Incidence and Effects of Beet Western Yellows Virus in Western Oregon Sugarbeet Seed Crops

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ABSTRACT

A 1986 to 1995 survey of beet western yellows luteovirus (BWYV) in western Oregon crop and weed species demonstrated that BWYV was endemic in at least 30 plant species. Because sugarbeet-seed crops (*Beta vulgaris* L.) were sometimes perceived as the primary western Oregon source of BWYV inoculum, we sought to examine all components of the inoculum reservoir. The array of BWYV hosts in western Oregon provided a year-round supply of BWYV inoculum comprising three interactive sub-reservoirs: (a) widespread annual, winter annual, and perennial weeds, (b) BWYV-susceptible vegetable crops, including garden beet, lettuce, spinach, Swiss chard, and turnip, and (c) sugarbeet-seed crops. We defined zones of high and low BWYV incidence in sugarbeet-seed fields within western Oregon, and monitored incidence of BWYV in a common weed species, *Brassica campestris* L. (field mustard). We demonstrated abrupt variations in BWYV incidence in sugarbeet-seed plantings in the vicinity of Corvallis near the Willamette River. BWYV incidence in sugarbeet-seed fields increased in localities where sugarbeet-seed crops were grown successively. Although marked differences in seed yields were observed, no reduction in sugarbeet seed yield was attributable to BWYV infection.

Additional Key Words: weeds, vegetable crops, BWYV, alternate hosts

The Willamette Valley of Oregon has been a premier U.S. sugarbeet-seed (*Beta vulgaris* L.) production area for almost 60 years. For an even longer period, crops of fresh and processing vegetables have been grown in the same region. Sugarbeet and several vegetable crops, particularly lettuce and spinach, are susceptible to beet western yellows luteovirus (BWYV) (Duffus, 1960; Duffus, 1972; Hampton et al., 1990). The inoculum reservoir of BWYV in western Oregon also includes several weed species common to sugarbeet-seed and vegetable cropping systems (Hampton et al., 1991; Hampton et al., 1998; see also Wallis, 1967b, Duffus, 1971; Tamaki, 1975; Tamaki and Fox, 1982; and Ellis, 1992), resulting in a continuous source of BWYV inoculum accessible to one or more of the six indigenous aphid species known to be vectors of this virus (Hampton and Jensen, 1998). In essence, the western Oregon BWYV pathosystem (Hampton et al, 1998) comprises three distinct sub-reservoirs of BWYV: BWYV-susceptible vegetable crops, BWYV-susceptible weed species, and sugarbeet-seed crops, each interacting with aphid vector phenologies and annual cycles of the BWY disease.

Although the green peach aphid, *Myzus persicae* (Sulzer), is the most-investigated vector of BWYV (Duffus, 1960; Wallis, 1967a; Tamaki, et al., 1979; Tamaki et al., 1982), five additional BWYV-vector aphid species occur in western Oregon (Hampton and Jensen, 1998) on one or more of the 30 weed and crop species infected by BWYV (Hampton et al., 1998): *Aphis gossypii* Glover, *Aulocorthum solani* (Kaltenbach), *Brachycaudus helichrysi* (Kaltenbach), *Brevicoryne brassicae* (L.) and *Macrosiphum euphorbiae* (Thomas).

Taking into account elements of the western Oregon agro-ecosystem that bear upon the seasonal spread of BWYV among the three inoculum sub-reservoirs, we measured the incidence of the virus in sugarbeet-seed fields selected to represent the Willamette Valley region, in which the principal U.S. sugarbeet-seed crop is produced annually. We attempted to identify localities of repeatedly low and high BWYV incidence, to determine the relationship of BWYV incidence in sugarbeet-seed fields to infected weed species and to sugarbeet-seed cropping history, and to estimate the influence of BWYV on sugarbeet seed yields.

MATERIALS AND METHODS

Sugarbeet-seed fields were selected during 1986 through 1995 as representative of the Willamette Valley (Johanson and Burt, 1970). Five of the 1992 locations were 0.5 to 4 km from the Willamette River and five were 9 to 30 km from the river (Table 1). Since sugarbeet-seed crops are never grown successively in the same field, locations chosen for 1993-95 studies were as close as practicable to the 1992 fields.

Table 1. Locations and attributes of ten sugarbeet-seed fields investigated in 1992, Willamette Valley of western Oregon

Field No./† Location	River Proximity‡	BWYV Severity Index (0-100)§	BWYV-suscept.§§ Weed Incidence	Seed Yield 100 wt/acre (Kg/HA)
1, Corvallis	2 km SE	6	Low	28.7 (3,220)
51, Jefferson	12 km W	9	Low	37.9 (4,250)
53, Stayton	25 km W	39	High	23.8 (2,670)
82, Salem	9 km W	25	Medium	30.2 (3,380)
60, Marquam	30 km W	16	Med-High	8.0 (900)
11, Woodburn	19 km W	40	Low	34.6 (3,880)
70, Newberg	0.5 km S	20	Med-High	20.0 (2,240)
102, St. Paul	2 km W	46	High	28.7 (3,220)
3 3, Wheatland	0.5 km W	42	High	22.6 (2,530)
39, Rickreall	4 km SE	11	High	33.4 (3,740)

†Field numbers, from West Coast Beet Seed Company production records, are designated by names of the nearest town/city.

