Barley Yellow Dwarf Luteoviruses in Montana Cereals

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ABSTRACT

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From 1978 through 1981, leaf samples of small grains and native aphid populations collected from 10 counties in central Montana were tested for barley yellow dwarf luteoviruses (BYD-LV) by aphid transmission and enzyme immunosorbent assay (EIA). Montana isolates were similar in most respects to the PAV, MAV (SAV), RMV, and RPV luteoviruses previously characterized in New York. Montana RMV types, however, failed to react in EIA tests using New York RMV immunoglobulin. Montana BYD-LV similar to PAV were the most prevalent and most virulent among the BYD-LV isolated. Barley yellow dwarf (BYD) disease appeared to be most important in fall-seeded winter wheat when large viruliferous aphid populations were present. In 1980 and 1981, two epiphytotics of BYD occurred in winter wheat as a result of early seeding and moderate temperatures during September and October that favored vector population increases. Planting winter wheat after 10 September appears to be an effective control measure for avoiding serious losses from BYD in Montana.

Luteoviruses that cause yellows-type diseases in plants are small, isometric, RNA-containing viruses (15). They are transmitted in a circulative, persistent manner by aphids and they replicate in the phloem tissues of infected plants (15).

Barley yellow dwarf (BYD) is an important disease of small grains caused by a group of luteoviruses that produce similar symptoms and have a similar etiology but show a range of biological and serological properties. Barley yellow dwarf luteoviruses (BYD-LV) were first differentiated on the basis of the specificity of virus transmission by aphid vectors.

Five types of BYD-LV have been studied in detail by Rochow (11,13–15). The PAV type is transmitted in a nonspecific manner by *Rhopalosiphum padi* (L.), *Sitobion* (=*Macrosiphum*) *avenae* (Fabriscius), and *Schizaphis graminum* (Rondani). The RPV, MAV (SAV), SGV, and RMV types are transmitted specifically by *R. padi, Sitobion avenae, Schizaphis graminum*, and *R. maidis* (Fitch), respectively. Based on serological studies (14) and ultrastructural alterations observed in infected plant cells (6), these five variants have been divided into two groups. One group includes the RPV and RMV types and the other includes the PAV, MAV, and SGV types.

Until recently, comprehensive studies to monitor BYD-LV in the western states have not been conducted. In Washington, recent surveys have indicated the predominance of a PAV type (17). Earlier work isolated some vector-specific types (19). Both vector-specific and nonspecific types from Idaho have been identified by enzyme immunosorbent assay (EIA) (W. F. Rochow, *personal communication*). Early reports by Allen (2) indicated that a PAV type isolate was prevalent in California. New studies by Gildow and Rochow (3) showed that PAV is still the most frequently isolated BYD luteovirus in California. In New York (12) and Canada (5), prevalence of different BYD-LV types has been shown to fluctuate over a period of years. Similar annual variations in the predominant BYD-LV types may be observed in western states as investigators begin to survey small grains more thoroughly.

In Montana, BYD was first diagnosed by Sharp (18) as a problem in late-planted spring barley. Until this study, the identity and prevalence of BYD-LV types were unknown. The purpose of this investigation was to determine the importance of the BYD-LV in small grains and to identify and characterize those found in the central grain-growing region of the state.

MATERIALS AND METHODS

To determine the incidence and prevalence of BYD in central Montana, grain fields in a 10-county area (Fig. 1) were monitored for four consecutive years beginning in 1978. Particular attention was given to Judith Basin and Fergus counties (Fig. 2) and to Pondera

