# Susceptibility and Immunity in Soybean to Beet Western Yellows Virus

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ABSTRACT

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Thirty-five soybean cultivars either related to or with a pedigree similar to that of cultivar Wells were evaluated for susceptibility to beet western yellows virus (BWYV). Some cultivars were susceptible, some apparently were immune, and the data for others indicated either heterogeneity in, or possibly an intermediate level of, susceptibility. All of the susceptible cultivars tested in this study were derived from crosses that traced back to Mandarin, a soybean cultivar introduced from northeastern China in 1911 and to AK which was introduced to the U.S. from Manchuria in 1912. Plants infected with BWYV showed various degrees of interveinal yellowing and stunting or were symptomless in the greenhouse. The data support the hypothesis that BWYV probably is related to other yellowing viruses of legumes reported from different parts of the world.

In view of the economic significance of the yellowing-type viruses on various other crops, we have been intrigued by their apparent absence in North American legumes. Pea leaf roll, soybean dwarf, subterranean clover stunt, subterranean clover red leaf, and groundnut rosette have caused serious losses in legumes in other parts of the world, but apparently have not been found in North America.

Beet western yellows virus (BWYV) causes stunting and chlorosis on a wide range of dicotyledonous species in North America, Europe, and Asia. It has been shown to induce yellowing, rolling, and stunting on various legumes, including *Lathyrus odoratus, Pisum sativum, Trifolium alexandrinum, T. incarnatum,* and *Vicia faba* (3, 4, 6).

The possibility that BWYV may be a factor in the yellowing-type virus diseases of legumes and indeed potentially may cause commercial losses in North American legumes, prompted this study of the possible effects of BWYV on soybean, *Glycine max* (L.) Merr.

## MATERIALS AND METHODS

Isolates of BWYV originally from several sources (5, 7) were maintained in dry plant tissue. For activation of virus strains the dried tissue was ground in 0.05M phosphate buffer (pH 7.0) containing 0.01M glycine in the proportion of one part plant tissue (fresh wt) to one part diluent. These extracts were placed directly on density-gradient tubes, centrifuged 2 hr at 73,450 *g*, and, after dilution with buffer made up to 20% sucrose, the virus-bearing zones (18-26 mm from the top of the tubes) were fed to aphids (5).

Soybean cultivars were obtained from the U.S. Regional Soybean Laboratory, Urbana, Illinois.

Nonviruliferous green peach aphids, *Myzus persicae* (Sulz.), were reared on radish (*Raphanus sativus* L.). After an acquisition feeding period of 24 hr on BWYV-infected source plants [*Capsella bursa-pastoris* L. (Medic) (shepherd's-purse)], groups of approximately 25 aphids were transferred to each healthy soybean plant (cotyledon to unifoliate leaf-stage) and control plants, which were shepherd's-purse seedlings, and allowed to feed for 48 hr. Glass insect cages were used to confine aphids to individual plants in pots. After inoculation, all plants were sprayed with nicotine sulfate solution, and the greenhouse was fumigated weekly thereafter with 2, 2-dichlorovinyl dimethyl phosphate (dichlorvos) for insect control. In preliminary studies, recovery of virus from the inoculated soybean plants was attempted 4 wk after inoculation. Nonviruliferous aphids were placed on groups of young detached leaves from the cultivars for a 24-hr acquisition feeding, and then transferred to shepherd's-purse indicator plants for a 48-hr infection-feeding interval. Results indicated that there was variation in the susceptibility of individual plants; thereafter, recovery attempts were made from each individual inoculated plant to verify susceptibility.

## RESULTS

**Preliminary susceptibility tests.**—Two cultivars, Amsoy and Wells, selected by chance, were inoculated in preliminary studies to determine the possible susceptibility of soybean to BWYV. These tests, conducted in the greenhouse at Salinas during October, November, and December of 1974, resulted in little or no symptom expression on inoculated plants. There was no recovery of virus from inoculated plants of cultivar Amsoy and only from a few plants of cultivar Wells. These preliminary results indicated that soybeans were

susceptible to BWYV, but apparently not uniformly so, and that under some conditions no symptoms were expressed by infected plants. The results indicated that cultivars related to Wells should be studied more critically and that susceptibility should be determined on an individual-plant basis.

