Barley Yellow Dwarf Virus in Pennsylvania: Effect of the PAV Isolate on Yield Components of Noble Spring Oats

F. E. GILDOW, Assistant Professor of Plant Pathology, and J. A. FRANK, Research Plant Pathologist, USDA-ARS, Department of Plant Pathology, The Pennsylvania State University, University Park 16802

ABSTRACT

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The effect of a single inoculation of Noble spring oats with the PAV isolate of barley yellow dwarf virus (BYDV) at either 4 or 6 wk after planting was evaluated in field trials in Pennsylvania. The virus was transmitted to the plants by the aphid *Rhopalosiphum padi*. In 1985, the number of heads per meter, number of seeds per head, thousand kernel weight (TKW), and overall yield were reduced by inoculation at 6 wk after planting. These components, except for the TKW, were reduced further when inoculation was made at 4 wk. In 1986, the greatest yield reduction occurred with the 6-wk inoculation, with a reduction in all yield components. Although a cold period during the aphid inoculation access period reduced the effectiveness of the inoculation at 4 wk, the overall plot yield was still less than that for the control. These data indicate levels of yield loss that could result from infections of some oat cultivars under field conditions with PAV-like isolates and substantiate the significance of early infections with BYDV.

Barley yellow dwarf virus (BYDV) causes significant yield losses on cereals throughout the world (3,4,9,10,16). The most dramatic losses in yield have been reported on spring oats (2–5,9,15). The yield losses are influenced by the cultivar grown (2,4,5,9), the growth stage of the plant at infection (3–5,14,15), and the number of aphids per plant (15). There are specific isolates of the virus (11), and disease severity and yield response may vary with each isolate (1,7,12). Therefore, yield loss studies should specify virus strain, aphid vector, and cultivar in order to provide meaningful results.

In a recent survey in Pennsylvania, the predominant BYDV isolates in oats were PAV-like isolates and the major aphid vectors were *Sitobion avenae* (Fabricius) and *Rhopalosiphum padi* L. (6). This study was conducted to determine whether BYDV isolates similar to PAV were affecting oat yields in Pennsylvania.

MATERIALS AND METHODS

Field experiments were conducted in 1985 and 1986 at The Pennsylvania State University Agricultural Research Farm in Centre County. Field plots of the oat (*Avena sativa* L.) cultivar Noble, a commonly grown cultivar in Pennsylvania, were established on 19 April 1985 and 1 April 1986. Seed was planted into soil that had wheat as the previous crop. The plots were 0.9 × 3.6 m and were seeded with a five-row cone-type planter at a rate of 167 kg/ha in rows spaced at 178 mm. Plots were fertilized with 672 kg of 5-10-10 (N-P-K) per hectare, incorporated into the soil prior to planting, and top-dressed with 33.6 kg/ha of nitrogen in the form of NH_4NO_3 at growth stage 5 (GS-5), based on the Feekes scale (8).

Two foliar pesticides were applied throughout the duration of the experiment. The systemic insecticide acephate (75WP, 0.56 kg/ha) was used for aphid control. Plants in the control plot received their first application of acephate 2 wk after planting and were sprayed on a 10-day schedule until they completed flowering (GS-10.54). Plants that would be infested with aphids were not sprayed the 2 wk prior to infestation. The fungicide mancozeb (80WP, 2.24 kg/ha) was applied to all plots on a 10-day schedule for control of Pyrenophora leaf blotch (*Pyrenophora avenae* Ito & Kuribay.). These applications were initiated at GS-7 and continued through GS-10.54. All pesticide applications were made with a backpack sprayer at approximately 207 kpa (30 psi) calibrated to deliver 280 L/ha. All five rows of the plot were treated.

The experimental design was a randomized complete block with four replications and three treatments. Each oat plot was surrounded on all sides by similar-sized plots of spring barley (*Hordeum vulgare* L. 'Lud') to provide a buffer zone between plots. The treatments were applied to one linear meter of plant row, which was demarcated in the center row of each five-row plot. The three treatments were: 1) noninoculated, 2) inoculated with BYDV when oat plants were 4 wk old, and 3) inoculated with BYDV when plants were 6 wk old. These inoculation dates represent the period when aphid activity appears to be most significant in oat fields in Pennsylvania (J. A. Frank, *unpublished*).

Aphids used for field inoculations of BYDV were from virus-free colonies of *R. padi*. The aphids were reared on caged winter barley cv. Barsoy, grown in 15-cm pots maintained under constant fluorescent light at 20 C. The aphids originally were obtained from characterized clones maintained by W. F. Rochow (USDA-ARS, Cornell University).