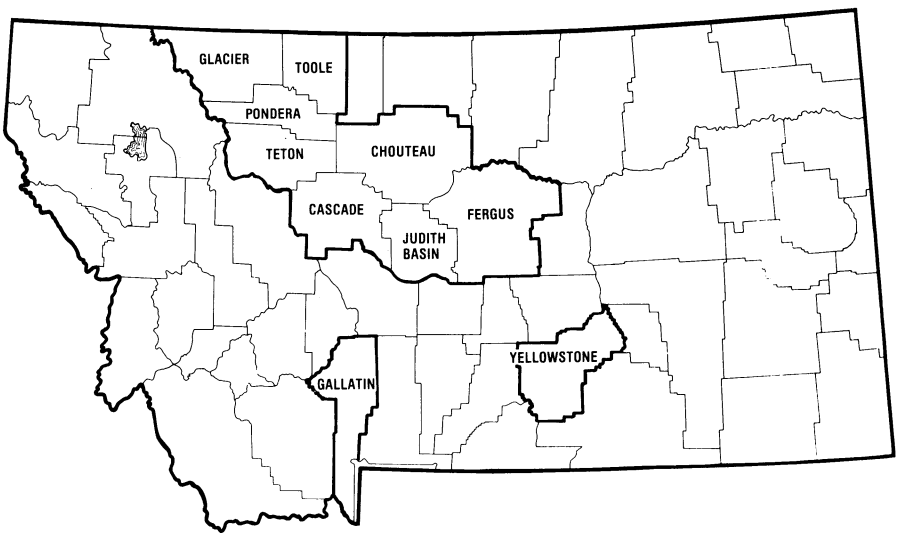

Fig. 1. Counties in central Montana surveyed for barley yellow dwarf luteoviruses from 1978 through 1981.

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and surrounding counties (Fig. 3) because BYD seemed important in these areas. During the surveys, fields of winter wheat, spring wheat, spring barley, and spring oats were examined for plants showing symptoms of the disease. Individual plants showing symptoms were collected and used as source material for vector transmission of BYD-LV to indicator test seedlings. Live aphids were also collected from naturally occurring infestations found in small grain fields. The aphid samples provided a means by which BYD-LV could be isolated directly from the vector population. Identification of BYD-LV transmitted from field plants or by aphids from native populations was accomplished by virus-vector specificity studies and EIA. The four aphid species used in transmission experiments were biotypes of *R. padi, Sitobion avenae, R. maidis,* and *Schizaphis graminum* kindly provided by W. F. Rochow, Cornell University, Ithaca, NY.

Aphid colonies were raised on Klages (CI 15478) barley, grown in sterilized greenhouse soil in 15-cm-diameter clay pots, and confined with a nylon fabric mesh cage. Aphids were reared for 21–25 days before they were used for a transmission experiment. After the necessary aphids were removed, the remaining ones were killed by placing the old colony plants in an oven at 270 C for 5–10 min. New aphid colonies were started every 3 wk by placing apterous adults in plastic dishes with detached barley leaves, then collecting 10–15 newly born nymphs after 24 hr. New colonies were started by transferring nymphs to Klages barley seedlings.

BYD-LV were recovered from diseased field plants by aphids, using the detached-leaf technique described by Rochow (9). Two leaf pieces, each 12–15 cm long, were taken from a single plant sample and placed into each of four covered plastic dishes along with 10–15 nonviruliferous aphids of one of the four species. These aphids were given a 48-hr acquisition access period.

The membrane feeding technique of Rochow (10) was also employed for virus recovery. Liquid extract was prepared by homogenizing the plant sample tissue in distilled water in a Waring Blendor. Usually, 50 g of tissue and 100 ml of water were used per sample. The homogenate was centrifuged at 3,550 *g* for 15 min in a GSA Sorvall Rotor at 4 C. The supernatant liquid was adjusted to 10% sucrose (w/v) and allowed to warm to room temperature before about 0.5 ml of the liquid was placed in each tube. Aphids were given a 16- to 18-hr acquisition access period at about 20 C, then transferred from the membranes to indicator test seedlings.

In the virus transmission studies, the indicator test plant for all experiments was oat (*Avena byzantina* K. Koch 'Coast Black'). Seeds of Coast Black oats were planted four or five per pot in sterilized greenhouse soil in 8-cm clay pots. Each of the 5- to 7-day-old seedlings were infested with 10–15 aphids previously allowed to acquire BYD-LV from detached leaves or plant tissue extracts. The seedlings were caged and allowed a transmission access period of 5 days. During the transmission access period, the indicator test seedlings were placed under cool-white fluorescent lights for a 24-hr/day photoperiod at about 10,000 lux and at 21 C. At the end of the transmission feeding period, the aphids were killed by fumigating the test plants in a closed chamber, using dichlorvos (Vapona) insecticide. Test seedlings were then placed in the greenhouse for a 21-day postinoculation period. The greenhouse facilities were fumigated with dichlorvos every 7–10 days to maintain an aphid-free environment.

