

# Effects of Barley Yellow Dwarf Virus on Root Growth in Spring Oat

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## ABSTRACT

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The effects of a nonspecifically transmitted strain of barley yellow dwarf virus (BYDV-PAV-IL) on root growth of four spring oat (*Avena sativa*) genotypes differing in BYDV tolerance were compared. Plants of each genotype were grown in a growth chamber using an aeroponic system. Half of the plants in each of two experiments were used as controls, and half were inoculated at the two- to three-leaf stage (Zadoks stage 12 or 13). For all four genotypes, the rate of root elongation was greater for control plants than for inoculated plants. When control and inoculated plants were compared, most parameters measured were reduced in inoculated plants in three of the genotypes, but the fourth genotype, Ogle, had a significant reduction only in root dry weight and rate of root elongation.

Barley yellow dwarf virus (BYDV) causes one of the most economically important viral diseases of small grains, including spring oat (*Avena sativa* L.) (3). Infection with BYDV, a phloem-restricted luteovirus obligately vectored by several species of aphids, is characterized by several symptoms, including leaf discoloration and reddening, leaf necrosis, stunting, and delay in or lack of heading (4,9). Under some environmental conditions, visual symptoms may be quite subtle or nonexistent, especially on wheat. Significant yield losses result from infection with BYDV in all small grains (3). Use of tolerant (5) cultivars has been the only economic means of controlling damage due to the disease (8,9,11).

Although the effects of BYDV on shoot growth have been well characterized (3, 4), not much quantitative information has been reported on differences in root growth in plants with different levels of tolerance to the disease. Effects of BYDV on root growth may be an important factor in determining cultivar tolerance, since the roots are responsible for the nutrient and water uptake of the plant.

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BYDV has been purified from oat root tissue (6), and in some cultivars the titer of BYDV has been found to be higher in root tissue than in the shoots (6). Since the effects of BYDV on root growth have not been quantified in cultivars varying in tolerance, our objective was to compare the root growth in infected and uninfected plants of four spring oat genotypes differing in tolerance to BYDV.

## MATERIALS AND METHODS

**Plant genotypes.** On the basis of their performance in artificially inoculated field evaluations of aboveground symptoms, four spring oat genotypes differing in BYDV tolerance were selected for this experiment (Table 1). These genotypes represent a broad range of tolerance to the PAV strain of BYDV from Illinois (BYDV-PAV-IL). IL 86-6404 and Ogle (2) are tolerant, Larry (1) is moderately tolerant, and Clintland 64 (10) is sensitive to BYDV. IL 86-6404 is an experimental breeding line developed in the oat breeding program at the University of Illinois.

**Virus strain and aphid vector.** A well-characterized (7), nonspecifically transmitted virus strain (BYDV-PAV-IL) was used for all experiments. Colonies of viruliferous *Rhopalosiphum padi* L. were established and maintained on barley (*Hordeum vulgare* L. 'Hudson') infected with BYDV-PAV-IL. Colonies were maintained in a growth chamber with a 13-hr day length and a day and night temperature of 23 and 19 C, respectively.

**Growth and inoculation of plants.** Plants of the four genotypes were grown in a growth chamber containing an aeroponic mist box that allowed root development of the plants to be studied easily (13). Seeds of each genotype were germinated in petri dishes on germina-

tion paper. When the coleoptile was approximately 3 cm long, seedlings of nearly uniform size were selected and transferred to the mist box in a completely randomized design. Day length in the growth chamber was 13 hr, with a 23 C day temperature, a 19 C night temperature, and a light intensity of 370  $\mu\text{E}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ . The roots of the plants were contained in a light-tight 61 × 61 × 61 cm aeroponic mist box and were misted with a half-strength Hoagland's solution for 1 or 2 sec every 5 min by four nozzles located in the bottom of the box. The aeroponic mist box apparatus has been described by Wagner (13).

Before the aphid vectors were introduced into the growth chamber, five or six control plants of each genotype were placed in 3 × 8 cm tubular cellulose butyrate cages to prevent accidental inoculation. Five or six plants of each genotype were inoculated at the two- or three-leaf stage with BYDV-PAV-IL using viruliferous *R. padi*. Three to five apterous, late-instar aphids were transferred to each plant with a damp paintbrush, and the plants were caged. After an inoculation access period of 48 hr, all plants were fumigated with dichlorvos (Vapona). The cages were left on the control plants for an additional 24 hr to ensure that no viruliferous aphids remained on the inoculated plants.

