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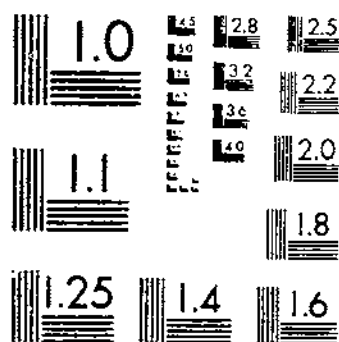
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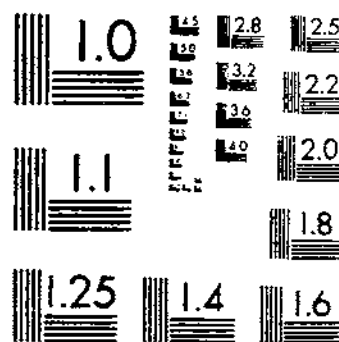
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ECOLOGY OF THE GREEN PEACH APHID AS A VECTOR OF BEET WESTERN YELLOW
IAMAKIS G. FOX L. BUIT, B. A. 1 OF 1

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ECOLOGY OF THE GREEN PEACH APHID AS A VECTOR OF BEET WESTERN YELLOWS VIRUS OF SUGARBEETS

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ABSTRACT

George Tamaki, Lee Fox, and B. A. Butt. Ecology of the Green Peach Aphid as a Vector of Beet Western Yellows Virus of Sugarbeets. U.S. Department of Agriculture Technical Bulletin No. 1599, 16 p., 1979.

Green peach aphids (GPA), *Myzus persicae* (Sulzer), overwinter in the Yakima Valley primarily as eggs on peach trees. They can also overwinter as viviparae in deep irrigation drainage ditches on weed host plants. Successful overwintering in the latter case appears to be correlated with the severity of the winter.

Four field evaluation sites were used to determine the occurrence of the first migrant winged GPA, the percentages of viruliferous winged GPA, and the intensity of spread of beet western yellows virus (BWYV), a yellowing disease of sugarbeets. In the 3 years of the study, 1975-77, the earliest collection of winged migrant GPA was on April 26, 1977, at the peach orchard trapping site, whereas the latest initial collection was on June 9, 1977, at the drainage site area. The earliest winged viruliferous GPA in the 3-year study were collected on May 6, 1976, at the drainage ditch site after a mild winter, but for the severe winters of 1975 and 1977, the initial trapping was delayed until June 22 and 24, respectively. The weekly percentage of viruliferous winged GPA ranged from 0 to 100. The time of steady high percentage of viruliferous GPA occurred at all evaluation sites during the winged population peak in June and July.

In 1975, about 75 percent of the indicator plants

at each site were infected with BWYV beginning the third week of June and through July. At the drainage and intermediate sites infection was cyclic, but at the orchard and station sites the infection rates continued high throughout the summer. In 1976, the infection was the same for all sites, but peak infection (100 percent) occurred only during July. In 1977, only the early season infection rate was studied. At that time, the orchard site alate (winged) aphid population showed an infection rate of 25 percent by mid-June.

These data on the activity periods of viruliferous GPA at the different field sites allowed us to suggest modification of chemical application timing to commercial sugarbeet fields. In most years, the first two of the three presently recommended chemical applications could be eliminated. Data indicate that only after a mild winter might it be necessary to treat sugarbeet fields as early as the first week of May and then only those fields near the drainage ditches.

KEYWORDS: Beet yellows virus, beet western yellows virus, green peach aphid, insect trapping, sugarbeet diseases, yellowing diseases.

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ECOLOGY OF THE GREEN PEACH APHID AS A VECTOR OF BEET WESTERN YELLOW S VIRUS OF SUGARBEETS

By George Tamaki, Lee Fox, and B. A. Butt¹

INTRODUCTION

In the Western United States, the two major virus yellows diseases on sugarbeets, *Beta vulgaris* L., are beet yellows virus (BYV) and beet western yellows virus (BWYV). BYV was the first component separated from the yellowing disease complex in Europe (17, 25).² It was positively identified as being present in the United States in 1951 (4). BWYV, the second component, was identified by Duffus (5) and is the most common and serious yellowing disease of sugarbeets in the Northwest.

When comparing sugarbeet yield losses caused by both virus yellows diseases, Shepherd et al. (18) reported BYV losses at 35 percent and BWYV at 6 percent, whereas Bennett and McFarlane (2) reported BYV losses at 35 percent and BWYV losses as high as 20 percent. Duffus (6) reported BYV losses at 16.6 percent and BWYV losses at 14.5 percent. In all these California studies, BYV caused the greater yield losses; however, BWYV is of greater economic importance because it is more prevalent than BYV in the United States (8) and because it infects weed hosts that serve as important virus sources. On the other hand, weed hosts are not an important overwintering source of BYV, sugarbeets being the principal source (1). Thus, the beet-free period in California (7, 10) has greatly reduced BYV in that State. BWYV causes stunting and

chlorosis in a wide range of dicotyledonous species (over 146 in 23 families). In sugarbeets, it causes a reduction in both root yield and percentage of sugar.

The green peach aphid (GPA), *Myzus persicae* (Sulzer), is the most important and efficient vector of BWYV. It has a minimum acquisition feeding period of 5 min, and a 10-min inoculation feeding period. The aphid retains the virus for life (5).

In the Yakima Valley, the major overwintering source of the GPA is its primary host, the peach tree, *Prunus persicae* L. GPA overwinter in the egg stage; the eggs hatch in late winter and early spring. There are several generations of wingless aphids on the peach trees in the spring, which increase the population. After the winged migrants develop, they usually begin to leave the trees during the second week of May and are gone by mid-June (20). They supposedly are nonviruliferous because the peach trees are not a known host of BWYV. Helson and Norris (13) attempted to transmit potato leafroll virus to peach by grafting and aphid feeding, but no symptoms were noted. Bennett (1) inoculated peach with BYV, but again no symptoms were noted. Wallis (27) reported that the population of aphids hatching from eggs on peach trees are virus free until they have migrated to and fed on an alternate host plant infested with BWYV. Although Wallis did not present any data, Duffus (8), Dunn and Kirkley (11), Heathcote et al. (12), and Wallis (26) have indicated that aphids moving from secondary hosts are much more likely to carry viruses than those from a primary host. Therefore, for GPA to serve as vectors, they must first acquire

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²Italic numbers in parentheses refer to items in Literature Cited, p. 15.