‡Distance and direction of Willamette River from sugarbeet-seed field.

§Severity index is the sum of products of the BWYV incidence (%) and a weighted factor (2.5 to 1.0) based on date of infection, January to May. The high severity index for Field 53 is attributable to its high January incidence of BWYV (Fig. 1) relative to other fields.

§§Relative incidence of BWYV-susceptible weed species in or near the sugarbeet-seed field.

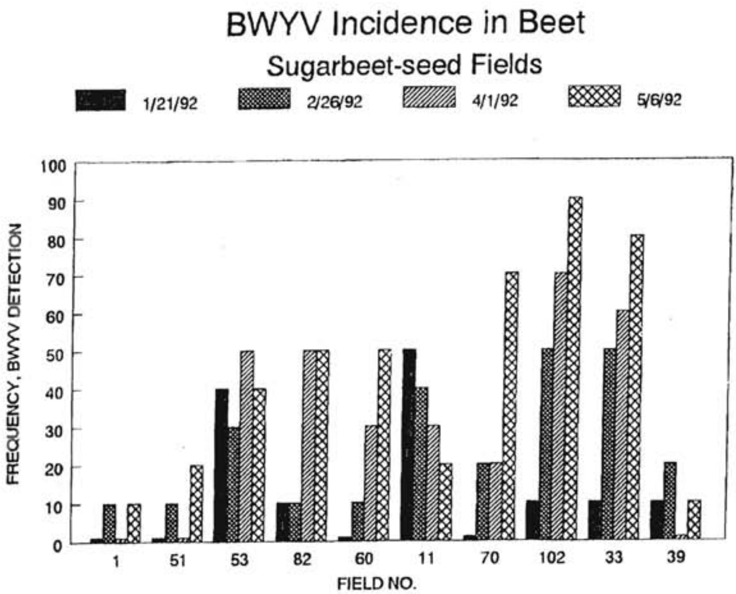

Fig. 1. Incidence of beet western yellows luteovirus (BWYV) in 10 Willamette Valley sugarbeet seed fields, January to May, 1992. Zero detections of virus were registered as 1%, for graph visibility.

To determine the incidence of BWYV in sugarbeet-seed fields, 10 to 20 leaf samples were taken repeatedly in 1992 within a representative 30 by 60 meter sampling area of each field. Leaves were stacked in the order sampled, labeled, wrapped in plastic, placed in a cold box, and taken to the laboratory. Disks of leaf tissue were removed from each leaf, numbered, triturated in ELISA (enzyme-linked immunosorbent assay) extraction buffer (Converse and Martin, 1990), appropriately diluted in that buffer, the extract placed into duplicate wells of microtiter plates with standardized BWYV-specific immunoglobulin G (antiserum kindly provided by P.E. Thomas, USDA ARS, Prosser, WA), and incubated overnight at 4 C. Tests were concluded on the following day after appropriate incubations, according to the two-step ELISA procedure described by Kaniewski and Thomas (1988). Each microtiter plate contained a positive control (extract from desiccated/frozen BWYV-infected turnip leaf tissues), a negative control (extract from virus-free sugarbeet leaf tissues), and a buffer control of ELISA extraction buffer. Positive and negative reactions were measured by a statistical reaction threshold, as described by Hampton (1982); however, few ELISA reactions required reference to minimal threshold values.

BWY-disease-severity indices (DSI) were calculated for 10 fields studied in 1992 for comparisons with corresponding sugarbeet-seed yields, and were based on evidence that early BWYV infection restricts sugarbeet root development to a greater extent than late infection (Tamaki et al., 1978). The DSI incorporated weighted "earliness-of-infection factors" of 2.5 to 1.0 for four sampling dates, at five-week intervals, between 21 January and 6 May.

DSI = (% I, Jan)(2.5) + (% I, Feb)(2.0) + (% I, Apr)(1.5) + (% I, May)(1.0) x 1/7, where "% I" is the estimated BWYV incidence per field, per sampling date and 7 is the sum of the four earliness-of-infection factors

DSI values thus calculated potentially range from 0 to 100. A DSI value for each field was calculated. The ten fields were then arrayed geographically (Fig. 1 and 2) and ascribed DSI values, with corresponding seed yields (Table 1). Comparisons of seed yields among these ten fields, expressed as 100-wt per acre and kg per hectare, were based on West Coast Beet Seed Company production records.

