Reaction of Selected Onion Cultigens to Pink Root under Field Conditions in New York

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ABSTRACT

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Levels of pink root, caused by *Phoma terrestris*, were assessed on onion (*Allium cepa*) growing in organic soils on farms in three New York counties during 1987 to 1990. Both commercial cultivars and lines from the USDA breeding program (collectively = cultigens) were evaluated for pink root incidence early in the season and for pink root severity later in the season. Onions were infected by *P. terrestris* as early as 6 to 8 weeks after field seeding. At maturity, portions of the root systems of all onions in all cultivars had turned pink. The cultigens with fewest symptoms were Sweet Sandwich, Keepsweet II, Spartan Banner 80, and inbred line MSU5785B.

Additional keyword: resistance

Onion (*Allium cepa* L.) is the most important vegetable crop in New York, where it is grown almost exclusively on organic soils. Nearly every field is infested with the fungus *Phoma terrestris* E. M. Hans., the causal agent of pink root. This disease is also common throughout the U.S. and the world. Roots infected by *P. terrestris* turn pink initially and then become brittle and die. Although *P. terrestris* can be present in roots or dry outer scales of the bulbs, it does not invade the basal plate or stem of the bulb (3,6,9). Therefore, root injury is of greatest concern to onion growers since it may cause a decrease in yield. Often both *P. terrestris* and *Fusarium oxysporum* Schlechtend.:Fr. f. sp. *cepae* (H. N. Hans.) W. C. Snyder & H. N. Hans. are isolated from the same root. *Fusarium* causes a dry rot in the basal plates of onions but does not produce pink color in roots of mature plants.

Reduction of initial inoculum via soil solarization or fumigation can control some soilborne diseases. Solarization increased yields of onion in Israel, Australia, and Texas (7,15,17). Fumigation with dazomet (15) or metam-sodium (7) increased yields and decreased incidence of pink root. In these studies, growth responses may have been due to a variety of factors in addition to the decrease in *P. terrestris* inoculum. In any case, solarization is not feasible in temperate climates such as New York's because onions must be in the field

throughout the warm months of the year. Fumigation is expensive, and there is growing concern about the environmental hazards of chemical fumigants.

Although crop rotation is often suggested to decrease inoculum of soilborne disease, the wide host range of *P. terrestris* makes this control strategy impractical. *P. terrestris* has been isolated from and/or has been shown to cause disease on many species of plants from 45 genera, including other *Allium* spp., broadleaf weeds, grasses, grains, and vegetables (1,6,9,16,18,19).

Use of resistant cultivars (defined as those that develop few pink roots in soils infested with *P. terrestris*) appears to be the most promising method for controlling pink root. Onion cultivars vary in their resistance to *P. terrestris* (10,11,13,14). Resistant cultivars suitable for western U.S. growing areas are available, but cultivars adapted for New York growing areas are highly susceptible to pink root. Assessment of breeding lines and cultivars (collectively = cultigens) for reaction to pink root and high yield is an important part of the development of onion cultivars suitable for commercial use in New York.

Various methods have been used to determine resistance of onion cultigens to pink root. Ratings for pink root resistance were performed on onion seedlings (2,4,13,14) or onion sets (12) grown in artificial media amended with inoculum. Onion seedlings (8) and onion tissue cultures (5) were exposed to toxins of *P. terrestris*. These methods isolate the effect of *P. terrestris* but do not measure yield losses, which are of primary importance to farmers.

These studies were undertaken to determine pink root reaction of selected culti-

gens throughout the growing season and the relationship between cultigen yield and pink root ratings. The major emphasis was on cultigens adapted to New York growing conditions (organic soil, cool and wet spring weather, and long days).