BWYV by feeding on any of the infected common weeds or neglected sugarbeets that have survived the winter.

The current recommendations for control of aphids on sugarbeets in Washington call for chemi-

cal applications the first and third week of May, followed by a third treatment the second week of June. A basic understanding of the ecological factors in this virus-vector relationship at the field level may provide a broader basis for the control recommendations that we have at present.

OBJECTIVES

To discover the ecological interrelationship of this virus-vector-host plant association, we determined when the winged GPA first acquired the virus, the percentage of them that were virulifer-

ous, and the rate of virus spread within a host plant community in relationship to the fluctuating winged GPA population.

MATERIALS AND METHODS

The BWYV-GPA-plant relationship was evaluated at four field sites in the Yakima Valley during 1975, 1976, and 1977. A peach orchard in Parker, Wash., was selected as one study site because it represented the primary overwintering source for the GPA. The floor of the orchard was cultivated, and weeds grew profusely between cultivations. As reported by Tamaki (21, 22), these weeds served as an important alternate food source of GPA in the spring. Another site, about 45 m away from the drainage ditches and about 17.7 km south of the orchard area, was selected because Wallis and Turner (28) found that the summer form or viviparous GPA were able to overwinter successfully on weed hosts in the warm spring-fed drainage ditches. A third or intermediate site was located about 4.8 km south of the orchard, between the drainage ditch and the orchard location. The fourth site was at our experimental station close to our greenhouses, vegetable crops, and peach trees, which harbored a large population of these aphids. This site was used only in 1975 and 1976.

Experimental Design

We attempted to determine the appearance of the first migrant winged GPA and to monitor the population trend at the four field locations. The population was sampled 4 days a week to detect the first viruliferous migrant and determine the percent viruliferous. This percentage was deter-

mined by collecting a maximum of 10 winged GPA each day of the 4-day period at each location from potted trap plants (five radish and five tomato). Each aphid selected from the trap plants was caged in a 40-dr plastic vial fitted over the indicator plant (shepherdspurse, *Capsella bursa pastoris* (L.) Medic.), and the plants were taken to the laboratory in covered carriers (fig. 1). The aphids were allowed to feed for 48 h before they were killed by methyl bromide fumigation (0.644 kg/28.32 m³). The shepherdspurse plants were held in an insect-free greenhouse for 6 weeks and examined weekly for expression of disease symptoms.

The radish and tomato plants used to attract the winged GPA were placed in the field each week for a 72-h period. The radish plants, *Raphanus sativus* L., are known hosts of BWYV (5). Fortunately, latent period of the virus in the plant is considered to be over 24 h; therefore, radish plants were changed daily to eliminate the possibility of aphids acquiring the virus from this source.

In addition, we placed 25 virus-free shepherdspurse plants at each site to determine the intensity of spread of BWYV. These plants remained exposed to the natural winged aphid population for approximately 72 h each week. Following exposure, plants were transported to the laboratory, fumigated to kill the aphids, then placed in the greenhouse where weekly observations were made for expression of BWYV symptoms.



FIGURE 1. — Case to carry 40 small potted plants to and from the field.

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Symptoms, Symptom Readings, and Indicator Plant Cultures

Duffus (5) described the initial symptoms of BWYV occurring on shepherds-purse 10 to 20 days after inoculation as follows: The lower leaves develop severe chlorosis and moderate leaf curl. As the disease progresses, the yellowing develops acropetally, the yellow leaves are thickened and hardened, and the plant is stunted. Symptom expression was evaluated at weekly intervals for 6 weeks using the following ratings: 0, no evident symptoms of BWYV; 1, possible symptoms of BWYV; 2, obvious symptoms of BWYV; and 3, severe symptoms of BWYV.

All plants used in the study were grown singly in individual 6- by 6- by 8-cm plastic pots, held in a covered metal tray. A Saran[®] covered wooden frame fit over each tray, protecting the plants from accidental aphid contamination (fig. 2). Diseased plants brought in from the field and virus-free plants due to be taken to the field were kept in

separate greenhouses. In addition to covering the trays of plants, aphid contamination in the greenhouse was minimized by using (1) sticky yellow boards, (2) yellow pan water traps, (3) exposed radish plants treated with systemic insecticide growing in yellow containers, and (4) a weekly mist fumigation of 10 ml Vapona[®] (24 oz/liter) and 15 ml acetone in 3.8 liter of water (17-m³ greenhouse)³.

The ingredients for the soil mixture we found most suitable for plant growth in the small pots used in the greenhouse and field are:

Peat moss (sifted)	29.1 L
Sand (moist)	19.4 L
Soil (sifted)	9.7 L
Calcium lime	61 g
Dolomite lime	183 g
Time released fertilizer (7-40-6)	184 g

³J. E. Duffus, personal communic., 1974.

The peat moss was placed in the cement mixer with moist sand and mixed. After 5 min, we began adding the soil, then the lime and fertilizer, and mixed another 5 min. One batch filled about 280 pots.

At the start of each season, 35 lemon yellow (Sherwin Williams Kem Lustral enamel) planter cans filled with a soil-peat moss mix (1:1 ratio) were placed at each field location as shown in figure 3. A 40-cm² yellow plastic sheet was placed under each planter since yellow has long been known to attract GPA (15). One small plastic pot containing the desired plant type was placed into each planter can. The larger planter, with its moist soil mix, helped to maintain the soil moisture in the smaller pot.

Climatological records to permit comparison of temperatures during the 3 years were obtained

from the National Oceanic and Atmospheric Administration Environmental Data Service, Yakima (9 km northwest of orchard site and 26 km northwest of drainage ditch site).