**Plant responses to BYDV-PAV-IL.** For each plant, the length of the longest primary root was measured and the number of primary root axes was counted every 2 or 3 days. The experiment was ended 19 days after inoculation when the roots of some control plants reached the bottom of the mist box. At that time, the number of tillers per plant was recorded and shoot and root fresh weights were measured. Shoot and root dry weights were determined after drying at 38 C for 7 days. A fresh root subsample of approximately 10% of the root fresh weight was taken, stored in a 20% alcohol solution, and subsequently dyed with methyl violet. A root area meter (Decagon Delta T Model MK2, Decagon Devices, Inc., Pullman, WA) was set to read root length and used to determine the length of these subsamples. Total root length was determined by subsample length multiplied by the quotient of total root fresh weight divided by root subsample fresh weight.

**Analysis.** The experiment was repeated and data from the two experi-

ments were combined for analysis. The rate of root elongation of infected and uninfected plants of each genotype was determined using the treatment means for longest primary root length measured repeatedly at 2- or 3-day intervals on the same plants. The SAS GLM procedure (12) was used to determine the regression line that represented the best fit to the root elongation data for healthy and infected plants of each genotype. A standard analysis of variance for completely

randomized designs was conducted, and the growth of inoculated plants of each genotype was compared with the growth of uninoculated plants.

## RESULTS AND DISCUSSION

For all four genotypes, the rate of root elongation was significantly lower in inoculated plants than in control plants (Fig. 1). Root elongation completely ceased in infected plants of Clintland 64 within 3 days of inoculation with BYDV. Although root elongation was reduced in infected plants of IL 86-6404 and Ogle, the reduction in these two tolerant cultivars was less severe than that observed in the two more sensitive cultivars.

Root dry weight was significantly reduced in all four genotypes (Table 2). Root dry weight and the rate of root elongation (Fig. 1) were the only parameters for which a significant reduction was observed for infected plants of Ogle compared with uninfected plants. For IL 86-6404, Larry, and Clintland 64, nearly all the parameters measured were significantly reduced.

Reductions in root fresh and dry weight, shoot fresh and dry weight, and total root length were much greater for Larry and Clintland 64 than for the two more tolerant genotypes (Table 2). Reductions in the root fresh weight, root dry weight, and total root length were especially large for infected plants of Clintland 64.

In the sensitive cultivar, Clintland 64, the virus had a greater effect on root growth than on shoot growth, although both effects were quite severe. The greater effect of the virus on root growth is evident from the increase in shoot/root ratio in Clintland 64 (Table 2). Shoot/root ratio was not significantly reduced in IL 86-6404, Ogle, or Larry.

Although IL 86-6404 has shown less

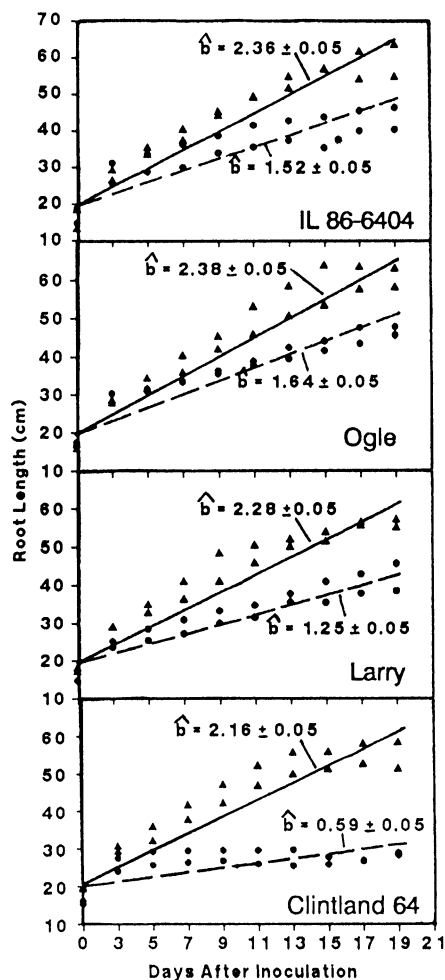
severe symptoms than Ogle in inoculated field tests (Table 1), on the basis of the parameters measured in this study, Ogle seemed to be more tolerant to the virus. Healthy plants of IL 86-6404 had extensive root growth; total root length of control plants of IL 86-6404 was greater than the root length of the control plants of the other three genotypes. The greater field tolerance of IL 86-6404 might be explained, in part, by the extensive root growth that appears to characterize this line. Perhaps when IL 86-6404 and Ogle are artificially inoculated with BYDV in the field, IL 86-6404 may suffer a greater percentage reduction in root growth, but the reduced root length is sufficient to provide adequate water and nutrients to the plant. Thus, the abundant root growth of IL 86-6404 may partially offset the effects of the root damage caused by BYDV-PAV-IL so that under field conditions, aboveground symptoms are not severe. We have not tested this hypothesis, since this study dealt only with plants grown in a growth chamber and the plants were not grown to maturity.