During the symptom development period, the indicator test plants were grown under metal halide, high-intensity discharge lights for a 16-hr daily photoperiod at about 40,000 lux. BYD symptom development in the indicator test plants was monitored weekly and final evaluations were made at the end of the 21-day symptom-expression period.

In all virus transmission studies where leaf samples were the virus source, test aphids of each species were transferred from the leaf samples after the virus acquisition period to separate groups of indicator test plants. In all experiments

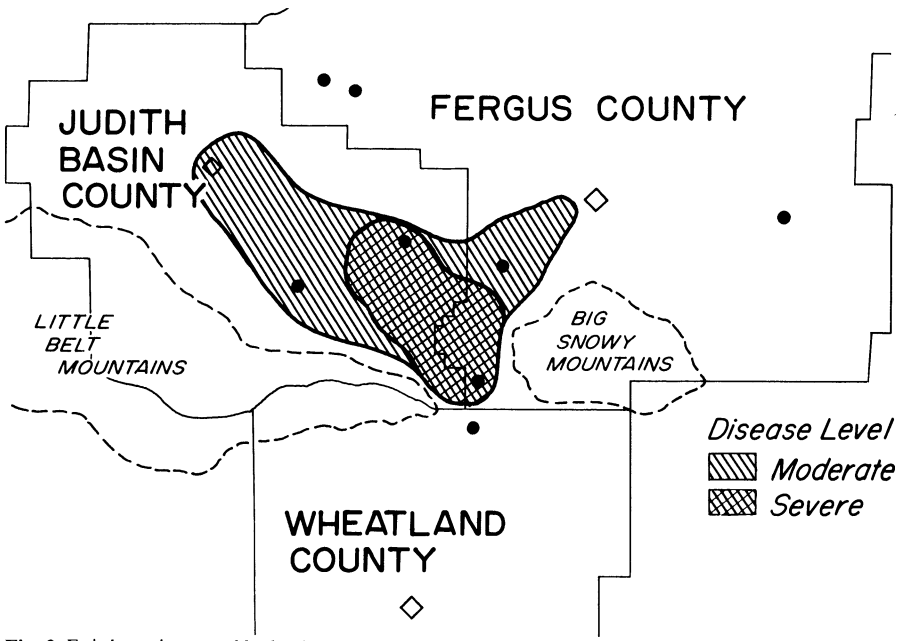

Fig. 2. Epiphytotic caused by barley yellow dwarf luteoviruses in winter wheat in Judith Basin and Fergus counties of Montana in 1980.