MATERIALS AND METHODS

Seeds of commercial onion cultivars were obtained from Abbott & Cobb (A & C), Feasterville, PA; Asgrow (As), Kalamazoo, MI; Ferry-Morse (F-M), Modesto, CA; Harris Moran (HM), Salinas, CA; Krummery (Kr), Stockbridge, MI; Peto-seed (Pet), Saticoy, CA; Seedway (Sdy), Hall, NY; Stokes (St), Buffalo, NY; and Sun Seeds (Sun), Eden Prairie, MN. Several entries were advertised as pink root resistant or had low levels of pink root in previous studies (data not shown), other entries were cultivars widely grown in New York. Seeds of breeding lines were also provided by M. Havey and P. Simon of the USDA-ARS (Department of Horticulture, University of Wisconsin-Madison), and by W. Gabelman (Department of Horticulture, University of Wisconsin-Madison). Onion cultigens were planted and grown to harvest in organic soil on commercial onion farms. Entries were seeded in 6-m plots at a rate of 39 seeds per m with a hand-pushed Planet Jr. planter.

Statistical analysis. When pink root severity was rated as percentage of pink roots (1987 experiments), ratings were arc-sine transformed prior to statistical analysis. The reported means are the means of percentages. When pink root severity was assessed with a pre-transformed scale, the ratings were converted to percentages before analysis, e.g., a rating of 7 was converted to 79%. Analysis of variance was performed on yield and severity with PROC ANOVA (complete block design) or PROC GLM (incomplete block design) (SAS Institute, Cary, NC). If $P > F$ was less than 0.10, means were compared with Fisher's least significant difference (LSD). The influences on yield from pink root alone (linear regression) or from pink root and relative maturity (multiple regression) were examined.

Yates and Genesee counties (1987). In Yates County, 16 commercial cultivars were planted on 28 March in two-row plots, arranged in a randomized complete block design with four replications. Disease incidence was measured on 21 May

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with 10 plants per entry sampled from one replication.

When plants were sampled in Yates County on 21 May, roots were washed in running tap water, surface sterilized in 0.5% sodium hypochlorite, and placed on either moist filter paper or wheat-straw agar. The entire root system of a plant was placed on one plate. Wheat-straw agar consisted of 2% water agar (20 g of agar per liter of water) to which a small amount of chopped, sterile wheat straw was added while the agar was still molten. The wheat straw was sterilized by gamma cell radiation from a radioactive cobalt source. In both procedures, roots were incubated at room temperature for 1 week, which allowed more pink color to develop. Pink color present after that time was presumed to be due to *P. terrestris* because Watson (20) found that only *P. terrestris* produces a pink pigment on wheat-straw agar. Disease incidence was measured on 13 June with two plants from each entry in each replication. One plant from each plot was put on filter paper, and one was plated onto wheat straw agar. Data were combined as incidence in the results.

Onions were sampled systematically, at a given location within the plot. All onions sampled were adjacent to each other, in order to minimize disturbance to the remainder of the experiment.

On 6 August, near the end of the season, relative maturity ratings were assigned to each entry, based on the percentage of tops that had fallen over and turned from green to brown. The following scale was used: 0 = no tops have fallen; 1 = 1 to 10% down; 2 = 11 to 20% down, etc., up to 10 = 91 to 100% down; 11 = 100% down plus <33% leaves brown; 12 = 33 to 67% leaves brown; and 13 = >67% leaves brown. Onion bulbs were harvested and weighed on 20 August immediately prior to field harvest by the cooperating grower.

In Genesee County, two experiments were conducted during 1987. Experiment 1 included USDA breeding lines arranged in a completely randomized design. Only two or three replications of one-row plots were planted because of limited seed quantity. Experiment 2 was arranged in a Latin square design, with four replications of two-row plots. Both Genesee County experiments were seeded on 2 May, rated for maturity on 18 August, and harvested on 6 September immediately prior to field harvest by the cooperating grower. Pink root incidence was assessed on 13 June by plating roots from one plant on wheat-straw agar and roots from two plants on filter paper. Severity was assessed on 18 August with three and five plants from each plot, respectively.

