Big-vein Resistance in Lettuce: Identifying, Selecting, and Testing Resistant Cultivars and Breeding Lines

Edward J. Ryder and Bert J. Robinson
U.S. Agricultural Research Station, U.S. Department of Agriculture, Agricultural Research Service, 1636 East Alisal Street, Salinas, CA 93905

Abstract. Screening for lettuce (Lactuca sativa L.) big-vein resistance in the F1 generation is highly inefficient. Efficiency improves in the F2 and following generations with continued inbreeding. Traits useful in ascertaining resistance are 0% of plants showing symptoms and percentage of plants showing symptoms at a given date. Breeding lines identified as resistant in greenhouse screening have proved resistant under field conditions. Forty-nine cultivars have been identified in preliminary testing as potentially resistant. Of these, 11 have been confirmed as resistant in greenhouse and field tests.

Big vein (BV) of lettuce was identified and named by Jagger and Chandler (1934). It was later shown to be transmitted to lettuce plants by a root-inhabiting fungus, Olpidium brassicae (Wor.) Dang. (Campbell and Grogan, 1963). The agent causing BV was identified as a virus (Kuwata et al., 1983; Vetten et al., 1987). The virus causes chlorotic vein banding on leaves and may hamper head formation.

Control of the disease has been attempted through cultural practices, soil fumigation, and resistance. Control through cultural practices is related to the association of BV symptom expression with temperature and soil type. Symptom expression is more severe when plants are grown at lower temperatures, i.e., in the late winter or early spring in California and Arizona, and in heavy-textured soils that remain moist for long periods. Therefore, in cooler seasons, growers attempt to schedule their lettuce plantings for slightly warmer, drier, and more light-textured soils. Cultural control is often limited by the number of fields with light-textured soil available to a given grower in the cool season. Campbell (1978) showed that methyl bromide fumigation reduced O. brassicae and BV levels temporarily for one season or two plantings. Fumigation with methyl bromide is expensive and requires repetition for continued effectiveness. Furthermore, methyl bromide will not be available after the year 2000. Resistance remains the most desirable method of control.

Moderate resistance was identified in the cultivar Merit (Thompson and Ryder, 1961), which was used as an original source in the Salinas breeding program, yielding ‘SeaGreen’ (Ryder, 1981a), ‘Thompson’ (Ryder, 1981b), and ‘Pacific’ (Ryder, 1991). ‘Thompson’ has been used principally as a resistance source, while ‘Pacific’ and ‘Sea Green’ are grown commercially.

Bos and Huijberts (1990) tested several lettuce cultivars in greenhouse and field trials. They concluded that BV resistance is not yet high enough for practical use and suggested continued search for resistance or immunity to BV and exploration for resistance to the vector as well. They reported that immunity may exist in the wild species Lactuca virosa. The U.S. Dept. of Agriculture-Agricultural Research Service (USDA-ARS) BV-resistance breeding program at Salinas began in 1957. During the ensuing period, a screening procedure was developed and modified, three cultivars were released, and an inheritance study was begun that is still in progress. This paper discusses the evolution of the screening program and its use in evaluating breeding materials and cultivars.

Materials and Methods

Greenhouse studies were conducted annually from late October to early April to take advantage of seasonal low temperatures, which are conducive to symptom development. Soils were treated only with Vapam, which does not kill the BV vector. Seeds were sowed in a sand-soil mixture and covered with fine sand. Seedlings were transplanted to plastic pots (8.25 cm on a side, 9.10 cm deep) filled with sandy loam. Although natural inoculation occurs in nonsterilized soil, symptom expression may not begin until 6 to 8 weeks after planting. Inoculation with a slurry of macerated roots from infected plants immediately after transplanting initiates symptom expression earlier, usually in 2 to 3 weeks. The latter procedure was used for the present study.

Table 1. Mean number of days from inoculation to 50% of plants showing symptoms and mean percentage of plants showing symptoms 73 days after inoculation of 13 cultivars, Winter 1992-93.

| Cultivar          | Days | Percent |
|------------------|------|---------|
| Passe-Partout     | 31.0 | 84.7    |
| Lobjots           | 28.7 | 94.3    |
| La Brillante      | 66.0 | 54.7    |
| Sea Green         | 40.3 | 97.3    |
| Bahia             | 24.0 | 94.3    |
| Little Gem        | 52.0 | 60.3    |
| Pavana            | 68.3 | 42.0    |
| Thompson          | 56.7 | 60.7    |
| Merit             | 31.0 | 100     |
| Parsberg          | 45.0 | 64.7    |
| Meikoningin       | 31.0 | 86.7    |
| Pacific           | 73.0 | 26.3    |
| Great Lakes 65    | 28.7 | 97.0    |
| LSD, 1%           | 22.7 | 15.8    |
The virus can be transmitted mechanically to *Chenopodium quinoa* and three *Nicotiana spp.*, but attempts to transmit it to lettuce have not been successful (Huijberts et al., 1990).