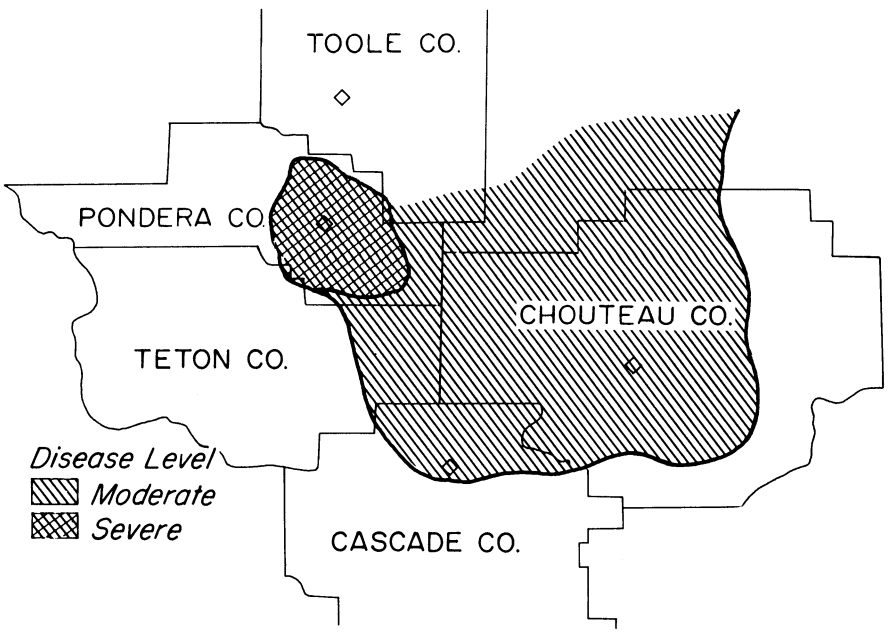

Fig. 3. Epiphytotic caused by barley yellow dwarf luteoviruses in winter wheat in Pondera and surrounding counties of Montana in 1981.

where reared aphids were used to vector BYD-LV, part of the aphid population from each colony was transferred as controls to test seedlings for a 5-day transmission access period. Test aphids collected from field populations were transferred to 5- to 7-day-old oat or barley (*Hordeum vulgare* L. emend Bowden 'California Mariout') seedlings for a 5-day transmission access period. Single aphids of a particular species from the field sample were transferred to single test seedlings. The identity of aphids collected in the field was determined by V. Eastop, British Museum of Natural History, London, England.

Two procedures were followed to differentiate and identify BYD-LV isolated from field-collected plants and native aphid populations. In the initial procedure, four aphid species were used in comparative tests. The initial transmission of a virus isolate from a field sample is usually not sufficient for identification. Therefore, at least three additional transmissions from infected test plants were completed with the four aphid species before determining the virus-vector specificity. After the isolate was characterized, a confirmation of the luteovirus identity was obtained by serology. Leaf samples of 4- to 6-wk-old oat test plants infected by a particular isolate were sent to W. F. Rochow for EIA (13).

Table 1. Isolates of barley yellow dwarf luteoviruses recovered from various survey sites in central Montana from 1978 through 1981

Isolate[a]	Luteovirus type[b]	Source[c]
MT 781	MAV z	Oats
MT 782	PAV z	Oats
MT 791-1	RMV x	*Rhopalosiphum maidis*
MT 791-2	RMV x	Barnyard grass
MT 792	PAV z	Barley
MT 793	RMV x	Barley
MT 801	PAV x	Winter wheat
MT 802	PAV z, RPV y	Spring wheat
MT 803	PAV z, RPV y	Barley
MT 804	PAV z	*Sitobion avenae*
MT 805	PAV z	*R. padiformis*
MT 806	PAV z	*S. avenae*
MT 807	PAV x	*R. padi*
MT 808	RMV x	*R. maidis*
MT 809	RMV x	*R. maidis*
MT 8010	RMV x	*R. maidis*
MT 8011	RMV x	Barley
MT 8012	RMV x	Winter wheat
MT 8013	RMV x	Barley
MT 811	PAV z, MAV z	Winter wheat
MT 812	MAV z	Winter wheat
MT 813	MAV z	Winter wheat
MT 814	PAV z	Winter wheat
MT 815	PAV x	Winter wheat
MT 816	PAV z	Spring wheat
MT 817	RMV x	Barley
MT 818	RMV x, PAV z	Winter wheat

[a] The first two numbers in the isolate code denote the year of collection.

[b] The letter x after the virus classification indicates it was characterized by aphid transmission only, y indicates enzyme immunosorbent assay (EIA) only, and z indicates both aphid transmission and EIA. Where two virus types are recorded, both were recovered from the same plant sample.

[c] Some isolates were recovered from plant sources by aphid transmission tests and/or identified by EIA. Other isolates were recovered from aphid sources directly after transmission of the virus by field-collected aphids of the indicated species.

RESULTS

During the 4-yr period, 179 plant and aphid samples were collected randomly from the survey area and tested for BYD-LV. Twenty-seven isolates of the BYD-LV virus were recovered. The virus type and source of each isolate are listed in Table 1. Among these 27 isolates, luteoviruses similar to PAV, RMV, MAV, and RPV were identified by aphid transmission tests and/or EIA.