Yellow Pans

In addition to the various trap and indicator plants, yellow pans were also placed at each study site. From 1975 to 1977, 9.5-liter cans painted gray on the outside and yellow on the inside were used. In 1976 and 1977, yellow plastic and all-yellow metal pans were added to permit a comparison of their trapping efficiency.

Sugarbeet Fields

In 1975 and 1976, a commercial sugarbeet field next to the drainage ditch site was selected for

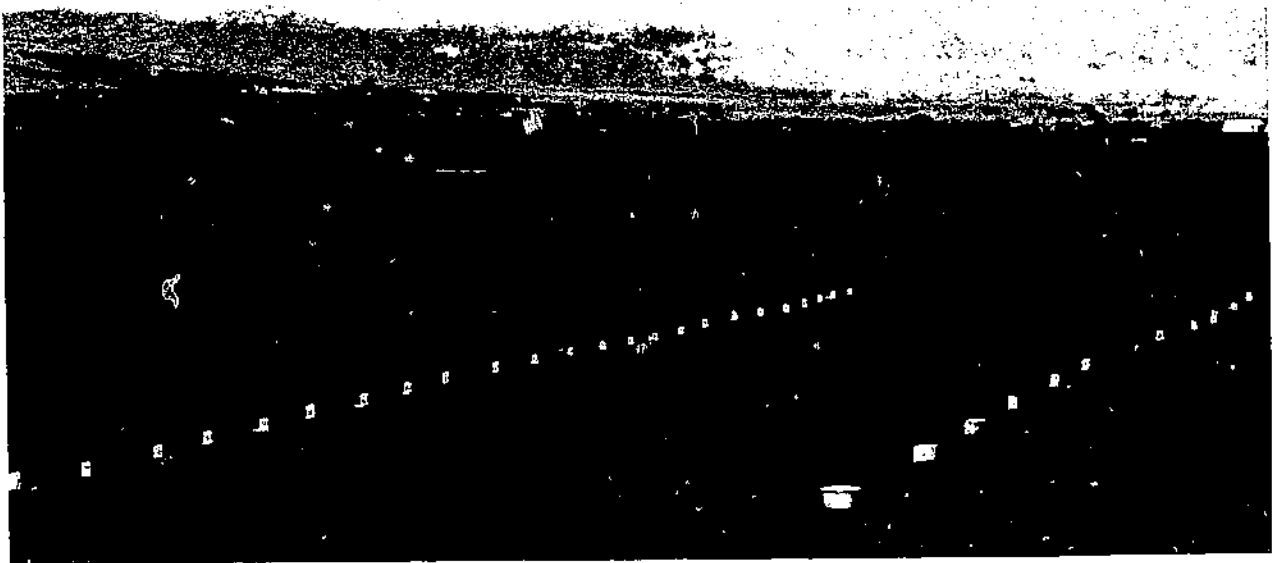


FIGURE 2. — The metal tray holding the 81 small potted plants fitted with a Saran® screen cover.

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weekly inspection. Samples of 100 leaves were selected randomly from sugarbeet plants, and the number of GPA per leaf was recorded. Sampling

was discontinued in 1977 because expected drought conditions in the Valley precluded the planting of sugarbeets near our drainage ditch site.



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FIGURE 3. — Area evaluation site showing layout of the 25 shepherdspurse plants, the 10 trap plants (tomato and radish), and the yellow pan traps.

RESULTS AND DISCUSSION

Climatological data together with our biological information and field observations were used to rank the winters of 1975, 1976, and 1977 as mild to severe. In evaluating the effect of winter temperatures on GPA survival in the drainage ditches, we recognized that we were not dealing with the true overwintering stage — the cold resistant eggs on peach trees — but with viviparae that were more susceptible to cold. The probability of viviparae successfully overwintering in the drainage ditches is dependent on (1) number of GPA present in early winter; (2) availability of host plants; (3) availability of suitable microenvironments, such as warm underground springs to keep the area around the GPA above the temperature threshold for survival; and (4) severity of the winter.

We have interpreted the extreme low and average minimum as the important temperature readings for evaluating aphid survival in the drainage ditches with the extreme low being the more important. During the mild winter of 1976, -12.2°C was the extreme low and 0.3°C the average minimum temperature. During the more severe winter (1975), -13.9° and -1.0° , and during the most severe winter (1977), -16.1° and -4.2° were the lows and average minimum temperatures.

Viruliferous Winged Green Peach Aphids

DRAINAGE DITCH

The major purpose of studying the ecology of the GPA was to establish a control program based on

the percentage of viruliferous aphids rather than on the total aphid population. In 1975, the first winged migrant GPA were collected at the drainage ditch site on May 29, following a moderately severe winter (table 1), and aphid populations were negligible until the first week in July (table 2). The first viruliferous GPA in 1975 were collected on June 24.

Table 1. — Date of appearance of the first winged migrant green peach aphid (GPA) and the first winged migrant viruliferous GPA at different field evaluation sites in the Yakima Valley

Year	Date first GPA sited	Date first viruliferous GPA sited ¹
DRAINAGE DITCH		
1975	May 29	June 24
1976	May 6	May 6
1977	June 9	June 22
INTERMEDIATE		
1975	May 22	June 19
1976	May 13	June 17
1977	May 3	May 25
ORCHARD		
1975	May 14 ²	May 14 ²
1976	May 5	May 12
1977	April 26	May 25
STATION		
1975	May 14 ²	May 14 ²
1976	April 22	April 22

¹GPA were singly caged on BWYV indicator plant, *Capsella bursa-pastoris*, for 48 h. Fumigated plants were held for 6 weeks for BWYV symptom readings.

²Date of first observation.

In 1976 — the mildest winter — the first GPA and the first viruliferous GPA were collected on May 6; thus, the first GPA appeared 23 days earlier and the first viruliferous GPA 49 days earlier than in 1975.

In 1977, the first winged GPA were collected on June 9 and the first viruliferous GPA 13 days later. Thus, in 1977, the winged GPA appeared the latest of all in the 3 years of study. The winter of 1977 was judged the most severe compared to the 2 earlier years. For instance, the areas along the drainage ditch that had harbored the GPA in the spring of 1976 had either very low numbers of GPA or no GPA in the spring of 1977.