Reaction to BV was observed with the appearance of the typical vein-banding symptom and recorded as time of symptom expression only, not as severity of expression.

Two types of data were analyzed: 1) percentage of plants showing symptoms at a given date and 2) date at which 50% of plants expressed the symptom. Statistical analysis was by ANOVA, with two- or three-way randomized block design.

Field studies were conducted each year from January to June in soils likely to be BV prone (Westerlund et al., 1978b). In these studies, cultivars and advanced breeding lines were compared under commercial field conditions. The percentage of plants showing symptoms was evaluated at harvest. Replicated trials were analyzed by ANOVA.

### Results

The series of experiments described had two broad goals. One was to establish that the screening procedure was effective in identifying resistant populations. The other was to develop a list of cultivars and breeding lines with resistance that could be useful in breeding programs.

#### Cultivar screening

In 1980-81, we began to screen our cultivar collection for additional sources of resistance to BV. Up to 125 cultivars were screened each season. We tested 12 plants per cultivar in a preliminary test. These were grown either in small plastic cups (6.8 cm in diameter, 3.5 cm deep) or in small square plastic pots (8.25 cm on a side, 9.1 cm deep). Natural inoculation was used first; inoculation with a root slurry began in 1986. Of 744 cultivars screened, 49 were identified in the preliminary screening as possibly resistant.

Most cultivars identified in the 1988-89 greenhouse screening and in subsequent years were subject to one or more confirming tests in the greenhouse and in the field. In 1992-93, seven cultivars were placed in a replicated test in the greenhouse and compared with six resistant and susceptible cultivars previously identified (Table 1). ‘Passe Partout’, ‘Parsberg’, and ‘Meikoningin’ were eliminated as potential resistant sources based on this and other tests. Although ‘Lobjoits’ performed poorly in this test, it showed resistance in other nonreplicated tests and was entered in subsequent tests and field trials. ‘La Brillante’, ‘Little Gem’, ‘Pavane’, and ‘Thompson’ did not perform as well as ‘Pacific’, but were clearly superior to the other cultivars.

In 1993-94, 12 potentially resistant cultivars and six check cultivars were compared in a replicated test. Based on the ANOVA for number of days to 50% with symptoms, which was significant, and from percent infection, which was not significant, ‘LaBrillante’, ‘Postillon’, and ‘Pavane’ showed the highest level of resistance (Table 2). ‘Plato’, ‘Plaza’, and ‘Lobjoits’ also showed reasonable potential.

The same cultivars, but with ‘Salinas 88’ substituted for ‘Pontiac’, were planted in two replicated field trials in Spring 1994. All of the test cultivars, including those that did not perform well in the 1993-94 greenhouse test, showed good to excellent field resistance compared with ‘Pacific’ and ‘Thompson’, the resistant controls, and

### Table 2. Reaction of resistant and susceptible cultivars to big vein in one greenhouse and two field trials. Greenhouse results are mean number of days to 50% plants showing symptoms and mean percentage of plants showing symptoms 67 days after inoculation. Field trial results are percentages of plants showing big vein at harvest, 5 and 11 May, respectively; Winter and Spring, 1993-94.

| Cultivar      | Greenhouse (days) | Greenhouse (%) | Trial 1 (%) | Trial 2 (%) |
|---------------|-------------------|----------------|-------------|-------------|
| La Brillante  | 85.7              | 25.0           | 2.6         | 0.5         |
| Little Gem    | 71.7              | 38.9           | 0           | 0.5         |
| Lobjoits      | 76.3              | 36.5           | 2.2         | 0.7         |
| Pacific       | 99.7              | 16.7           | 0           | 3.4         |
| Pavane        | 118.3             | 19.4           | 0           | 0           |
| Plaza         | 78.7              | 53.1           | 0           | 2.0         |
| Postillon     | 85.7              | 30.5           | 0.7         | 0.6         |
| Racy Red      | 62.3              | 55.9           | 4.7         | 0           |
| Sea Green     | 81.0              | 42.0           | 6.3         | 1.1         |
| Thompson      | 76.3              | 36.1           | 6.2         | 7.3         |
| Plato         | 78.6              | 47.6           | 8.0         | 7.7         |
| Plenos        | 57.7              | 72.2           | 2.6         | 7.5         |
| Portato       | 67.0              | 52.8           | 2.5         | 6.1         |
| Prestine      | 67.0              | 47.6           | 0.6         | 6.1         |
| Pontiac       | 51.1              | 61.1           | 61.1        | 61.1        |