**Survey of soybean cultivars.**—Thirty-five soybean cultivars either related to or with a pedigree resembling that of Wells (Fig. 1) were evaluated for susceptibility to four strains of BWYV. Virtually all of the plants of some cultivars (Table 1) were susceptible; those of other cultivars apparently included both susceptible and immune plants or possessed an intermediate level of susceptibility which resulted in an apparent infectivity level of less than 100% of the inoculated plants; and other cultivars apparently were immune. There was no apparent difference among the virus strains in regard to infection or immunity in the soybean cultivars. There is always a possibility of error in any inoculating procedure involving aphids in both the inoculation feeding and recovery process. Only inoculations of soybean cultivars for which the control shepherd's-purse seedlings were 100% infected were considered in the totals. Control aphids from the same colonies but which did not have access to the virus were tested at each inoculation to ensure that no viruliferous aphids were in the stock colonies.

We believe that cultivars such as Beeson, which exhibited a high percentage of infected plants, probably are uniformly susceptible, but that others such as Kent and Harosoy in which a high number of plants apparently escaped infection either have segregated for susceptibility, have mixtures of susceptible or resistant seed, or possess an intermediate level of susceptibility.

The pedigree of cultivar Wells (2) is derived through Harosoy and Lincoln back to the original plant introductions Mandarin (P.I. 36.653 from Pehtuanlintza, Manchuria, 1911), and AK (Manchuria, 1912). All of these cultivars and all of the susceptible cultivars tested in this study have been derived from crosses that can be traced back to Mandarin and AK. There are several cultivars, including Shelby, Columbus, Protana, and Calland which (although they had Mandarin and/or AK in their pedigree) were not susceptible to BWYV. These probably were derived from $F_2$ or later generations, selected by chance, that were immune to the virus. In the one case in which both parents were immune (Blackhawk) the resulting cultivar was immune to BWYV.

**Symptoms.**—Symptom expression in the susceptible soybean cultivars differed in the greenhouse tests, ranging from those that were symptomless carriers to those that showed marked yellowing symptoms. The different responses of cultivars inoculated at different times of the year under varying light conditions may have been a source of variability in these tests that resulted in a poor comparison of their symptom expression. A high light intensity is necessary for optimum symptom expression in many plants infected with this yellowing virus. For example, it is virtually impossible to distinguish most BWYV strains on sugarbeet in the greenhouse.

In general, however, symptoms produced were of the same type: irregular chlorotic blotches produced 2-3 wk postinoculation on the interveinal areas of the intermediate-aged to older leaves. This was followed by