INTERMEDIATE SITE

In 1975, after a moderately severe winter, the first GPA were collected at the intermediate site one week earlier than at the drainage ditch site. The first viruliferous aphids were found June 19 at the intermediate site and 5 days later at the drainage ditch site. The late appearance of the GPA near that site could be expected because the severe winter would have more effect on the viviparous GPA than on overwintering eggs on the peach trees.

In 1976, after a mild winter, the first GPA were collected at the drainage ditch 1 week earlier than at the intermediate site. This was also expected at the drainage ditch site after a mild winter. The first viruliferous GPA were found 42 days earlier in the drainage ditch site than at the intermediate site.

In 1977, after the most severe of the three winters, the GPA appeared a month earlier at the intermediate site than at the drainage ditch site (tables 1 and 3).

The intermediate site is primarily an outside collection station for aphids leaving the orchard rather than the drainage ditch site. Following the more severe winters of 1975 and 1977, the first winged GPA trapped in the drainage ditch area appeared 1 to 4 weeks later than those at the intermediate site. These data indicate that during the severe winters the overwintering aphid population in the drainage ditches are greatly reduced as are the number of sites where overwintering is successful. For instance, one drainage ditch site (near Harrah, Wash.) harbored a heavy GPA population on hoary cress, *Cardaria draba* (L.), Desv., in 1976; however, after the severe winter in 1977, GPA were not found at that site. We attributed this to the overwintering mortality caused by low temperature since GPA were found at the site at the onset of winter. Those few sites that still harbored the GPA were considered to have a more favorable habitat. For instance, GPA were found only on the hoary cress growing inside a 15- by 20- by 60-cm long crevice along the ditchbank but not on the surface of the bank.

ORCHARD SITE

Winged migrant GPA were collected earlier at the orchard site than at the drainage ditch site and the intermediate site in all years. In 1975, the first GPA were trapped during our first sampling week

Table 2. — Total green peach aphids found on 5 tomato and radish trap plants at the drainage site after 72 h field exposure. Aphids were removed and counted daily¹

Month	Week	1975		1976		1977	
		Total winged aphids ²	Percent viruliferous	Total winged aphids	Percent viruliferous	Total winged aphids	Percent viruliferous
April	2	—	—	—	—	0	0
	3	—	—	0	0	0	0
	4	—	—	0	0	0	0
May	1	—	—	1	100	0	0
	2	0	0	4	50	0	0
	3	0	0	0	—	0	0
June	4	2	0	8	13	0	0
	1	1	0	1	0	0	0
	2	0	0	7	0	1	0
July	3	0	0	11	0	3	0
	4	2	100	20	55	20	5
	1	51	93	287	24	73	3
August	2	166	67	1,357	13	—	—
	3	34	85	4,100	7	—	—
	4	61	27	1,344	27	—	—
	5	33	68	39	4	—	—
	1	18	78	13	8	—	—
	2	43	52	35	26	—	—
	3	53	48	11	30	—	—
	4	45	85	10	13	—	—

¹On each sampling day, 10 winged GPA were placed singly on BWYV indicator plants, *Capsella bursa-pastoris*, for 48 h and fumigated. Plants were held for 6 weeks for BWYV symptom readings. The percentage of viruliferous GPA was calculated from these samples, and the data were used to estimate the total percentage of viruliferous GPA per week.

²— = no data.

and may have been active before that time. In 1976 and 1977, the first viruliferous GPA were caught in the orchard on May 5 and April 26, respectively (table 4), after several weeks when no aphids were collected. In any case, the first migrant GPA collected in the orchard sites are likely to be from the winged GPA population developing on peach trees. The first migrant viruliferous aphids trapped in the orchard site are probably from the GPA that moved from the trees to the broadleaf weeds on the floor of the orchard. Many of these weeds are known to be hosts of BWYV; for example, yellowflower pepperweed, *Lepidium perfoliatum* L., hoary cress, and shepherdspurse (6, 22, 26). Therefore, they may also serve as a source of viruliferous GPA.

Only after the mild winter in 1976 were the first viruliferous GPA collected earlier at the drainage ditch site than the orchard site. This again indicates that after mild winters, survival of the GPA in drainage ditches permits the early development of winged GPA from the viviparous overwintering GPA.

YAKIMA FIELD STATION SITE

At the Yakima field station in 1975, GPA were collected the first day of sampling on May 14 in both the orchard and the station sites. These aphids were also found to be viruliferous. In 1976, the first viruliferous GPA was collected on April 22, the third day of sampling (table 5). This was the earliest

Table 3. — Total winged green peach aphids found on 5 tomato and 5 radish trap plants at the intermediate site between the orchard and the drainage ditch after 72-h field exposure. Aphids were removed and counted daily¹

Month	Week	1975		1976		1977	
		Total winged aphids ²	Percent viruliferous	Total winged aphids	Percent viruliferous	Total winged aphids	Percent viruliferous
April	2	—	—	—	—	0	0
	3	—	—	0	0	0	0
	4	—	—	0	0	0	0
May	1	—	—	0	0	1	0
	2	0	0	2	0	1	0
	3	3	0	0	0	6	0
June	4	0	0	1	0	12	17
	1	0	0	0	0	21	5
	2	0	0	0	0	65	0
July	3	3	100	5	20	401	3
	4	2	100	16	29	—	—
	1	58	98	331	25	—	—
August	2	227	87	2,595	7	—	—
	3	160	90	3,480	10	—	—
	4	45	23	841	30	—	—
August	5	3	33	70	4	—	—
	1	15	90	23	0	—	—
	2	4	25	17	0	—	—
August	3	21	29	20	0	—	—
	4	17	73	14	17	—	—

¹On each sampling day, 10 winged GPA were placed singly on BWYV indicator plants, *Capsella bursa-pastoris*, for 48 h and fumigated. Plants were held for 6 weeks for BWYV symptom readings. The percentage of viruliferous GPA was calculated from these samples, and the data were used to estimate the total percentage of viruliferous GPA per week.