| Cultivar      | Field (%) |
|---------------|-----------|
| Great Lakes 65| 46.0      | 30.4          | 30.4        |
| Merit         | 69.3      | 44.4          | 44.4        |
| Salinas       | 55.3      | 64.2          | 64.2        |
| Salinas 88    | 55.3      | 64.2          | 64.2        |
| LSD          | 38.8      | 4.9           | 9.8         |

LSD at 1% for greenhouse and 5% for field results.
Table 3. Big-vein resistance rating of F$_3$ families from the cross Salinas x PI 273589 compared to the number of days to symptom expression for their F$_2$ parents.

| F$_3$ family | Rating | Days | Percentage | F$_2$ parent |
|--------------|--------|------|------------|--------------|
| A-7 | S | 28.5 | 87.5 | 52 |
| A-8 | S | 30.0 | 91.7 | 52 |
| B-12 | S | 30.0 | 100 | 59 |
| E-3 | S | 30.0 | 100 | 31 |
| G-3 | S | 28.5 | 100 | 45 |
| A-5 | R | 65.0 | 16.7 | 38 |
| A-6 | R | 58.0 | 37.5 | 59 |
| A-11 | R | 61.5 | 41.7 | 45 |
| B-9 | R | 61.5 | 30.4 | 45 |
| B-11 | R | 58.0 | 41.7 | 73 |
| D-3 | R | 54.5 | 31.8 | 31 |
| D-4 | R | 61.5 | 37.5 | 31 |
| D-9 | R | 61.5 | 17.4 | 38 |
| F-3 | R | 58.0 | 37.5 | 59 |
| F-6 | R | 58.0 | 37.5 | 94 |
| F-10 | R | 54.5 | 33.3 | 94 |
| F-12 | R | 58.0 | 33.3 | 38 |

*Rating based on days to first symptom and percent plants infected, consistent in two replications; R = resistant, S = susceptible.

*Mean number of days from inoculation to 50% of plants with symptoms.

*Percent infected at 44 days from inoculation.

*Number of days from inoculation to appearance of symptoms

‘Salinas’ and ‘Salinas 88’, the susceptible cultivars (Table 2).

Of the 49 cultivars identified as potentially resistant, the following showed consistent reactions in all or most tests in the greenhouse and field (Tables 1 and 2) and are being considered for further breeding work (cultivar, type):

LaBrillante, Batavia; Little Gem, Latin; Lobjoits, Cos; Pavane, Latin; Plato, Cos; Plaza, Butterhead; Plenos, Butterhead; Portato, Butterhead; Postillon, Butterhead; Prestine, Butterhead; and Racy Red, Leaf

‘Lobjoits’ and ‘Little Gem’ have also been cited by Bos and Huijberts (1990) as resistant. The remaining 38 cultivars will be tested further in replicated trials to ascertain their level of resistance.

Screening procedure

Reaction of single plants. Screening for disease resistance normally begins with selection in an F$_2$ population, and the resistance is then confirmed in F$_3$ families. With BV, however, single-plant selection, as in an F$_2$ population, is not a reliable indicator of F$_3$ family performance.

An F$_2$ population from the cross ‘Salinas’ (susceptible, S) x PI 273589 (resistant, R) was grown in Winter 1989-90. Plants showing symptoms were rated resistant if the first symptom appeared 59 to 94 days after inoculation. Among F$_3$ families grown the following winter, five were identified as susceptible and twelve as resistant based on two measures: number of days from inoculation to symptom expression of 50% of the plants, and percentage of plants infected (Table 3). Only the families in which the readings were consistent for both measures in both replications were rated. Those families rated as susceptible were derived from four F$_2$ plants rated as susceptible (31 to 52 days) and one as resistant (59 days). The resistant F$_3$ families were derived from seven F$_2$ plants rated as susceptible (31 to 45 days) and five as resistant (59 to 94 days). The F$_3$ ratings were not consistently confirmed by F$_3$ family performance.