All aphid colonies were initiated with 24-hr-old nymphs produced on detached leaves of healthy barley. Approximately 30 nymphs were used to initiate each colony, and colonies were used 3 wk later. Aphids for field inoculations were allowed a 48-hr acquisition access feeding on detached leaves of oats (*A. byzantina* C. Koch 'California Red') infected with the PAV-NY isolate of BYDV obtained from W. F. Rochow (11). The characterized New York PAV isolate was used to allow future comparisons among other cultivars and comparison of our results with those at other locations. Approximately 200 aphids were distributed on three 6-cm leaf pieces in plastic petri dishes with tight-fitting lids and kept at 20 C in the dark during the acquisition period. Some aphids from each colony were allowed to feed on healthy oats to serve as controls.

Following the acquisition feeding, approximately 10 aphids per plant from the healthy oat or PAV-infected tissue were given a 5-day inoculation access feeding on 7-day-old oat seedlings. These plants were then fumigated and observed for 4 wk to verify the nonviruliferous condition of the original aphid colonies and PAV infection of the BYDV source tissue. In addition, the PAV-source plants and randomly selected inoculated plants from the field were tested by enzyme-linked immunosorbent assay (ELISA) against polyclonal antisera, provided by W. F. Rochow, to the RPV, RMV, MAV, and PAV isolates of BYDV (11) to verify the identity of the isolate.

For field inoculations, dishes containing three leaf pieces with approximately 200–300 viruliferous *R. padi* were used to

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infest field plots. The leaf pieces with feeding aphids were gently removed from the dishes and interwoven horizontally between the leaves of the target plants in the plot. Aphids remaining in the dish were shaken out over the plants in the row, and the plot area was covered immediately with a fine mesh cage, specially designed to cover the target area. Three dishes were used for each meter row. Plants remained caged for 3 days. At that time, cages were removed and the average number of aphids per plant was estimated. The aphids were killed 7 days after inoculation with a foliar application of acephate, and these plants were henceforth included in the 10-day spray schedule as described previously. Because the disease symptoms were extremely severe in 1985 (more severe than normally observed under Pennsylvania growing conditions), the number of dishes of aphids per plot was reduced in 1986 from three to one.

Disease severity was evaluated at GS-9 by classifying the discoloration on each leaf on a main tiller with an index designed by Doodson and Saunders (3). Their index values range from 0 to 8, with 0 indicating a healthy plant and 8 indicating total leaf necrosis. The mean of all leaves from 25 tillers per replication (100 total tillers) was recorded as the disease index.

At maturity, the plants in the designated meter were hand-harvested and stored in bundles until the grain was dry. At this time, the components of yield were determined by counting the number of tillers, heads, and seeds and weighing the grain. All yield data were subjected to analysis of variance and mean separation with the Waller-Duncan *k*-ratio *t* test.

RESULTS

In 1985 the temperatures were near the seasonal norm but the average monthly rainfall was below normal for the entire growing season. The average number of aphids per plant 4 days after infestation was 13 for the 4-wk inoculation and 16 for the 6-wk inoculation. Every plant examined within the target area had aphids on the foliage. Aphids were not observed in test plots after the initiation of the 10-day acephate spray schedule. Both inoculations were judged successful on the basis of visual symptoms. Reduction in plant height was associated with both inoculation dates. Most plants within the target area had significant yellowing of the leaves, with many plants showing the typical red leaf symptoms. Plants inoculated at 4 wk had significantly more red leaf tissue than those inoculated at 6 wk. ELISA tests of the six oat plants used as virus sources and of 10 randomly selected inoculated field plants indicated that all plants were infected with only the PAV isolate of BYDV in 1985 and 1986.

All components of the 1985 yield except the thousand kernel weight (TKW) were reduced when plants were inoculated with BYDV (Table 1). The TKW for plants inoculated at 6 wk was less than that for the control but did not differ for the plants inoculated at 4 wk and the control. With all the other components, yield was reduced with inoculation at 6 wk but reduction was significantly greater with inoculation at 4 wk.