The aeroponic mist box system of growing plants employed in this study should be useful for evaluation of the effects of the virus on root growth and for studies of the mechanism of BYDV tolerance. Because this procedure requires more time and labor than field evaluation of the artificially inoculated hills we are currently using, and because this procedure is not suitable for handling large numbers of genotypes, we do not anticipate that it will be useful as a screening tool. However, this procedure may be useful for identifying genotypes (for use as parents) with different mechanisms of tolerance to BYDV and for further study of the effects of BYDV on root growth.

**Table 1.** Barley yellow dwarf virus (BYDV) ratings of four spring oat genotypes

Genotype	Relative tolerance to BYDV	BYDV rating <sup>a</sup>	
		1988	1989
IL 86-6404	Very tolerant	1.3	2.2
Ogle	Tolerant	2.7	3.2
Larry	Moderately tolerant	4.3	5.8
Clintland 64	Sensitive	8.3	8.0
LSD <sub>0.05</sub>		1.2	0.9

<sup>a</sup>Based on visual symptoms rated on a scale where 1 = very tolerant and 9 = very sensitive. Values are the means of three replications of hills infected with BYDV-PAV-IL rated each year (*unpublished*).



**Fig. 1.** Comparison of root elongation in BYDV-infected plants (●) and uninfected plants (▲) of four spring oat genotypes.

**Table 2.** Root and shoot data for four spring oat genotypes infected and not infected with barley yellow dwarf virus

Treatment	Root fresh weight (g)	Root dry weight <sup>a</sup> (g)	Total root length <sup>b</sup> (cm)	Shoot fresh weight (g)	Shoot dry weight <sup>d</sup> (g)	Tillers <sup>c</sup>	Primary root axes <sup>c</sup>	Shoot/root ratio <sup>d</sup>
IL 86-6404								
Control	7.26 <sup>**c</sup>	0.49 <sup>**</sup>	3,085 <sup>**</sup>	8.23 <sup>**</sup>	1.44 <sup>**</sup>	3.1 <sup>**</sup>	15.5 <sup>**</sup>	3.18
Infected	2.63	0.26	1,384	4.83	0.93	2.0	13.2	3.66
Ogle								
Control	5.30	0.41 <sup>*</sup>	2,302	5.97	0.97	2.8	17.9	2.60
Infected	3.31	0.26	1,505	4.45	0.81	2.4	15.7	2.99
Larry								
Control	5.54 <sup>**</sup>	0.47 <sup>**</sup>	2,433 <sup>**</sup>	6.07 <sup>**</sup>	1.00 <sup>**</sup>	2.9 <sup>**</sup>	16.8 <sup>**</sup>	2.33
Infected	1.26	0.11	712	1.81	0.37	1.1	9.5	3.29
Clintland 64								
Control	4.42 <sup>**</sup>	0.29 <sup>**</sup>	2,043 <sup>**</sup>	4.38 <sup>**</sup>	0.80 <sup>**</sup>	2.7 <sup>**</sup>	13.0 <sup>**</sup>	3.17 <sup>**</sup>
Infected	0.55	0.06	335	1.20	0.10	1.1	11.3	5.74

<sup>a</sup>Determined after drying at 38 C for 7 days.

<sup>b</sup>Determined with a root area meter on a subsample that was approximately 10% of the root fresh weight.

<sup>c</sup>Tiller number and number of primary root axes 19 days after inoculation.

<sup>d</sup>Based on individual plant shoot dry weight/root dry weight.

<sup>e</sup>Significantly different from inoculated at \* =  $P < 0.05$  and \*\* =  $P < 0.01$ .

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