Three types of BYD-LV recovered by aphid transmission experiments were identified by vector-specificity studies. Three of the isolates were MAV type, 12 were PAV type, and 10 were RMV type (Table 1). Two other isolates proved to be doubly infected: MT 811 (MAV plus PAV) and MT 818 (RMV plus PAV). The transmission results for the MAV-, PAV-, and RMV-like isolates were consistent with those reported in the literature (4,7,12). MAV-like isolates were consistently transmitted only by *Sitobion avenae*, PAV-like isolates were transmitted in order of efficiency by *R. padi, S. avenae,* and *Schizaphis graminum*, and RMV-like isolates were transmitted most efficiently by *R. maidis* and occasionally by *R. padi* and *S. graminum* (Table 2).

A fourth type of BYD-LV, RPV, was identified by EIA in isolates MT 802 and MT 803 (Table 3) but not detected by comparative aphid transmission studies because of the presence of a PAV type isolate in the plant samples tested. Isolates MT 802 and MT 803 were transmitted from infected spring wheat and barley plants, respectively (Table 1). In aphid transmission studies, both isolates were transmitted in descending order of efficiency by *R. padi, Sitobion avenae*, and *Schizaphis graminum*, indicating that PAV, the vector-nonspecific type, was the one involved. Coast Black oat plants infected with either of the MT 802 or MT 803 isolates, however, were severely stunted with respect to uninoculated control plants or plants inoculated with known PAV-like isolates.

Subsequent analysis by EIA (Table 3) determined that isolates MT 802 and MT 803 were mixed infections of PAV and RPV viruses. The identity of 17 of the 27 BYD-LV isolates was determined or confirmed by EIA results (Table 3). The Montana MAV, PAV, and RPV isolates were remarkably similar in homologous and heterologous reactions with immunoglobulins prepared against New York MAV, PAV, and RPV type antigens, respectively (Table 3). The RMV-like isolates found in Montana, however, failed to react with the immunoglobulin prepared against the New York RMV.

Although all the RMV-like isolates recovered were characterized as *R. maidis* vector-specific types, there was considerable variability in the transmission pattern by the less efficient vectors *R. padi* and *Schizaphis graminum* (Table 4). Isolate MT 791-2 was transmitted by *R. maidis* only, whereas isolates MT 809, MT 8010, and MT 808 were relative among the aphid vectors, with *R. padi* and *S. graminum* transmitting these isolates less frequently. In several experiments, all four isolates were tested during the same period so that environmental influences could be discounted as affecting the pattern of transmission.

Eight isolates were recovered from samples of aphid populations in 1979 and 1980 (Table 1). Four species found were *R. padi, Sitobion avenae, Schizaphis graminum*, and *R. maidis*. The fifth species was identified as *R. padiformis* (Richards), previously known only from British Columbia, Canada (8). Only PAV and RMV types were recovered directly

Table 2. Aphid transmission results for barley yellow dwarf luteoviruses collected in Montana

Vector species	Virus type[a] PAV	MAV	RMV	Control[b]
Rhopalosiphum padi	379/417[c]	22/148	32/254	0/301
Sitobion avenae	360/434	171/226	0/249	0/315
R. maidis	0/381	0/140	178/264	0/298
Schizaphis graminum	120/374	3/131	30/271	0/298

[a] For each virus type, the transmission data is a consolidation from similar isolates, each being transferred through three cycles of comparative transmission tests using the four aphid species. In each transmission experiment, aphids were allowed a 2-day acquisition feeding period on detached leaves from infected plants. Ten to 15 aphids were then transferred to each of four or five Coast Black oat seedlings for a 5-day inoculation test feeding.

[b] Control results are consolidated over all transmission tests for all of the virus types. In each separate transmission experiment, 40–60 aphids were taken directly from each of the aphid colonies used in the experiment and placed on indicator test seedlings to ensure that the aphids were nonviruliferous before their use in an experiment.