In an F$_2$ population from the cross ‘Thompson’ (R) x ‘Vanguard 75’ (S), symptom expression occurred late, from 108 to 169 days. Over 50% of the plants showed no symptoms at the end of the experiment. Several F$_2$ families were rated for two successive years in the greenhouse for BV reaction (Table 4). Ten resistant

Table 4. Percentage of plants showing big vein symptoms for 10 resistant and 10 susceptible F$_3$ families from the cross Thompson x Vanguard 75 and the number of days to symptom expression for their F$_2$ parents.

| Family | % | F$_2$ parent | Family | % | F$_2$ parent |
|--------|---|--------------|--------|---|--------------|
| 1075   | 21 | 108          | 1675   | 85 | 115          |
| 1683   | 25 | 132          | 1679   | 83 | 129          |
| 1695   | 25 | 150          | 1682   | 83 | 136          |
| 1702   | 13 | 169          | 1691   | 75 | 139          |
| 1704   | 22 | 169          | 1694   | 83 | 148          |
| 1706   | 29 | NS           | 1701   | 92 | 155          |
| 1713   | 25 | NS           | 1704   | 71 | 162          |
| 1734   | 26 | NS           | 1712   | 71 | NS           |
| 1739   | 26 | NS           | 1715   | 74 | NS           |
| 1745   | 13 | NS           | 1716   | 77 | NS           |

*Number of days from inoculation to symptom expression. NS = no symptom at end of experiment.
(also confirmed in field trials) and ten susceptible families were compared to their F₁ parent plants. The F₁ parent plants showing symptoms were in the same range for susceptible and resistant families. Of eight F₂ families for which the F₁ parent showed no symptom, five were rated resistant and three susceptible.

Both experiments indicate that symptom expression in F₁ plants is not a good predictor of F₂ family response.

Selection in populations. In the F₁ and subsequent generations, selection was practiced on a population basis. This allowed us to use two criteria for resistance: proportion of infected plants at a given date and number of days to 50% of plants with symptoms. The plantings could also be replicated for greater reliability of readings. These factors increased confidence in our ability to select and confirm resistance in the following generation. For example, seven F₂ families from the cross ‘Pacific’ (R) x N-2 (a BV resistant breeding line from a different source) were identified as resistant. Of 31 F₂ families, nearly half were equal or superior to the resistant control ‘Pacific’ (data not shown). These results showed that selection on a population basis is a better predictor of success than selection of single plants.

Field evaluation
Cultivars and breeding lines that were identified as resistant in greenhouse trials or that needed further evaluation were planted in commercial fields, usually in replicated trials. These trials were conducted to confirm greenhouse evaluations and demonstrate consistency of response of lines and cultivars to BV disease over variable soil types and temperature ranges. This variation affects BV expression.

A series of six replicated trials were grown during 1983 in the Salinas Valley to evaluate BV resistance and yield. These trials included seven BV-resistant breeding lines selected in greenhouse plantings, three breeding lines without BV resistance, and two resistant and two susceptible cultivars. BV evaluations were made 1 to 3 days before harvest (Table 5). All seven BV-resistant lines consistently showed less BV over all six trials than the other entries. The BV-resistant ‘Thompson’ performed slightly less well than the breeding lines. The three susceptible breeding lines and the susceptible ‘El Toro’ were consistently poor performers.

‘Salinas’ was usually in the susceptible group, but, in one trial, was less affected than ‘Sea Green’, which was usually in the resistant group.

‘Salinas 88’ and ‘Pacific’ were crossed to combine lettuce mosaic virus (LMV) resistance from ‘Salinas 88’ and BV resistance from ‘Pacific’. Seven LMV-resistant F₁ families were planted in replicated field trials in 1993 and 1994 to evaluate their resistance to BV. These lines had been selected for BV resistance in F₁ and F₂ populations in greenhouse plantings as follows. A mass F₂ population was grown and inoculated in 1990-91. Plants showing symptoms in the first 3 weeks were eliminated as probable susceptibles. Several plants showing symptoms each week from the fourth through the ninth were saved as well as several showing no symptoms at 9 weeks. During 1991-92, 32 F₂ families were grown and inoculated. Seven were selected as equal or superior to ‘Pacific’ in percentage of plants showing symptoms 52 days after inoculation. Of the seven families, two were derived from F₁ plants selected in the fifth week after inoculation, one in the sixth week, three in the eighth week, and one in the ninth week. In the replicated field trials, five of the seven lines were confirmed as resistant under field conditions, while two lines, 90-1549-14M and 90-1549-41M, were equivalent to the ‘Salinas 88’ parent (Table 6). There was no apparent correlation with time of selection in the F₁ generation.