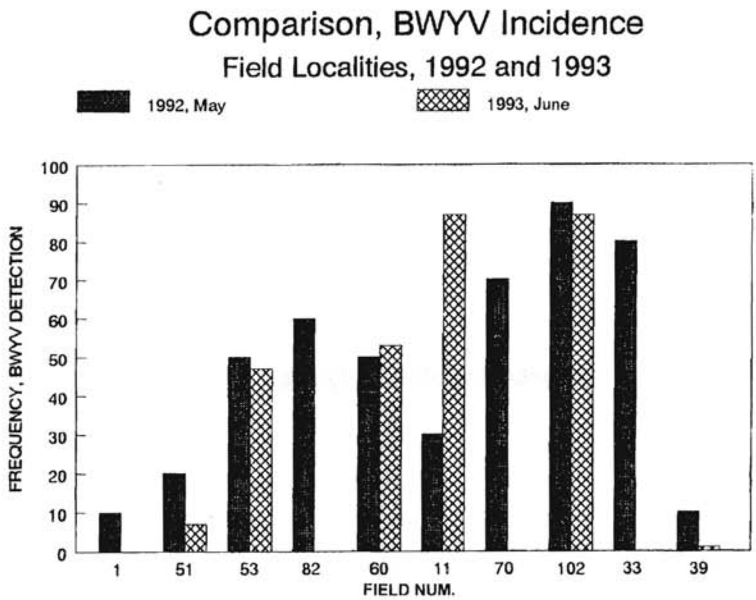

Fig. 2. Beet western yellows luteovirus (BWYV) incidence in the localities of 1992 fields, generally confirming in 1993 the zones of low- and high-BWYV incidence.

Linear regression was employed to assess the relationship between BWYV incidence and sugarbeet-seed cropping history. The relationship between beet western yellows (BWY) disease severity indices and sugarbeet seed yield was investigated by correlation analysis.

RESULTS AND DISCUSSION

ELISA-based estimates of seasonal BWYV incidence in ten 1992 sugarbeet-seed fields (Table 1; Fig. 1 and 2) indicated that: (a) the numbers of plants collected per field (10 to 20), per sampling date, yielded generally reproducible estimates of BWYV incidence, (b) BWYV was detectable in six of the ten fields by the third week of January (i.e., all but Fields 1, 51, 60, and 70), (c) the distribution of BWYV in western Oregon was zonal in both 1992 and 1993, with a roughly south-to-north gradient of increasing BWYV (plus a lesser NE to NW gradient of increasing BWYV), (d) there was a lower, season long 1992 incidence of BWYV in sugarbeet-seed Fields, 1 (Corvallis), 51 (Jefferson), and 39 (Rickreall) than in other tested fields, and (e) increased BWYV incidence was associated with river proximity only where sugarbeet-seed fields were planted less than 2 km from the Willamette River.

BWYV incidence in sugarbeet-seed fields.

Ten 1992 sugarbeet-seed fields (Fig. 1) could be grouped into three categories according to the incidence of BWYV: Low, 10 to 20% (Fields 1, 51, and 39); Intermediate, 40 to 50% (Fields 53, 82, 60, and 11); and High, 70 to 90% (Fields 70, 102, and 33). In the intermediate and high categories, an increase in BWYV incidence occurred between 21 January and 6 May, except in Fields 11 (Woodburn) and 53 (Stayton). We conclude that the BWYV incidence at these two sites was essentially unchanged during this period, with differences attributable to sampling variation. In the case of Field 11, with the highest January incidence of BWYV, we believe the apparent decrease in BWYV incidence was attributable to the gradual overgrowth of early-infected plants by healthy plants, causing them to be less accessible on post-January sampling dates.

Zonal distribution of BWYV in western Oregon.

Three fields in southern and southwestern Willamette Valley locations (Corvallis, Jefferson, and Rickreall), comprised a zone of low BWYV incidence during 1992 and 1993 (Fig. 1 and 2). Fields 11, 102, and 33, arrayed along the Willamette River near Newberg, St. Paul, and Wheatland, Oregon, respectively, comprised a zone of high BWYV incidence. Sugarbeet was planted at only one of these three locations in 1993, (St. Paul; Fig. 2), allowing us to observe only the center of this zone of high BWYV incidence during 1993. Field 11, intermediate in BWYV incidence in 1992, was heavily infected by June 1993, suggesting an eastward extension of the 1992 zone of high BWYV incidence (eastward from Field 102 or 33 by 18 km).

Generally, however, no apparent association was observed between proximity of sugarbeet-seed fields to the Willamette River and seasonal incidence of BWYV in 1992 (Table 1; Fig. 1). Fields 1, 39, and 102, of contrasting BWYV incidences, were all within 4 km of the river; Field 60, of intermediate BWYV incidence, was 30 km from the river.