²— = no data.

collection date for GPA as well as the first viruliferous GPA for all sites and years. This was not unexpected because GPA are reared continuously in the greenhouses at our station and early infestation of weeds by aphids at our station is a common occurrence.

TRAP PLANTS

Tomato and radish plants were used as trap plants to assess the weekly winged migrant GPA population. After each daily count, either the plant was changed or all the aphids were removed from the plant. Substantially more GPA were found on tomato plants than on radish plants. The arrival of

winged aphids at an area of vegetation is known to be undirected, but at what distance from a host plant an aphid can begin to direct its landing is still unknown (24). We have assumed that the winged GPA probably landed on either host plant with equal frequency because Kennedy et al. (14) and Müller (16) found no difference in the number of GPA alighting on host and nonhost plants. In our study, 43,188 winged GPA were found on tomato plants, whereas 25,577 were found on the radish plants. A major reason for 63 percent more winged GPA on tomato than on radish was the degree of pubescence. Hairs covered most of the tomato leaf and stem surface — the radishes were only sparsely

Table 4. — Total green peach aphids found on 5 tomato and radish trap plants at the orchard site after 72 h of field exposure. Aphids were removed and counted daily¹

Month	Week	1975		1976		1977	
		Total winged aphids ²	Percent viruliferous	Total winged aphids	Percent viruliferous	Total winged aphids	Percent viruliferous
April	2	—	—	—	—	0	0
	3	—	—	0	0	0	0
	4	—	—	0	0	246	0
May	1	—	—	1	0	355	0
	2	51	10	33	5	483	0
	3	33	27	50	3	944	0
June	4	443	0	86	11	3,786	13
	1	548	13	64	38	1,836	3
	2	216	40	274	3	4,586	10
	3	125	57	91	21	2,700	4
July	4	243	83	545	43	360	7
	1	726	100	3,858	18	186	5
	2	1,254	67	8,190	13	—	—
	3	1,032	93	6,781	7	—	—
	4	352	23	3,246	30	—	—
August	5	28	47	104	10	—	—
	1	43	48	40	12	—	—
	2	19	42	11	10	—	—
	3	16	31	8	0	—	—
	4	21	83	1	0	—	—

¹On each sampling day, 10 winged GPA were placed singly on BWYV indicator plants, *Capsella bursa-pastoris*, for 48 h and fumigated. Plants were held for 6 weeks for BWYV symptom readings. The percentage of viruliferous GPA was calculated from these samples, and the data were used to estimate the total percentage of viruliferous GPA per week.

²— = no data.

haired. That many winged GPA were entrapped by the hairs of tomato plants was more evident on hot days when a large number of winged aphids were found dead even though the tomato foliage had been cleaned of aphids 24 h before.

Potential Rate of Spread

The primary purpose of this phase of study was to estimate the potential infection rate of BWYV on sugarbeets by comparing infection rates of indicator plants weekly throughout the season. Although we estimated the percentage of viruliferous GPA by removing the winged GPA from the trap plants and allowing them to inoculate the indicator plants,

this method did not enable us to estimate the potential spread of BWYV. For instance, 10-percent viruliferous GPA of 100 total migrants on one particular day would differ from 10 percent of 1,000 migrant GPA on another day and may make a 10-fold difference in the potential rate of spread.

The estimate of the rate of spread of BWYV was based on the percentage of indicator plants expressing the symptoms of BWYV after 72 h exposure in the field. After the moderate winter of 1975, infection by BWYV (at the drainage ditch site) had increased to 78 percent during the last weeks of June (fig. 4). The level of infection was then much lower during the next 2 weeks in July at the drainage and also at the intermediate site. At the orchard and

Table 5. — Total winged green peach aphids found on 5 tomato and 5 radish trap plants at the station after 72-h of field exposure. Aphids were removed and counted daily¹

Month	Week	1975		1976		1977	
		Total winged aphids ²	Percent viruliferous	Total winged aphids	Percent viruliferous	Total winged aphids	Percent viruliferous
April	2	—	—	—	—	—	—
	3	—	—	2	100	—	—
	4	—	—	1	—	—	—
May	1	—	—	7	75	—	—
	2	2	100	9	11	—	—
	3	5	17	5	0	—	—
June	4	53	13	7	29	—	—
	1	155	27	3	33	—	—
	2	75	57	7	14	—	—
	3	2	100	12	27	—	—
July	4	21	85	4	50	—	—
	1	218	100	176	50	—	—
	2	889	87	1,058	27	—	—
	3	656	97	1,596	13	—	—
	4	951	60	1,705	57	—	—
August	5	115	67	595	40	—	—
	1	184	87	191	31	—	—
	2	179	60	88	36	—	—
	3	73	47	13	36	—	—
	4	72	86	13	25	—	—

¹On each sampling day, 10 winged GPA were placed singly on BWYV indicator plants, *Capsella bursa-pastoris*, for 48 h and fumigated. Plants were held for 6 weeks for BWYV symptom readings. The percentage of viruliferous GPA was calculated from these samples, and the data were used to estimate the total percentage of viruliferous GPA per week.

²— = no data.

station sites, there was no drop in the percentage of infected plants. The number of aphids, the percentage of viruliferous aphids, and temperature were not determined to be responsible.

Of the four sites, indicator plants at the station location in 1975 near a large source of viruliferous GPA (greenhouses, weeds, and peach trees) had the earliest high infection rate (25 percent or more), which occurred during the second week of June (fig. 4). They also had the highest infection rate (100 percent) for the second and third weeks of July. Plants at the orchard site had the next highest infection rate.

In 1976, after a mild winter, the plants at the orchard site were the first to reach the 25-percent infection rate, this by the third week of May (fig.

5). A week later, plants at both the station and the intermediate sites also reached the 25-percent level of infection. Plants at all sites reached the 100-percent level of infection during the second week of July and remained at that level for 3 weeks. The winged GPA population reached its peak during this same time period as indicated by trap plant counts. The weekly percentage of viruliferous winged GPA ranged from 7 to 27 percent at the drainage site; 7 to 30 percent at the intermediate and orchard; and 13 to 57 percent at the station. During the fifth week of July, the percentage of infected plants decreased rapidly with the concomitant decrease of viruliferous GPA (tables 2, 3, 4, and 5).