Table 5. Percentage of plants with big vein symptoms and rank of big vein-resistant and susceptible breeding lines and cultivars in early spring field trials, 1982-83. Planting and harvest dates: 1 = 30 Dec., 2 May; 2 = 6 Jan., 5 May; 3 = 10 Jan., 5 May; 4 = 3 Feb., 25 May; 5 = 11 Feb., 26 May; 6 = 22 Feb., 2 June.

| Entry | 1 Rank | 1 % | 2 Rank | 2 % | 3 Rank | 3 % | 4 Rank | 4 % | 5 Rank | 5 % | 6 Rank | 6 % | Means |
|-------|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|-------|
| 80-1655 | 26 | 3 | 26 | 3 | 6 | 4 | 8 | 2 | 9 | 5 | 9.7 | 3.2 | 80-1657 | 13 | 3 | 27 | 4 | 9 | 7 | 9 | 1 | 3 | 1 | 9.8 | 2.8 | 80-1658 | 18 | 6 | 22 | 1 | 3 | 1 | 9 | 3 | 5 | 3 | 9.2 | 3.5 | 80-1659 | 8 | 1 | 25 | 6 | 4 | 9 | 2 | 3 | 1 | 8.1 | 2.3 | 80-1662 | 14 | 4 | 30 | 6 | 5 | 3 | 19 | 9 | 7 | 4 | 15.6 | 5.3 | 80-1663 | 19 | 7 | 22 | 1 | 8 | 5 | 10 | 5 | 11 | 7 | 13.0 | 5.0 | 80-1671 | 16 | 5 | 41 | 7 | 13 | 8 | 12 | 6 | 10 | 6 | 15.8 | 6.0 | 82-655 | 48 | 12 | 55 | 9 | 22 | 11 | 37 | 12 | 84 | 14 | 57.6 | 11.3 | 82-657 | 54 | 13 | 78 | 14 | 26 | 12 | 35 | 11 | 75 | 13 | 57.4 | 12.8 | 82-693 | 46 | 11 | 72 | 12 | 13 | 8 | 16 | 7 | 30 | 10 | 42.1 | 10.0 | El Toro | 40 | 10 | 70 | 11 | 39 | 14 | 64 | 14 | 74 | 12 | 61.5 | 12.3 | Salinas | 35 | 9 | 73 | 13 | 29 | 13 | 47 | 13 | 62 | 11 | 56.0 | 11.7 | Sea Green | 66 | 14 | 63 | 10 | 18 | 10 | 28 | 8 | 33 | 8 | 30.0 | 10.2 | Thompson | 28 | 8 | 47 | 8 | 8 | 5 | 17 | 8 | 12 | 8 | 18.9 | 7.5 |

aDuncan’s multiple range test. Items with same letter are not significantly different in big vein percentage at 1% level.

Discussion
Several aspects of BV expression in lettuce are unique and make evaluation for resistance difficult. Olpidium brassicae is nearly ubiquitous in soils of California and Arizona. The proportion of plants expressing symptoms is higher at relatively low temperatures and in soils with greater moisture-holding capacity (Westerlund et al., 1978a, 1978b). In soils in which BV symptoms are expressed on lettuce plants, the virus is likely to be present in symptom-expressing and nonexpressing plants (Westerlund et al., 1978a). Plants known to harbor the virus expressed symptoms or not depending on the air temperature. Symptom expression at progressive growth stages would express or not depending upon the temperature immediately before each growth stage. In our experiments, no plant that was symptomless at the onset of bolting
and seed production produced progeny that were also symptomless. Therefore, in any population of plants grown in unsterilized soil, we have assumed that all plant roots are infected with O. 

\textit{brassicae} and that the virus is transmitted to all plants. Presence of the virus in plants can be evaluated serologically (Vetten et al., 1987), but we have not done so in the experiments reported. The failure of a plant to show symptoms was, therefore, not necessarily an indication of resistance. The term resistance as used here is defined in terms of the time to symptom expression and/or the proportion of plants in a population that show symptoms.