Field 53, classed as intermediate in BWYV incidence, exhibited unusual within-field variability on 1 April. Supplementary April samples from three locations within this field yielded BWYV infection frequencies of 90%, 20% and 40%, necessitating use of the average (50%) for the April incidence of BWYV (Fig. 1). Upon verification that this field contained diverse sugarbeet genotypes, we confined the subsequent 6 May sampling to a single, widely used sugarbeet variety, whose BWYV incidence closely conformed to the infection trends of January and February samples.

Incidence of BWYV in weed and other crop species

The following 29 plant species/forms other than sugarbeet contained BWYV during the course of these studies (BWYV-hosts not previously reported, underlined; proportions found BWYV-infected in parentheses; see illustrations of BWYV-induced yellows symptoms, Hampton et al., 1998): *Amaranthus blitoides* Wats. (5/8), *A. powellii* Wats. (13/16), *Anthemus cotula* L. (16/24), *Arctium minus* (5/12), *Beta vulgaris*, garden beet (40/66); *B.* vulgaris var. *cicla* L. (4/5), Brassica *campestris* L. (44/174), *B.* nigra (L.) Koch (2/6), B. *oleracea* var. *italica* Plenk. (16/20), *B. rapa* L. (9/18), *Capsella bursa-pastoris* (L.) Moench. (1/26), *Cirsium arvense* (L.) Scop. (10/32), *Crepis setosa* Hal.f.. (4/10), *Erodium circutarium* L'Her. (6/7), *Geranium dissectum* L. (2/6), *Lactuca sativa* L. (28/41), *L. serriola* L. (10/32), *Phaseolus accutifolius* var. *latifolius* Freem. (3/5), *Pisum sativum* L. (30/39), *Raphanus sativus* L. (14/40), *Senecio vulgaris* (10/22), *Sonchus oleraceus* L. (2/3), *Spinacea oleracea* L. (33/52), *Stelaria media* (L.) Cyr. (1/80), *Tetragonia expansa* Murr. (5/8), *Trifolium pratense* L. (10/12), *T. subterraneum* L. (13/15), *Vicia faba* L. (8/17), and *V. sativa* L. (1/5)

No ELISA-detectable BWYV occurred in samples of the following plant species (reported BWYV hosts underlined; no. plants tested in parentheses): *Brassica caulorapa* (6), *Cardamine oligosperma* (10), *Cerastium vulgatum* (11), *Convovulus arvensis* (12), *Daucus carota* (21), *Echinocystis oregana* (2), *Epilobium angustifolium* (3), *Euphorbia lathris* (2), *Hypocharis radicata* (6), *Matricaria matricaroides* (10), *Plantago major*

(6), *Polygonum aviculare* (4), *Portulaca oleraceae* (5), *Radicula armoracia* (10), *Senecia jacobeae* (6), *Sisymbrium officinale* (7), *Solanum nigrum* (8), *Sonchus arvensis* (6), *Sonchus asper* (6), *Taraxacum officinale* (6), *Trifolium repens* (2), and *Veronica persica* (9). In all cases, these species/forms were sampled principally at locations where sugarbeet, other crops, or other weed species were infected with BWYV. Failure to detect BWYV in the above species could have been due to small numbers of plants available for testing, to plants having escaped vector inoculation, to limitations of host-specific vectors, or to inherent plant biotype immunity to BWYV.

Association between BWYV-infected weed species and sugarbeet-seed fields.

The precipitous increases of BWYV-infected beet plants in the fields near St. Paul and Wheatland between 21 January and 26 February (Fig. 1) indicated that BWYV had spread dramatically during this period. We thus immediately sampled and tested resident weed species that were potential hosts of BWYV. The BWYV hosts common to these sites were *Anthemus cotula* (dog fennel), *Brassica campestris* (field mustard), *Raphanus sativus* (wild radish), *Senecio vulgaris* (groundsel), and *Sonchus oleraceus* (common sowthistle). The incidence of BWYV among plants of these species ranged from 33% to 56% in Field 102 and from 50% to 90% in Field 33, which was the highest concentration of BWYV-infected weed plants encountered during these studies.

The high incidence of BWYV in field weed species at these locations in late February, relative to that of proximal sugarbeet plants on January 21, suggests the possibility that this reservoir of BWYV (Hampton et al., 1998) provided inoculum for aphid transmission of the virus to sugarbeet in January-February 1992. All of these weed species are capable of behaving as winter annuals in western Oregon, and can be present with sugarbeet plants from emergence to maturity.