In 1986, the environmental conditions during the growing season were near normal. During the period of the 4-wk inoculation, however, the temperatures were below normal. The average daily temperature and average minimum temperature during the first 4 days of the first inoculation feeding period were 14 and 6 C, respectively, in 1985 and 5 and 0 C, respectively, in 1986. After the cold period during the inoculation feeding in 1986, temperatures returned to normal (10–15 C). Average daily temperatures during the inoculation period at 6 wk in 1985 and 1986 were similar and varied from 10 to 21 C. No significant rainfall occurred during any of the inoculation periods. The average number of aphids per plant 4 days after inoculation was five for the 4-wk inoculation and six for the 6-wk inoculation. Every plant had at least one aphid after the 6-wk inoculation, but after the 4-wk inoculation, 12% of the plants did not have any aphids. The disease symptoms in 1986 were greatly reduced from those in 1985. The amount of stunting and red leaf symptoms was minimal. The primary symptom was a foliar chlorosis.

The early inoculation of 1986 did not appear to have the dramatic effects on yield that were apparent in 1985. The consistently lower temperatures in 1986 during the inoculation at 4 wk would be expected to lower aphid feeding activity and plant-to-plant spread. The number of heads, the number of seeds per head, and the TKW were not significantly different from the control values. However, minor reductions of these components in infected plants contributed to an overall reduction in plot yield. The plants inoculated at 6 wk had the lowest component values in 1986. The values for heads per meter, seeds per head, TKW, and plot yields were all lower after inoculation than the same values for the control plots. Also, both the heads per meter and the TKW values were significantly lower for the 6-wk inoculation than for the 4-wk inoculation.

DISCUSSION

Because both field inoculations in 1985 were successful, on the basis of disease index and yield reductions, it was evident that inoculations at the earlier stage of growth had the most significant influence on yield. This confirms the results of previous workers (3–5,9,14,15), although in most of these studies, the virus isolate or the aphid vectors were not identified or the natural aphid populations in the field were not controlled. The influence of dosage response with increasing number of aphids has been questioned (13), but in this study no attempt was made to establish the titer of the virus in the inoculated plants. The 1985 data simply indicate a greater yield reduction with the earlier inoculation.

The early stage of inoculation closely approximates the earliest stages of insect activity in Pennsylvania, according to our preliminary observations. Aphid activity prior to 4 wk after planting is usually minimal because of the cool temperatures generally prevalent at that time. In 1986, the cold temperatures slowed the activity of the aphids, and the yield reductions from this inoculation (23%, calculated from seed weight per plot in Table 1) were comparable to those for the later inoculation (28%). Also, the number of aphids used for the 1986 inoculations had been reduced from that used in 1985 to provide a more representative yield loss. The early inoculation in 1985 reduced yields by 87%. Yield reductions of this magnitude have been reported (4), but this degree of

Table 1. Effects of field inoculations with the PAV isolate of barley yellow dwarf virus at two growth stages on disease symptoms and yield components of the spring oat cultivar Noble in Pennsylvania, 1985–1986

Plant age at inoculation	Disease index[w]	Heads per meter (no.)	Seeds per head (no.)	Weight (g/plot)[x]	TKW[y] (g)
		1985			
Control	0.0 a[z]	102.0 a	24.3 a	79.4 a	32.0 a
6 wk	4.7 b	89.3 b	21.9 b	57.6 b	29.4 b
4 wk	6.6 c	48.3 c	6.7 c	10.6 c	32.4 a
		1986			
Control	0.0 a	128.0 a	22.4 a	88.3 a	30.8 b
6 wk	3.8 b	113.3 b	17.4 b	62.8 b	32.4 a
4 wk	3.1 b	122.1 a	19.0 ab	68.0 b	29.4 b

[w] Based on a 0–8 scale, with 0 = healthy plant, 8 = total leaf necrosis (3). Values represent mean of all leaves on 25 main tillers selected at random from each of four replications.
[x] Total seed weight from plants in a linear meter of row.
[y] Thousand kernel weight.
[z] Means followed by the same letter in a column are not significantly different according to the Waller-Duncan *k*-ratio *t* test ($k = 100$).

yield reduction does not normally occur in Pennsylvania.

The 6-wk inoculation represents the period in which the aphids appear to be most active. This is based on counts of aphids per plant over the growing season. Once stem elongation begins, the aphid populations appear to decline. This may be due to the buildup of aphid predators. In this study, the aphids were controlled after their 7-day inoculation feeding period. This was done to control the inoculation period and the virus isolate. If the aphids were not destroyed after this period, the feeding would have continued and the amount of yield loss could have been greater. Therefore, the results presented here do not exactly represent the natural field situation but do indicate the potential damage of a controlled inoculation with a specific virus isolate at a specific growth stage. The potential for significant disease losses is evident. This study should be expanded, however, to include additional cultivars and growing seasons.

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