The BV screening procedure developed for our program was devised for two purposes: 1) to select for resistance among plants in a segregating population and 2) to evaluate cultivars, plant introductions, and breeding lines for reaction to BV. The procedure can identify immune or highly resistant materials, but it also distinguishes populations with low to intermediate resistance. The latter group has been shown to be of importance in the materials tested so far. At this point, no sources have been identified with a high level of resistance that does not vary as the severity of the disease varies. For example, ‘Thompson’ and ‘Pacific’ were consistently superior to susceptible lines in relative response to the disease. However, in the series of field tests grown in 1983 (Table 5) BV percentage for ‘Thompson’ varied from 8% to 47% and for ‘Pacific’ from 9% to 41%.

The procedure is poor at distinguishing susceptible from resistant single plants, as in an F1 population. We have assumed that, in all the materials we have investigated, the virus is present regardless of presence or absence of symptoms. The expression of resistance to disease development in the plant varies according to several environmental conditions. It seems likely that the environmental variation substantially obscures the genetic variation among single plants.

Resistance appears to be available from a wide variety of sources. The USDA-ARS Salinas BV program began with the cross ‘Merit’ x USDA 2741. ‘Merit’ was derived from crosses involving several cultivars of soft crisphead or Batavia types, cos, butterhead, and leaf types. USDA 2741 was a breeding line with a mental variation substantially obscures the genetic variation among single plants.

The resistance manifested in the materials screened to date is best described as resistance to the BV disease rather than to the virus. Neither the action of the virus in causing symptoms nor the reaction of the plant in delaying symptom expression has been adequately described. The virus titer in resistant cultivars compared with susceptible cultivars is not known.

The host-BV virus relationship is poorly understood. The host-BV virus relationship is poorly understood. The host-BV virus relationship is poorly understood.

The BV screening procedure described can identify resistance to BV disease, if not to the virus itself. Resistance to the BV disease is useful in commercial field production. Further improvement in the screening procedure is desirable. There is potential for higher levels of resistance through recombination of genes from various sources. Resistance to the virus itself continues to be a desired goal of BV research.

\textbf{Literature Cited}

Bos, L. and N. Huijberts. 1990. Screening for resistance to big-vein disease of lettuce. Crop Protection 9:446-452.

Campbell, R.N. 1978. Lettuce virus and virus-like diseases(1977-78). Annu. Rpt. Iceberg Lettuce Res. Program, 1 Apr. 1977-31 Mar. 1978. p. 78-81.

Campbell, R.N. and R.C. Grogan. 1963. Big-vein virus of lettuce and its...
transmission by *Olpidium brassicae*. Phytopathology 53:252-259.

Huijberts, N., D.-R. Blystad, and L. Bos. Lettuce big-vein virus: Mechanical transmission and relationships to tobacco stunt virus. Ann. Appl. Biol. 116:463-475.

Jagger, I.C. and N. Chandler. 1934. Big vein, a disease of lettuce. Phytopathology 24:1253-1256.

Kuwata, S., S. Kubo, S. Yamashita, and Y. Doi. 1983. Rod-shaped particles, a probable entity of lettuce big vein virus. Ann. Phytopathol. Soc. Jpn. 49:246-251.

Ryder, E.J. 1980. Effects of big vein resistance and temperature on disease incidence and percentage of plants harvested of crisphead lettuce. J. Amer. Soc. Hort. Sci. 104:665-668.

Ryder, E.J. 1981a. ‘Sea Green’ lettuce. HortScience 16:571-572.

Ryder, E.J. 1981b. ‘Thompson’ lettuce. HortScience 16:687-688.

Ryder, E.J. 1991. ‘Pacific’ lettuce. HortScience 26:437-438.

Thompson, R.C. and E.J. Ryder. 1961. Descriptions and pedigrees of nine varieties of lettuce. U.S. Dept. of Agr.-Agr. Res. Serv. Tech Bul. 1244.

Vetten, H.J., D.-E. Lesemann, and J. Dalchow. 1987. Electron microscopical and serological detection of virus-like particles associated with big vein disease. J. Phytopathol. 120:53-59.

Westerlund, F.V., R.N. Campbell, and R.G. Grogan. 1978a. Effect of temperature on transmission, translocation, and persistence of the lettuce big-vein agent and big-vein symptom expression. Phytopathology 68:921-926.

Westerlund, F.V., R.N. Campbell, R.G. Grogan, and J.M. Duniway. 1978b. Soil factors affecting the reproduction and survival of *Olpidium brassicae* and its transmission of big vein agent to lettuce. Phytopathology 68:927-935.