[c] The denominator is the total number of plants infested with test aphids and the numerator is the total number of test plants that became infected.

by transmission from the sampled aphid populations. In most vector transmission experiments, the percentage of viruliferous aphid populations was very low or zero. In two situations, however, the percentage was very high (Table 5). Among the *R. maidis* colonies from Huntley, Bozeman, and Buffalo, MT, collected on 8 August 1979 and 15 and 30 September 1980, respectively, the highest percentage of infective aphids was found at the latter two locations.

DISCUSSION

In-depth studies conducted in different geographic areas have revealed that the etiology and epidemiology of BYD varies with respect to the luteoviruses and species of aphid vectors that interact to incite the disease (5,7,12). This study further exemplifies the diversity of BYD luteoviruses. Four different luteoviruses and their principal aphid vectors were found in grain fields of central Montana. Because the survey area of this study was confined to a relatively small portion of the state, it is possible that other BYD luteoviruses and/or important aphid vectors exist in other locations.

Recovery of BYD-LV from plant material was best achieved with the detached-leaf technique. In 1978, one isolate, MT 781, an MAV type, was recovered by the membrane feeding technique, using *Sitobion avenae* as the vector. In 1978 and 1979, 16 additional plant samples were tested by the membrane feeding technique. None of the test aphids transmitted virus from these samples. Rochow (10) has reported that among the four species of test aphids used, only *S. avenae* consistently acquires virus from plant tissue extracts. It is quite possible that these 16 samples expressing "typical" BYD symptoms may have been infected with vector-specific viruses not readily transmitted by *S. avenae*.

Direct transmission from aphid vectors collected in the field was also a viable method of recovery. Aphids from the field, however, are not necessarily viruliferous, or the percentage of viruliferous aphids is so low that recovery of BYD-LV by limited aphid sampling is difficult. Thus, this method of virus recovery was less desirable than collecting plants with symptoms of virus infection.

Results of aphid transmission tests and EIA confirm the presence of MAV, PAV, and RPV types similar to those reported elsewhere (11,12,14). The *R. maidis* vector-specific types were somewhat unique, however, compared with RMV types found in New York (13) and Canada (4). EIA data (Table 3) for Montana RMV-like isolates indicates that they are serologically distinct in not reacting with RMV immunoglobulin. Rochow (13) reported that among RMV-like isolates tested by EIA, there is a range of homologous and heterologous reactions with RMV and RPV immunoglobulins, respectively. Apparently, the Montana RMV-like isolates fall at the end of this reaction spectra because they fail to show either a homologous or strong heterologous reaction with the respective RMV or RPV immunoglobulins.

The Montana RMV-like isolates may possibly represent a distinct group within the heterogeneous array of barley yellow dwarf viruses transmitted most readily by *R. maidis* (primary vector). Variation in serological relatedness is probably a result of differences in the intrinsic biological properties among such RMV isolates, a hypothesis supported by Rochow (13). Variations in transmission patterns by less efficient vectors (secondary or tertiary) are observed among the Montana RMV-like isolates (Table 2), which further supports the possibility of diversity in virus capsid composition existing within one particular group of BYD luteoviruses. From an epidemiological view, the Montana RMV type isolates transmitted regularly by *R. padi* and *Schizaphis graminum* have a greater potential for dissemination than RMV types transmitted in a more absolute manner by only *R. maidis*.

In four cases, plants were found to be doubly infected by two different BYD-LV, PAV, and MAV types in winter wheat and PAV and RPV in both spring wheat and spring barley. Rochow and Muller (16) reported that mixed infections are most often found in winter wheat or

Table 3. Enzyme immunosorbent assay (EIA) results for Montana barley yellow dwarf luteovirus isolates tested at Cornell University, Ithaca, NY, from 1979 to 1981