After the severe winter in 1977, only 0 to 2

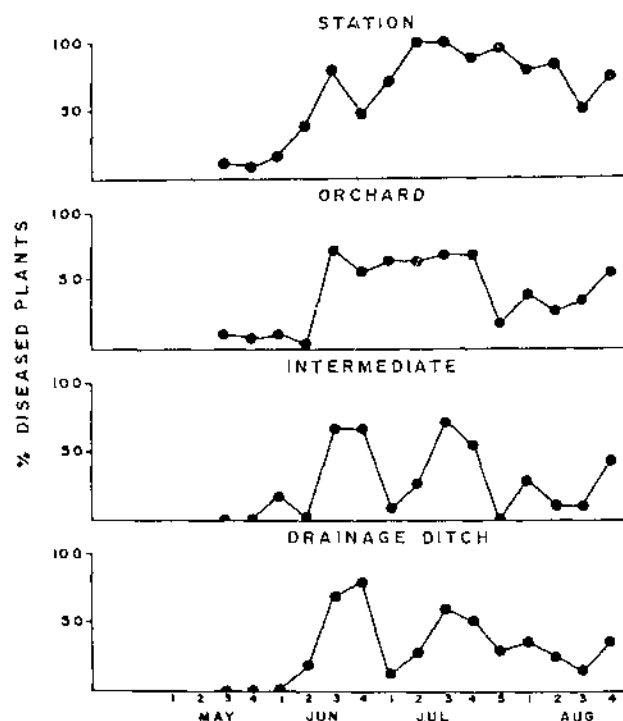


FIGURE 4. — The percentage of indicator plants, *Capsella bursa-pastoris*, expressing symptoms of BWYV based on 100 plants weekly from four evaluation sites in 1975 after a moderate winter.

plants per 25 exposed shepherdspurse plants became infected from mid-April to early July at the drainage site (fig. 6). The infection rate of plants at the intermediate site was also low. At the orchard site, the 25-percent diseased plant level was reached during the second week of June, 3 weeks later than 1976.

Although the use of field-exposed indicator plants may at first appear to be useful for assessing the potential level of crop infection, the method whereby the winged GPA are collected and placed singly on indicator plants is more accurate because: (1) The indicator plants kept in the greenhouse were insect and disease free; (2) the field indicator plants were left exposed for 72 h before the plants were fumigated and held for observation of BWYV symptoms. While in the field, these plants could have been fed upon by many different insect species or other aphids capable of transmitting pathogens or toxins yielding symptoms that might be mistaken for those of BWYV; and (3) the indicator plants were taken to the field and exposed to severe environmental conditions after being removed from

a controlled greenhouse. During April and May, the nights were cold, and many of these seedlings were injured as indicated by higher mortality rates in the early season. Thus, the data regarding field exposure of shepherdspurse should be interpreted as an indicator of the trend of BWYV intensity spread in a host plant community and should not be used as a method to determine the early season levels of BWYV.

APHID PRESENCE ON INDICATOR PLANTS

The number of winged and wingless GPA on each field indicator plant at the end of each 72-h period was recorded. Using this data, we segregated the plants at each sampling site into groups with no GPA and those with one or more winged GPA. The data for all 3 years were combined for the drainage ditch evaluation site (fig. 7) and the orchard site (fig. 8). In the drainage ditch site, plants with no aphids averaged 9.6 percent diseased plants. This indicates that aphids fed on many of these plants and had successfully inoculated them but had not settled permanently on the plant.

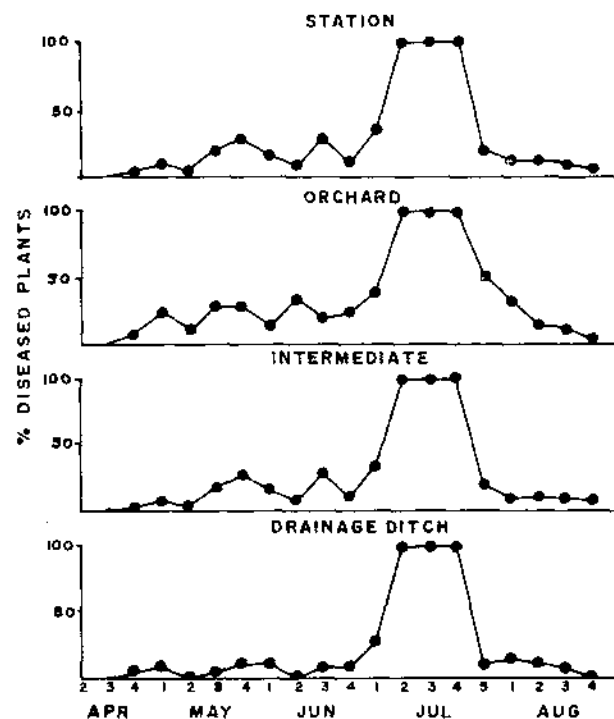


FIGURE 5. — The percentage of indicator plants, *Capsella bursa-pastoris*, expressing symptoms of BWYV based on 100 plants removed weekly from four evaluation sites in 1976 after a mild winter.

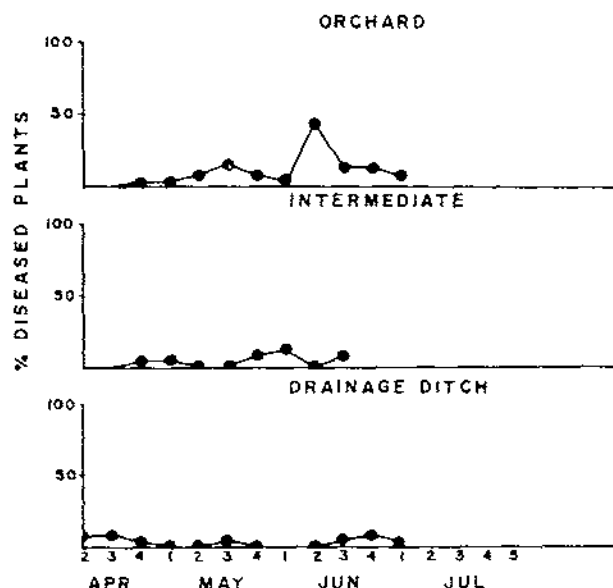


FIGURE 6. — The percentage of indicator plants, *Capsella bursa-pastoris*, expressing symptoms of BWYV based on 75 plants removed weekly from three evaluation sites in 1977 after a severe winter.