Aphid species that are recognized vectors of BWYV and known to occur on one or more of these weed species in western Oregon (Hampton and Jensen, 1998) are *Aphis gossypii* Glover, *Brachycaudis helichrysi* (Kaltenbach), *Brevicoryne brassicae* (L.), *Microsiphum euphorbiae* (Thomas), and *Myzus persicae* (Sulzer). A sixth aphid vector of BWYV, *Aulocorthum solani* (Kaltenbach), also occurs in western Oregon on other BWYV-host species, including cut leaf geranium, lettuce, pigweed, red clover, red stem filaree, and spinach (Hampton and Jensen, 1998).

The dynamics and sequence by which weed and crop species become BWYV-infected undoubtedly depend on temporal and local-climatic influences, on aphid vector species present and their distinctive phenologies, and perhaps on other factors (Hampton et al., 1998). As a case in point, BWYV-susceptible weed species were abundant in and around Field 39 (Table 1; Fig. 1 and 2); however, most weeds and sugarbeet plants in this field remained remarkably free of BWYV during 1992 and 1993. The zonal distribution of BWYV in sugarbeet-seed fields suggested an inherently limited BWYV inoculum accumulation in the southwestern Willamette Valley.

Distribution of BWYV in field mustard

Among the weed species commonly infected with BWYV in western Oregon (Hampton et al., 1991; Hampton et al., 1998), field mustard (*Brassica campestris*) is one of the most omnipresent. In April 1991, field mustard was sampled from seven sites between Corvallis and Washougal, WA (Fig. 3), a distance of 132 km. The two northern-most sites were chosen as "exit points" for east-to-west air currents from the Columbia Gorge and for possible east-to-west migratory flights of the green peach aphid from eastern Washington orchards (Tamaki et al., 1978; Tamaki et al., 1979; Tamaki et al., 1980; Wallis, 1967a and 1967b). Higher BWYV incidence in field mustard from these locations compared to other Willamette Valley sites could suggest viral spread by such aphid flights.

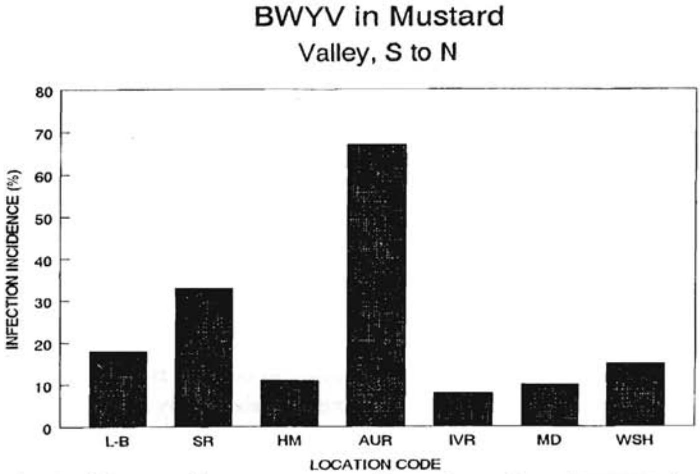

Fig. 3. Incidence of beet western yellows luteovirus (BWYV) in field mustard (weed; *Brassica campestris*), in a south-to-north, 132-km transect of the Willamette Valley. Location codes are: L-B, Lewis-Brown Farm, Oregon State University, 6.5 km SE of Corvallis; SR, Santiam River, near crossing of Interstate Highway I-5; HM, vicinity of Hopmere; AUR, vicinity of North Willamette Research and Extension Center, Aurora; IVR, vegetable-production field W of AUR; MD, vegetable-production area near Marine Drive, east Portland; WSH, vicinity of Washougal, Washington.

BWYV-detection data from these samples, however, suggested no relationship between Columbia River-associated air currents and the distribution of BWYV in wild mustard (Fig. 3). Rather, ELISA data from the 125 plants indicated that plants from the two northern-most sites (Washougal and Marine Drive) were infected at rates of only 15% and 9.5%. BWYV incidence was highest (67%) in plants from the Aurora vicinity. Of 21 plants collected there, 11 exhibited red-basal-leaf symptoms characteristic of BWYV-infected *Brassica campestris* plants (Hampton et al., 1998), and 10 were asymptomatic. Extracts from all 11 symptomatic plants produced strong-positive ELISA values, whereas only three of 10 asymptomatic plants contained ELISA-detectable BWYV (14/21 = 67%). Interestingly, the highest incidences of BWYV in vegetables (Hampton et al., 1990), sugarbeet (Fig. 1, 2) and weeds (Hampton et al., 1991) occurred within 20 km of Aurora. Aurora is located 18 km east of the 1992 zone of highest BWYV-infection of sugarbeet (i.e., Fields 33, 70 and 102, Fig. 1) and 12 km north of Field 11, the location of highest BWYV incidence in June 1993 (Fig. 2).