Virus isolate	Absorbance readings at 405 nm through a 1-mm light path with immunoglobulin shown				Luteovirus type
	RPV	MAV	PAV	RMV	
MT 781	0.009	1.40	0.123	0.004	MAV
MT 811-2	0.005	1.50	0.055	0.002	MAV
MT 812	0.001	1.12	0.043	0.022	MAV
MT 813	0.049	0.202	0.017	0.035	MAV
MT 782	0.030	0.60	0.209	0.008	PAV
MT 792	0.007	0.115	1.25	0.006	PAV
MT 804	0.011	0.036	0.288	0.007	PAV
MT 805	0.009	0.062	0.489	0.007	PAV
MT 806	0.009	0.088	0.668	0.010	PAV
MT 811-1	0.003	0.096	0.865	0.012	PAV
MT 814	0.016	0.062	0.324	0.009	PAV
MT 815	0.000	0.076	0.784	0.002	PAV
MT 818-1	0.005	0.100	0.624	0.010	PAV
MT 791[a]	0.039	0.018	0.011	0.011	RMV
MT 791[a]	0.055	0.039	0.016	0.018	RMV
MT 791[a]	0.015	0.007	0.010	0.009	RMV
MT 817[a]	0.002	0.002	0.010	0.005	RMV
MT 818-2[a]	0.012	0.010	0.025	0.011	RMV
MT 802[b]	0.982	0.054	0.203	0.005	RPV, PAV
MT 803[b]	0.308	0.034	0.294	0.007	RPV, PAV
NY RPV[c]	0.750	0.24	0.11	0.20	...
NY MAV	0.018	1.10	0.095	0.10	...
NY PAV	0.020	0.170	0.730	0.011	...
NY RMV	0.054	0.015	0.021	0.150	...
Healthy check 1[d]	0.008	0.007	0.005	0.011	...
2	0.031	0.023	0.025	0.015	...

[a] *Rhopalosiphum maidis* vector-specific isolates from Montana did not react strongly with any of the four immunoglobulins. Indication of these isolates as RMV types was based on the comparative aphid transmission tests only.

[b] For isolates MT 802 and MT 803, both RPV and PAV were indicated by EIA data to be present in the infected oat test plants assayed. In comparative aphid transmission tests, these two luteoviruses were inseparable.

[c] Absorbance readings for the New York RPV, MAV, PAV, and RMV types are from a single test in April 1980.

[d] The absorbance readings for healthy oat plant tissue are from two test dates showing the range of readings obtained with uninfected material.

Table 4. Results of comparative aphid transmission tests for four *Rhopalosiphum maidis* vector-specific isolates

Vector	Transmission results for isolate shown[a]			
	MT 791-2	MT 809	MT 8010	MT 808
R. maidis	34/60[b]	26/33	48/57	57/63
R. padi	0/60	0/28	8/50	24/64
Schizaphis graminum	0/60	5/33	7/50	21/67
Sitobion avenae	0/60	0/33	0/52	0/60

[a] Transmission data is consolidated over several transmission experiments where infected test plants were used as the virus source. Aphids of the four species were allowed a 2-day acquisition access period followed by a 5-day transmission access period on Coast Black oat test seedlings.

[b] The numerator is the number of Coast Black oat indicator test seedlings that became infected and the denominator is the number of seedlings infested with test aphids. None of 319 test plants used as controls became infected.

winter barley samples and seldom in spring oats. Both MT 802 and MT 803 isolates were recovered from spring grains, which may have important epidemiological significance. Doubly infected spring grains may provide an inoculum reservoir for aphid species not yet present in the crop-producing area.

Although vector populations were not monitored on a regular basis, the limited findings of this study (Table 5) indicate that for *R. maidis* vectors, late summer or early fall infection of winter wheat may be an important epidemiological factor in Montana. A'Brook and Dewar (1) found that during a 10-yr period, the species with the greatest proportion of infective alatae was *R. maidis*. Furthermore, the greatest proportion of infective aphid vectors was often caught in August through early October. Similar results were found in Montana, where large numbers of infective *R. maidis* colonies were found in late August and September (Table 5).

In 1978 and 1979, the prevalence of BYD symptoms in fields surveyed in the 10-county area was very low to negligible. In 1980, however, a severe BYD epiphytotic on winter wheat was diagnosed in Judith Basin and Fergus counties based on observable symptoms (Fig. 2). In the epiphytotic area, it was noted that fields of winter wheat planted before about 10 September 1979 were severely affected, whereas those planted after that date were only slightly affected or free of the disease. Numerous samples of winter wheat were collected during the summer of 1980 and tested for BYD by aphid transmission, but these studies failed to detect virus. This failure was a result of high greenhouse temperatures during these particular transmission experiments that were not ideal for symptom expression.