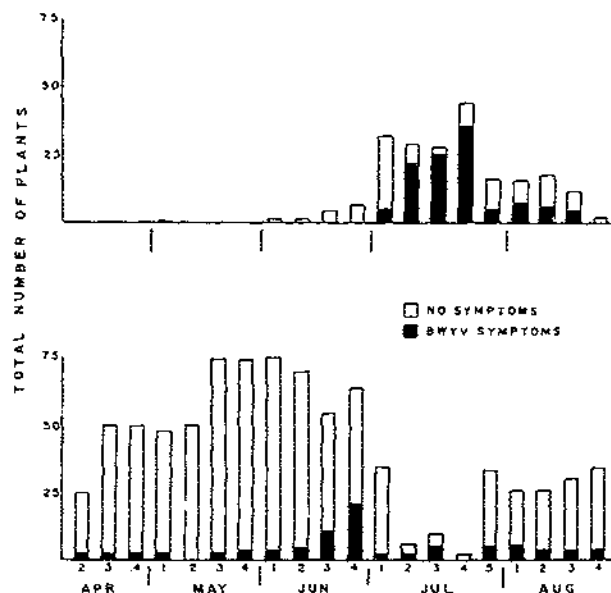


FIGURE 7. — The comparison of the number of indicator plants, *Capsella bursa-pastoris*, with no symptoms or with BWYV symptoms after being exposed in the field for 72 h. The upper histogram shows plants with one or more winged aphid per plant, and the lower histogram shows plants with zero aphids per plant. The data are based on a 3-year study at the drainage ditch evaluation site.

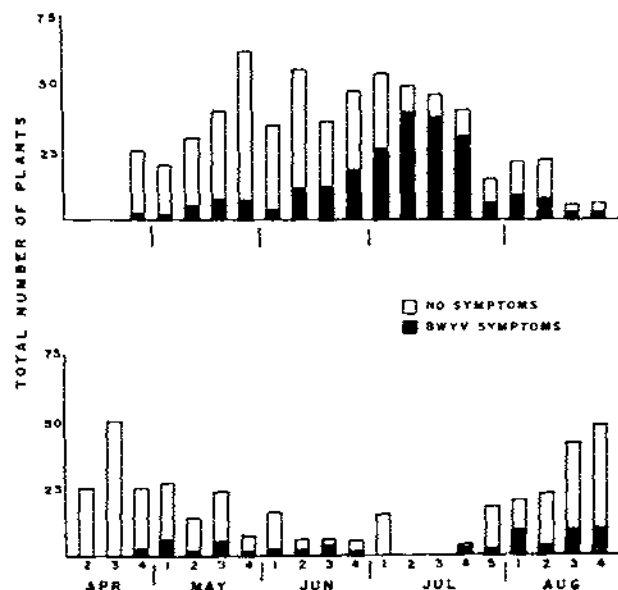


FIGURE 8. — The comparison of the number of indicator plants, *Capsella bursa-pastoris*, with no symptoms or with BWYV symptoms after being exposed in the field for 72 h. The upper histogram shows plants with one or more winged aphid per plant, and the lower histogram shows plants with zero aphids per plant. The data are based on a 3-year study at the orchard evaluation site.

Fifty-four percent of the plants with one or more aphids per plant had symptoms of BWYV (fig. 7). The highest percentage of diseased plants occurred during July, reaching a high of 94 percent, concomitant with the number of viruliferous aphids (table 3).

The total number of plants with one or more aphids per plant and the percentage infected with BWYV at the intermediate site were similar to that at the drainage ditch site (fig. 7). The plants with no aphids had a 12-percent infection rate of BWYV, and the plants with one or more aphids had a 51-percent infection rate.

The orchard site had more plants with one or more aphids per plant than the drainage ditch site had and earlier in the season (fig. 8). The orchard site had 605 plants with one or more aphids per plant as compared with the 210 plants at the drainage ditch site and 221 diseased plants compared with 113 for the 3-year study period. However, since most of the infection of the plants in the orchard having one or more aphids per plant occurred early in the season, the percentage rate of infection was 37 percent compared with 54 percent for the drain-

age ditch. Again, as the number of viruliferous GPA increased (table 5), the percentage of BWYV infection increased (fig. 8).

YELLOW PANS

Every year, yellow-gray pans were placed at each sampling site as another tool to aid in the study of the aphid activity. Table 6 shows that, in most cases, yellow pans caught GPA earlier or about the same time as the trap plants. GPA were caught by a yellow pan at the drainage ditch as much as 7 weeks earlier than by the trap plants; however, in 1976, the first GPA was found 1 week earlier on trap plants than in yellow pans at the orchard sites.

The yellow-gray, yellow metal, and the yellow plastic aphid pans were compared at three different sites in 1976 and 1977 (table 7). At low GPA flight activity levels, there were only slight differences between the three types of traps; however, during high GPA flight activity levels, such as at

the orchard site in 1977, the number of GPA trapped in the yellow plastic pans was three times, and the metal yellow pans two times, greater than in the yellow-gray pans. The yellow plastic pans were two times more effective in trapping other species of aphids than the two other types of yellow pans (table 7).

SUGARBEET FIELDS

The sugarbeet fields adjacent to the drainage ditch were sampled beginning the second week of June 1975. This was a month after the trapping sites had been activated. Most aphid infestations in the fields were of wingless aphids. In fact, only one winged GPA was found during the entire sampling period. We found that 22 percent of the leaves samples were infested even though flight activity was low (table 8). This was the result of the accumulation and movement of the wingless aphids.