The Santiam River sampling locality, where 33% of the field mustard plants were BWYV-infected (Fig. 3), was unique in being sparsely cropped and the only location in the Willamette Valley where common vetch (*Vicia sativa* L.) was infected with BWYV. Although *Vicia faba* L. is a recognized host of BWYV (Duffus, 1971), we know of no prior report of BWYV in *V. sativa*. Ellis (1992) reported BWYV in an unidentified field species of *Vicia.*

Temporal variability in BWYV incidence in the Corvallis vicinity

Despite a neutral relationship between BWYV incidence and sugarbeet-field proximity to the Willamette River in 1992 (Table 1; Fig. 1), a 10-year variability of BWYV incidence in the vicinity of Corvallis deserves further comment. In the seven-year period, 1986 to 1992, no sugarbeet-seed field in this area was found to contain BWYV at an incidence exceeding 15% (Fig. 4). However, an aberrantly high (80%) incidence of BWYV occurred there in 1994, prompting additional tests in 1995. The fields available for sampling in 1986 to 1992 were at least 2 km from the river, whereas the field sampled in 1994 was 400 m from the river. Factors other than river proximity could have contributed to this much higher BWYV incidence in 1994 than in prior years. However, temperature-dependent, low-velocity air flows along the river may have channeled aphid flights, thus increasing the probability that sugarbeet fields very near the river would have higher populations of BWYV-infective aphids, e.g., cool-air movement downward during evening-night and warm-air movement upward during morning-afternoon.

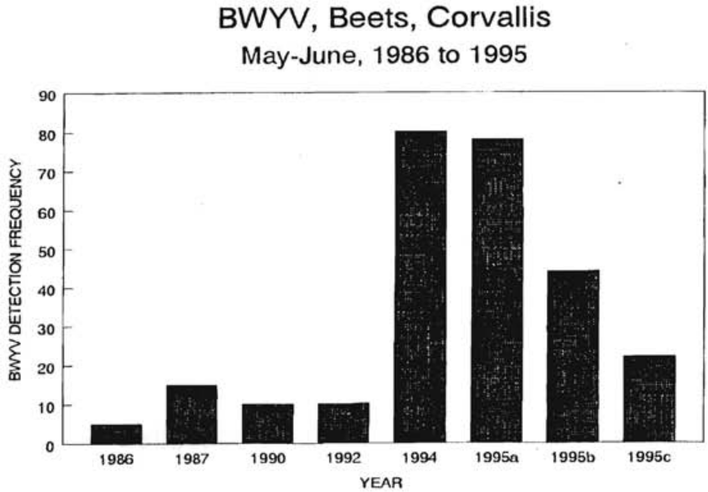

Fig. 4. The beet western yellows luteovirus (BWYV) incidence in the 1992 Field-1 locality (see Table 1) during 1986 to 1992 differed markedly from that of 1994. The variable 1995 incidence of BWYV within the same field (1995a, b, c) was measured in three transections of the field, perpendicular to the Willamette River.

The field sampled in 1995 paralleled the river for 520 m at a distance of 80 m. This field was sampled along three 100-m transections 130 m apart, evenly spaced along its length (see Fig. 4; 1995a, b, c). The BWYV-incidence variability among the three field transections (78%, 44%, and 21%) approximated the variability among fields in this vicinity in prior years, suggesting localized influences in the aphid dissemination of BWYV. The localized 78% BWYV incidence closely approximated the 80% incidence measured in the prior year, in a field 500 m southwest of this site, along the river.

Relationship between sugarbeet-seed cropping history and locality-incidence of BWYV.

In 1994, 10 Willamette Valley sugarbeet fields were selected to represent durations of sugarbeet cropping history (Fig. 5a). Each field represented a locality where sugarbeet-seed crops had been grown for 3 to 50 years. From each field, 10 plants were sampled as previously described on 13 May and assayed for BWYV. The differences among fields suggested increases in BWYV-infection rates with increasing durations of sugarbeet-seed production from 3 to 35 years (Fig. 5a), particularly when BWYV incidence for the 4-year sugarbeet-cropping duration was averaged among three 4th-year fields (Fig. 5a: 4-1, 4-2, and 4-3). When configured with this 4th-year average, these data (Fig. 5b) demonstrated a significant linear trend of increased BWYV incidence between 0 and 35 years [Y = 23.3 = 2.5X, where Y is the estimated BWYV incidence value and X is duration of sugarbeet-seed cropping, with $R^2 = 0.918$]. Thus, 92% of the observed BWYV-incidence increase among these fields/localities was explainable by increasing durations of sugarbeet-seed cropping within localities. Reliability of these statistics assumes that the fields available for study were representative of Willamette Valley localities cropped to sugarbeet seed for 3 to 35 years. We offer no rationale for an apparently reduced effect of prolonged cropping, beyond 35 years.