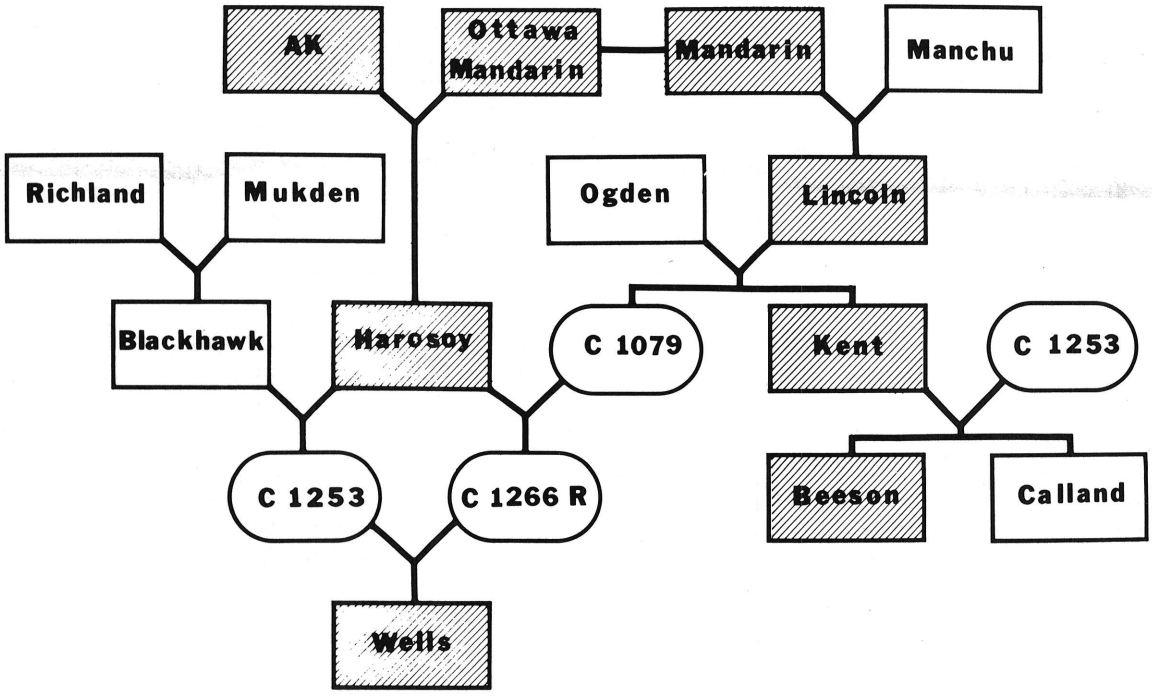


**Fig. 1.** Pedigree of soybean cultivar Wells and related cultivars. Shaded boxes indicate cultivars susceptible to beet western yellows virus and nonshaded boxes indicate immune cultivars. Ovals indicate breeding lines not tested for susceptibility.

various degrees of interveinal chlorosis and plant stunting.

Under conditions of fairly high light intensity in the Salinas greenhouses (September and October) the cultivars Wells and Kent were symptomless carriers. Good symptom development was shown by cultivar Beeson followed in order of decreasing severity by Lincoln, Cutler, and Pomona. Strain 7 induced the most severe yellowing on these cultivars followed in decreasing order by Strain 1, Strain 12, and Strain 9.

## DISCUSSION

A survey of 35 soybean cultivars showing a degree of relationship to the cultivar Wells has shown for the first time susceptibility and immunity to BWYV, a virus not previously known to affect this crop.

Nothing is known of the natural occurrence of BWYV in soybean. Although the crop has been studied extensively in California, it has not become commercially important in the State (1). No surveys to determine the incidence of BWYV in experimental plantings in California or in commercial acreages in other states have been made.

Thus far, the evidence obtained indicates that BWYV susceptibility in Wells probably was derived from the soybean introductions Mandarin and AK which were introduced to the U.S. in 1911 and 1912, respectively. The numerous crosses made from these original introductions have resulted in the development of a number of susceptible cultivars, including Pomona, which was released in 1974.

It is of interest that the two rogues or "off-types," the cultivars Fabulin and Ennis I, which were selected from the susceptible cultivar Lincoln, apparently are immune to BWYV.

A listing of the major ancestors of the currently grown cultivars of soybean in the United States (9) indicates that Mandarin was used more frequently (in 58% of the cultivars) than any other source and that it has contributed more maternal ancestry (74% of the northern cultivars, 51% of the major cultivars in the United States) than any other cultivar. Cultivar AK ranks second in both categories; it was used in 42% of the cultivars and has

TABLE 1. Susceptibility of selected soybean cultivars to four strains of beet western yellows virus (BWYV)