Table 6. — Yellow-gray metal aphid pans

Month	Week	Number of green peach aphids trapped daily								
		Site A drain			Intermediate			Orchard		
		1975 ¹	1976	1977	1975	1976	1977	1975	1976	1977
April	2	—	—	0	—	—	0	—	—	0
	3	—	0	<1	—	0	0	—	0	0
	4	—	0	0	—	0	0	—	0	17
May	1	—	<1	0	—	0	<1	—	0	25
	2	—	0	0	—	0	0	—	1	111
	3	—	0	0	—	0	2	—	3	60
June	4	<1	<1	<1	0	0	3	22	6	456
	1	0	<1	0	0	0	3	19	3	383
	2	0	2	<1	<1	0	5	14	10	1,601
July	3	0	3	1	0	<1	8	15	8	605
	4	<1	2	3	0	<1	6	34	47	77
	1	3	85	10	2	35	7	122	501	18
August	2	19	171	—	28	236	—	269	847	—
	3	5	653	—	22	120	—	232	317	—
	4	18	213	—	6	67	—	76	—	—
August	5	4	5	—	0	5	—	11	3	—
	1	4	1	—	1	2	—	8	3	—
	2	17	3	—	1	1	—	5	1	—
August	3	25	2	—	7	1	—	10	<1	—
	4	15	1	—	5	1	—	9	0	—
Total (Σ)		111	1,141	15.2	72.6	46.8	33.1	846	1,750	3,353
Total weeks (n)		14	19	12	14	19	12	14	18	12
Mean (\bar{X})		8	60	1	5	25	3	60	97	279

¹ — = no data.

In 1976, the early infestation of sugarbeet leaves (table 9) corresponded with aphid activity on the drainage ditch site (table 2). Again the

number of winged GPA was low, but more were collected than during the same period in 1975.

Table 7. — Average daily catch of aphids by site and trap pan configuration, 1976-77

Year	Site	Green peach aphids			Other aphids			Total aphids trapped ¹	Mean per trap
		Yellow-gray	Yellow-metal	Yellow-plastic	Yellow-gray	Yellow-metal	Yellow-plastic		
1976	Drainage ditch	<1	<1	1	7	7	13	267	5.0
	Intermediate	<1	<1	<1	2	4	6	225	2.1
	Orchard	3	6	5	12	15	28	630	11.7
1977	Drainage ditch	<1	<1	<1	3	3	5	79	1.9
	Intermediate	<1	<1	<1	<1	<1	2	37	.9
	Orchard	96	191	288	1	2	3	4,064	96.8
Total aphids trapped		712	1,409	2,085	222	270	494	—	—
Weighted mean per trap ²		15	29	43	5	6	10	—	—

¹ — = no data

² Based on sampling of 9 weeks in 1976 and 7 weeks in 1977.

Table 8. — Green peach aphid (GPA) infestation of sugarbeet leaves, drainage ditch area, 1975 based on 100 leaves per sample

Month	Week	No. of leaves infested	No. of winged GPA	No. of wingless GPA	Other aphids
April	2	—	—	—	—
	3	—	—	—	—
	4	—	—	—	—
May	1	—	—	—	—
	2	—	—	—	—
	3	—	—	—	—
June	1	—	—	—	—
	2	22	1	50	1
	3	28	0	48	0
July	1	33	0	67	0
	2	39	0	79	0
	3	43	0	86	0
August	1	45	0	94	0
	2	40	0	72	0
	3	20	0	43	0
August	1	21	0	30	0
	2	9	0	12	0
	3	3	0	3	0
	4	1	0	0	1

¹ — = no data

Table 9. — Green peach aphid (GPA) infestation of sugarbeet leaves, drainage ditch area, 1976, based on 100 leaves per sample

Month	Week	No. of leaves infested	No. of winged GPA	No. of wingless GPA	Other aphids
April	2	—	—	—	—
	3	0	0	0	0
	4	1	0	1	0
May	1	3	0	6	0
	2	11	1	19	5
	3	10	0	13	0
June	1	15	0	33	0
	2	19	0	52	0
	3	33	0	104	0
July	1	25	0	62	0
	2	46	0	126	0
	3	37	1	82	2
August	1	65	6	322	0
	2	47	5	159	—
	3	31	2	71	—
August	1	32	0	43	6
	2	4	0	4	—
	3	1	0	2	—
	4	0	0	0	—

¹ — = no data.

CONCLUSION

Data indicate that for the chemical control of GPA on sugarbeets in the Pacific Northwest treatment should begin in the first week of May (3). Some winged GPA were found in the orchard site before May 1, but in most years the production of winged GPA starts in early May and peaks at the end of May (20). At the intermediate site, the earliest detection of viruliferous GPA leaving the orchard area was at the end of May. Therefore, to control the GPA leaving the peach trees and weeds on the floor of the orchard, data indicate that chemical protection is not required until the end of May.

The control of GPA near the drainage ditch area depends on their initial abundance and overwintering survival. For example, following two cold winters, the first viruliferous GPA were not found until the last week of June. After the mild winter of 1976, however, the first viruliferous GPA were found in the first week of May. Although only a few viruliferous GPA were found, these were more important than those from the orchard because the drainage ditches interlace many sugarbeet fields.

Some drains are only a few feet from the fields, whereas the peach trees are generally a number of miles away. Thus, the few aphids from the drains are more likely to feed on sugarbeets than are the many aphids from the orchards, primarily because their numbers are diluted by area and distance. For instance, if a GPA needs to travel 4.8 km from the orchard area to find a sugarbeet field, the dilution factor can be the area of a circle (19); therefore, if $r = 2.4$ km, an area of 18 million m^2 results. If we assume, however, that a movement from a greater distance will occur with the prevailing winds (23), a narrow flight pattern of only one-fourth of a circle would be more realistic, but this area would still be 4.5 million m^2 .

Thus, the recommended spray schedule would be appropriate only in years following a mild winter and when substantial numbers of GPA are overwintering in nearby drainage ditches. However, when sugarbeets are growing in an area where GPA overwinter only on peach trees, data indicate that chemical control need not be initiated until the end of May or early June.

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