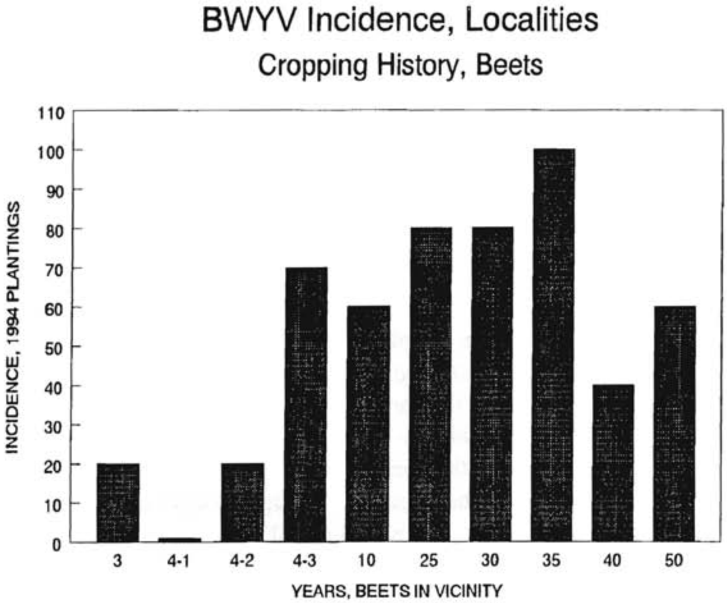

Fig. 5a. Relationship between beet western yellows luteovirus (BWYV) incidence and continuity of sugarbeet-seed cropping in Willamette Valley localities, 3 to 50 years. Three localities that had been cropped to sugarbeet-seed crops for 4 years, 0, 20%, and 70% BWYV incidence, are represented as 4-1, 4-2, and 4-3.

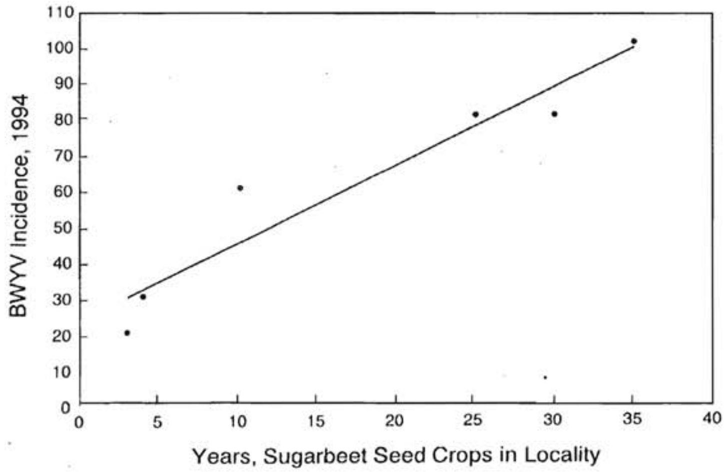

Fig. 5b. Same relationship 3 to 35 years, depicted linearly, using the average (30%) for 4th-year plantings. Linear equation: ˜ = 23.3 + 2.15X; $P<0.05$; $R^2 = 0.918$.

This cause-effect relationship was concluded to be attributable to accumulating BWYV inoculum in all susceptible plant species within localities, not only in sugarbeet. In this context, it was interesting to learn in 1996 that 15 of the 19 sugarbeet-seed growers involved in our 10-year study also grew BWYV-susceptible vegetable crops, as part of their crop rotation. With the expectation that BWYV would also accumulate in susceptible weeds, BWYV probably increased in all three interactive inoculum sub-reservoirs (Hampton et al., 1998).

Relationship between beet western yellows disease severity and sugarbeet-seed yields

For a cursory view of this relationship, 1992 BWYV severity indices (DSI's; see Methods) from 10 sugarbeet-seed fields (Fig. 1) were arrayed in descending order of BWYV severity (Fig. 6). This array of DSI's was then matched with corresponding yield data (100 wt/A; kg/HA; Table 1). Although the lowest DSI's, Fields 39, 51, and 1, were associated with marginally higher seed yields, little effect of BWYV on yield was indicated. For example: (a) seed yields among the five fields with the highest DSI's ranged from 2530 to 3880 kg/ha; (b) although the DSI value for Field 102 was the highest of ten fields, its per-acre seed yield exceeded that of Fields 33 or 53; and (c) the seed yield of Field 60 was 30% that of Field 102, despite having a DSI that was 35% that of Field 102.

