonium L.); snapdragon (Antirrhinum majus L.), var. (rust-resistant strain); muskmelon (Cucumis melo L.), var. Milwaukee Market; watermelon (Citrullus vulgaris Schrad.), var. Stone Mountain; dandelion (Taraxacum officinale Weber); China-aster (Callistephus chinensis Nees), var. Giant Blue (wilt-resistant strain); French marigold (Tagetes patula L.), var. Harmony; and florists cineraria (Senecio cruentus (L'Her.) DC.), var. Multiflora Nana. Subsequent reinoculations to young cabbage and tobacco with the extracted juice from the foregoing inoculated plants failed to cause infection.

TRANSMISSION OF THE VIRUS

The strain of the ring necrosis virus used in the experimental studies on insect transmission was obtained from systemically infected mature cabbage grown at Madison, Wis. After the establishment of the virus on healthy cabbage seedlings by mechanical inoculation, a constant source of fresh inoculum was maintained in the greenhouse on this host. The virus remained virtually unchanged through successive transfers. All inoculations were conducted in a greenhouse where the temperature usually ranged from 22° to 25° C. and where weekly fumigation was practiced for the control of insects. The artificial inoculations of test plants were regularly made by dusting the leaves with powdered carborundum and lightly rubbing with a small piece of absorbent cotton soaked with juice extracted from diseased cabbage plants.

Studies on insect transmission of this virus involved the use of the green peach aphid (Myzus persicae (Sulz.)) and the cabbage aphid (Brevicoryne brassicae (L.)). The methods of culture and transfer of the aphids were essentially the same as those described in a recent paper (2). Healthy cabbage seedlings infested with nonviruliferous aphids and uninoculated plants free of aphids served as controls. Reinoculations from all test plants for the recovery of the virus were made to cabbage seedlings to determine the presence of the ring necrosis virus. It was determined by repeated trials that both species of aphid transmit the ring necrosis virus readily.

PROPERTIES OF THE VIRUS

Undiluted juice expressed from recently infected cabbage was used for the study of the properties of the ring necrosis virus. Young cabbage plants were used as test plants. The results are given in table 1.
TABLE 1.—Properties of ring necrosis virus in vitro as determined by infection on cabbage

[25 plants used in each test]

<table>
<thead>
<tr>
<th>Longevity in vitro</th>
<th>Thermal inactivation</th>
<th>Tolerance to dilution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period aged at 20°-22°C. (hours)</td>
<td>Plants infected in trial No.—</td>
<td>Temperature (10-minute period)</td>
</tr>
<tr>
<td></td>
<td>No.</td>
<td>No.</td>
</tr>
<tr>
<td>12</td>
<td>24</td>
<td>23</td>
</tr>
<tr>
<td>24</td>
<td>18</td>
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</tr>
<tr>
<td>60</td>
<td>0</td>
<td>0</td>
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In table 2 the inactivation points recorded in the literature for other crucifer viruses are listed in comparison with those of the ring necrosis virus. Insofar as these physical properties are concerned, the latter resembles most closely the cabbage black ring virus and the cabbage mosaic virus, but differs from them very definitely in having lower thermal and dilution inactivation points. It has many points of difference in host range and symptoms from all others except the cabbage black ring virus. As already stated, in symptoms produced on cabbage it resembles the black ring and ring spot viruses. The last of these is not described adequately enough by Smith (4) to permit comparison, because no physical properties were recorded and the host range and symptoms were studied in only a limited way. The chief distinctions between the ring necrosis virus and the black ring virus, aside from the differences in physical properties just mentioned, are infectivity of radish, sugar beet, and chard by the former, the difference in optimal temperatures for disease development, and differences in symptoms on various common hosts already mentioned.

TABLE 2.—Inactivation points of ring necrosis virus for longevity in vitro and for resistance to high temperatures and dilutions, compared with those recorded for other crucifer viruses

<table>
<thead>
<tr>
<th>Virus</th>
<th>Authority</th>
<th>Period aged in vitro</th>
<th>Temperature (10-minute period)</th>
<th>Dilution</th>
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</thead>
<tbody>
<tr>
<td>Ring necrosis</td>
<td>Larson and Walker</td>
<td>48</td>
<td>Hours</td>
<td>50</td>
</tr>
<tr>
<td>Turnip mosaic</td>
<td>Hoggan and Johnson (1)</td>
<td>72</td>
<td></td>
<td>54</td>
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<tr>
<td>Cauliflower mosaic</td>
<td>Tompkins (6)</td>
<td>300</td>
<td>75</td>
<td>1:2,000</td>
</tr>
<tr>
<td>Chinese cabbage mosaic</td>
<td>Tompkins and Thomas (10)</td>
<td>96</td>
<td>75</td>
<td>1:5,000</td>
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<tr>
<td>Turnip mosaic</td>
<td>Tompkins (6)</td>
<td>48</td>
<td>63</td>
<td>1:4,000</td>
</tr>
<tr>
<td>Cabbage black ring</td>
<td>Tompkins et al. (9)</td>
<td>48</td>
<td>57</td>
<td>1:1,000</td>
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<tr>
<td>Mild stock mosaic</td>
<td>Tompkins (7)</td>
<td>144</td>
<td>60</td>
<td>1:5,000</td>
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<tr>
<td>Severe stock mosaic</td>
<td>do</td>
<td>192</td>
<td>60</td>
<td>1:4,000</td>
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<td>Radish mosaic</td>
<td>Tompkins (6)</td>
<td>384</td>
<td>68</td>
<td>1:15,000</td>
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<tr>
<td>Cabbage mosaic</td>
<td>Larson and Walker (2)</td>
<td>72</td>
<td>55</td>
<td>1:2,000</td>
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Ring necrosis is a virus disease of cabbage, which is here described in comparison with other crucifer virus diseases.

The virus infects all crucifers tested, including some 25 species and subspecies or botanical varieties, and certain other noncruciferous hosts, including sugar beet, chard, spinach, tobacco, Nicotiana glutinosa, N. langsdorffii, N. rustica, N. repanda, petunia, zinnia, and calendula.

The virus is transmitted readily by mechanical inoculation and by the green peach and cabbage aphids.

The physical properties investigated are distinct from those already reported for other crucifer viruses.

LITERATURE CITED