Although virus was not recovered by aphid transmission from field plant samples collected in 1980 from Judith Basin County, a PAV-like type (isolate MT 805) was transmitted by *R. padiformis* colonies collected at the Moccasin Agricultural Experiment Station (Table 1).

In September 1980, both *R. maidis*, but not the *R. padi* populations, were in abundance in several fields of volunteer winter wheat and spring barley. *R. maidis*, but not the *R. padi* field populations, proved to be infective (Table 5). Therefore, the potential for a second epiphytotic in winter wheat was present for the following year. In 1981, a second BYD-LV epiphytotic on winter wheat was encountered in Pondera County and surrounding areas (Fig. 3). Again, fields planted before 10 September were severely affected, whereas those planted after that date showed considerably less incidence of disease. PAV and MAV were identified as the predominant BYD-LV by aphid transmission studies (Table 1) and EIA results (Table 3). A third type, RMV, was identified in a winter wheat sample also infected with a PAV type (isolate MT 818, Table 1).

Table 5. Percentage of infective aphids in population samples collected in central Montana in 1979–1980 as determined by inoculation of indicator test seedlings

Location	Aphid species collected[a]	No. colonies tested[b]	Percent of infective aphids in sampled populations
Huntley	*Rhopalosiphum maidis*	12	12
	Schizaphis graminum	11	0
	Sitobion avenae	2	0
Buffalo	*R. maidis*	12	85
	R. padi	6	0
Bozeman	*R. maidis*	13	71

[a] During field surveys, aphid populations were sampled randomly from both healthy and diseased plants. Single aphids were selected and placed directly onto individual indicator test seedlings of Coast Black oats or California Mariout barley for a 5-day transmission feeding period.
[b] An aphid colony consisted of a group of aphids found on a single leaf. From each colony, five individual insects were selected for aphid transmission assay on indicator test seedlings.

Winter wheat samples collected on 13 May 1981 in certain fields within Pondera County contained BYD-LV according to EIA results (Table 4). As the growing season progressed, however, remission of BYD symptoms was observed in many of the fields for which BYD-LV infection had been positively identified.

Rochow and Muller (16) have noted that BYD-LV can be recovered from winter wheat plants that appear to be healthy, indicating that under certain environmental conditions, the effects of the virus may become masked in the host. This may be especially true for less virulent isolates of virus. At one location in the Pondera County epiphytotic area, MAV (isolate MT 812) was the infecting virus. By mid-June, BYD symptoms were not apparent, but in another field 3 miles north of that location, where PAV (isolate MT 815) was the infecting virus, however, symptoms were evident throughout the growing season. Thus, the virulence and prevalence of the infecting viruses along with climatic conditions may have facilitated the early remission of BYD symptoms in some fields in the Pondera County epiphytotic area.

Diagnosis of BYD later in the 1981 season was further confounded by a coincidental epiphytotic of wheat streak mosaic in central Montana. In fact, some winter wheat samples were doubly infected with both BYD-LV and wheat streak mosaic virus.

Because fields of winter wheat planted after 10 September 1979 in the 1980 epiphytotic area apparently escaped infection, a statewide recommendation was made to delay winter wheat planting until after 10 September. In the fall of 1980, growers in Judith Basin County followed the recommendation and BYD was not a problem in this area the following spring, although large populations of *R. maidis* and *R. padi* were present in fields of volunteer barley and winter wheat that fall. The *R. maidis* population, but not the *R. padi* population, proved to be viruliferous (Table 5). Thus, the potential for a second BYD epiphytotic was observed but did not occur because of the delayed winter wheat planting in the area.

Although we have only 2 yr of field observation and monitoring of BYD in winter wheat areas where the disease appears to be important, delayed planting seems to be an effective manner by which to escape large vector populations, and thus, the high infection rate of winter wheat by BYD-LV.

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