| | BWYV strain | | | | |
|---|---|---|---|---|---|
| Cultivar | ST-1 | ST-7 | ST-9 | ST-12 | Totals |
| Adams | 9/10[a] | 7/10 | 8/10 | 8/10 | 32/40 |
| Adelphia | 8/10 | 9/10 | 8/10 | 9/10 | 34/40 |
| AK | 9/10 | 10/10 | 6/10 | 9/10 | 34/40 |
| Amsoy | 0/24 | 0/24 | 0/24 | 0/24 | 0/96 |
| Beeson | 9/9 | 9/10 | 10/10 | 8/10 | 36/39 |
| Blackhawk | 0/20 | 0/20 | 0/20 | 0/20 | 0/80 |
| Calland | 0/10 | 0/10 | 0/10 | 0/10 | 0/40 |
| Chippewa | 0/10 | 0/9 | 0/9 | 0/9 | 0/37 |
| Clark | 0/10 | 0/10 | 0/10 | 0/10 | 0/40 |
| Columbus | 0/10 | 0/10 | 0/10 | 0/10 | 0/40 |
| Cutler | 6/9 | 4/10 | 6/10 | 8/10 | 24/39 |
| Dunfield | 0/10 | 0/10 | 0/10 | 0/10 | 0/40 |
| Ennis I | 0/10 | 0/10 | 0/10 | 0/10 | 0/40 |
| Fabulin | 0/10 | 0/10 | 0/10 | 0/10 | 0/40 |
| Ford | 0/10 | 1/10 | 2/10 | 3/10 | 6/40 |
| Grant | 9/10 | 8/10 | 10/10 | 9/10 | 36/40 |
| Harosoy | 0/20 | 0/20 | 1/20 | 2/20 | 3/80 |
| Illini | 9/10 | 8/10 | 9/10 | 8/10 | 34/40 |
| Kent | 12/20 | 9/20 | 10/20 | 14/20 | 45/80 |
| Lincoln | 9/10 | 7/10 | 8/10 | 10/10 | 34/40 |
| Manchu | 0/10 | 0/10 | 0/10 | 0/10 | 0/40 |
| Mandarin | 5/9 | 3/10 | 3/10 | 9/10 | 20/39 |
| Mandarin, Ottawa | 3/10 | 2/10 | 2/10 | 4/10 | 11/40 |
| Mukden | 0/10 | 0/10 | 0/10 | 0/10 | 0/40 |
| Ogden | 0/10 | 0/8 | 0/10 | 0/10 | 0/38 |
| Pomona | 10/10 | 10/10 | 7/9 | 7/9 | 34/38 |
| Protana | 0/10 | 0/10 | 0/10 | 0/10 | 0/40 |
| Richland | 0/10 | 0/10 | 0/10 | 0/9 | 0/39 |
| Seneca | 0/10 | 0/10 | 0/10 | 0/10 | 0/40 |
| Shelby | 0/10 | 0/10 | 0/10 | 0/10 | 0/40 |
| Wayne | 0/10 | 0/10 | 0/10 | 0/10 | 0/40 |
| Wells | 5/24 | 3/24 | 4/24 | 3/24 | 15/96 |
| Williams | 0/10 | 0/10 | 0/10 | 0/10 | 0/40 |
| Woodworth | 0/10 | 0/10 | 0/10 | 0/10 | 0/40 |
| Wye | 6/7 | 6/6 | 9/10 | 10/10 | 31/33 |
| Totals | 109/402 | 96/401 | 103/406 | 121/405 | 429/1614 |

[a]The numerator indicates the number of plants infected and the denominator, the number of plants inoculated.

contributed maternal ancestry to 23% of the major cultivars grown in the United States.

The existence of susceptibility and resistance in a crop to a pathogen probably indicates a long-time association of the two. The domestication of soybean took place in central east Asia (8). It is of interest that susceptibility and resistance to BWYV occurred in these cultivars, first introduced into the United States over 65 years ago. This could indicate that active selection for resistance to BWYV took place in Asia prior to the present century, and that this resistance was carried on without knowledgeable manifestation until the present investigations.

Beet western yellows virus induces yellowing diseases of several economically important leguminous crops including pea *(Pisum sativum), Trifolium alexandrinum, Trifolium incarnatum, Vicia faba* (3, 4, 6), and soybean. It is highly probable that this virus has occurred and still does occur on these species in nature and that the disease induced is at least a portion of the yellowing complex on legumes in various parts of the world. Indeed, the similarities of some of these diseases to BWYV, for example, soybean dwarf virus (10) indicates that they may even be strains of BWYV.

Further work is continuing on the natural occurrence of BWYV in soybean and the economic significance of the disease, as well as the inheritance and nature of resistance and possible relationships of BWYV to other viruses that infect legumes.

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