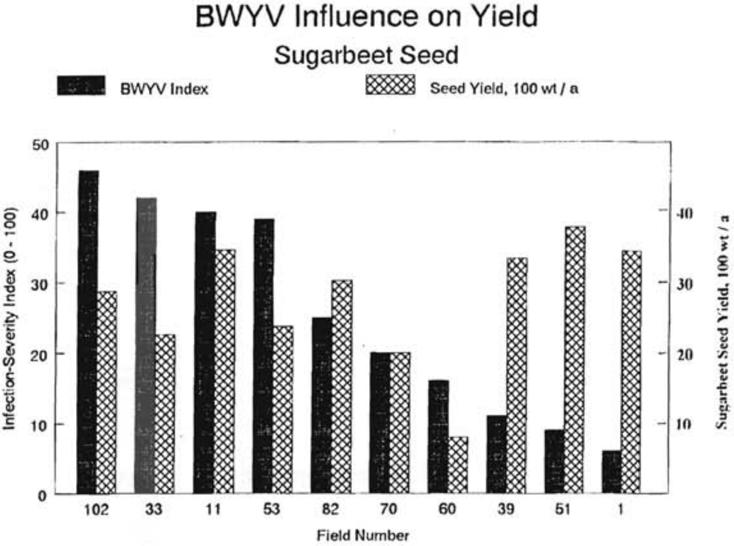

Fig. 6. Relationship between beet western yellows disease severity index (DSI) and associated sugarbeet seed yields. DSI values for each sugarbeet-seed field were arrayed from left to right in descending order, with corresponding seed yields. Correlation coefficient: r = –0.140*.

The correlation between DSI and seed yield did not differ significantly from zero (r = –0.14, P>0.05, n=10). The negative value of "r" reflects the average yield of 3,140 kg/ha for five fields with DSI's of 25 to 46, compared to an average yield of 2,990 kg/ha for the other five fields with DSI's of 6 to 20. The extent to which seed yields from Fields 39, 51, and 1 (average yield 3,950 kg/ha) were attributable to low BWYV incidence or low BWYV severity indices cannot be known from these studies.

Although we know of no prior estimates of BWYV-induced seed-yield reduction, Duffus (1961) reported that BWYV reduced sugarbeet root yield by 14.6% and sugar yield by 19%. Tamaki et al. (1978) found similar BWYV-induced reductions in sugarbeet root weights and sugar content, whereas Lewellen & Skoyen (1984) reported sugar-yield reductions as high as 36%. Tamaki et al (1978) determined that roots of plants BWYV-inoculated in May yielded 10% less sugar than those inoculated in June.

CONCLUSIONS

The location of sugarbeet seed fields in the Willamette Valley of Oregon, including locality-related BWYV inoculum sources, appeared to influence the extent to which sugarbeet-seed fields became infected by BWYV (Fig. 1 and 2).

Although infested with BWYV-susceptible weed species, sugarbeet-seed Field 39 (Rickreall) (Table 1) had fewer BWYV-infected sugarbeet plants and weeds than Fields 102 and 33 located in the far-northwest sector of the Willamette Valley (St. Paul and Wheatland). Cursory tests near Field 11 (Woodburn) suggested the same relationship: Lower incidence of BWYV in susceptible weeds was associated with a lower BWYV incidence in sugarbeet plants within localities.

The most severely BWYV-infected fields studied in 1992 (Fields 33, 60, and 102) were located within 0.5, 0.5, and 2 km of the river, respectively. Other studies suggested that only very close proximities of sugarbeet-seed fields to the Willamette River predisposed them to higher BWYV infection rates: (a) two of four 1992 sugarbeet-seed fields located within 4 km of the Willamette River (Fields 1 and 39) and were nominally infected with BWYV (Table 1; Fig. 1 and 2), and (b) the 10-year variability in BWYV incidence in the Corvallis vicinity (Field 1, Fig. 1 and 4), suggested that proximities of less than 1 km subjected sugarbeet plants to greater BWYV inoculum exposure than those located approximately 4 km from the river.

In the 1991 south-to-north plant-sampling transect of the Willamette Valley, the incidence of BWYV in field mustard (weed) plants was highest in the vicinity of Aurora (Fig. 3). An aphid vector of BWYV, *Myzus persicae*, occurs on field mustard (*Brassica campestris*), radish (*Raphanus sativus*), and sugarbeet in western Oregon (Hampton and Jensen, 1998). Both *M. persicae* and a second vector of BWYV, *Brevicoryne brassicae*, occur on field mustard and cruciferous vegetable crops [turnip (*Brassica rapa*) and broccoli (*B. oleracea* var. *italica*)] in western Oregon. Thus multidirectional transmissions of BWYV in the Aurora area could involve field mustard, vegetable crops, and/or sugarbeet-seed crops.

The trend toward higher BWYV incidence in vicinities where sugarbeet-seed crops had been planted repeatedly up to 35 years was significant (Fig. 5) ($R^2 = 0.918$).

On the basis of BWYV-severity indices in 1992 sugarbeet fields, no relationship between the incidence of BWYV and sugarbeet seed yields was detected (Fig. 6).

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