Genesee County (1989). Both commercial cultivars and breeding lines were planted on 29 April, 32 entries in one-row plots, in a randomized incomplete block design. There were four replications, ex-

cept for entries 1717B and 8155B, which had three replications. Pink root severity was rated on 14 September with a pre-transformed scale, on five plants from each plot. A rating of 1 = 2.5% pink roots; 2 = 10% pink roots; 3 = 21%; 4 = 35%; 5 = 50%; 6 = 65%; 7 = 79%; 8 = 90%; 9 = 97.5%; and 10 = 100%.

Maturity was rated on 14 September, based on the percentage of onion tops down, as in 1987, except 11 = 100% down and <50% brown and 12 = 100% down and >50% brown. Bulbs were harvested on 22 September immediately prior to field harvest by the cooperating grower.

Yates and Genesee counties (1990). Seeds for these experiments were from the USDA and University of Wisconsin breeding programs. In Yates County, eight entries were planted on 27 April in two-row plots in a randomized complete block design with five replications. Pink root severity was assessed with a pre-transformed scale on 1 August on nine or 10

plants per plot. Maturity was rated on 12 September with the same scale as in the 1987 experiments. Onions were harvested 18 September immediately prior to field harvest by the cooperating grower.

In Genesee County, entries were planted on 23 April in one-row plots in a randomized incomplete block design with three or four replications. Pink root severity was assessed on 31 July on 15 plants per plot, with a pre-transformed scale. Onions were harvested 20 and 21 September immediately prior to field harvest by the cooperating grower.

Statistical analysis. When pink root severity was rated as percentage of pink roots (1987 experiments), ratings were arc-sine transformed prior to statistical analysis. The reported means are the means of percentages. When pink root severity was assessed with a pre-transformed scale, the ratings were converted to percentages before analysis, e.g., a rating of 7 was converted to 79%. Analysis of variance was

Table 1. Pink root incidence, severity, and onion maturity and yield for onion cultivars in Yates County, NY, during 1987

Entry	Seed source ^y	Pink root incidence (%) (June 13)	Pink root severity (%) (Aug. 6)	Maturity ^z	Yield (kg/ha)
Bronze Reserve	F-M	63	83	11	45,448
Columbia	F-M	25	76	11	49,203
Paragon	Sun	50	72	10	50,324
Sassy Brassy	F-M	88	66	9	49,539
Progress	HM	50	65	11	62,092
Sleeping Beauty	F-M	75	65	10	41,806
Sentinel	HM	13	63	10	65,231
Spartan Banner 80	As	25	58	9	59,851
Copra	Sdy	25	58	10	49,427
Bullseye	F-M	50	58	10	57,665
Krummery Banner	Kr	63	57	9	61,644
Class Pak	F-M	50	54	10	60,803
Spartan Banner 80	Sun	0	52	10	59,122
Surecrop	HM	0	47	8	65,287
Keepsweet II	A&C	38	43	9	67,584
Sweet Sandwich	A&C	13	40	10	61,420
LSD 0.05			26		5,306

^y See text for definition of abbreviations.

^z Maturity rating scale was 0 = no tops have fallen, 1 = 1 to 10% down, 2 = 11 to 20% down, etc., up to 10 = 90 to 100% down, 11 = 100% down plus <33% leaves brown, 12 = 33 to 67% leaves brown, and 13 = >67% leaves brown.

Table 2. Pink root incidence, severity, and onion maturity and yield, for onion breeding lines in the 1987 Genesee Co., NY, experiment 1

Entry	Expected reaction ^y	Pink root incidence (%) (June 13)	Pink root severity (%) (Aug. 18)	Maturity ^z	Yield (kg/ha)
MSU5718B	Sus	11	55	8	21,183
B1834B	Res	35	55	11	4,427
MSU2399B	Sus	11	53	1	12,497
B2429B	Res	0	30	9	5,268
MSU8155B	Sus	11	28	1	1,625
B2352B	Res	11	24	3	6,333
B1717B	Res	0	23	4	8,854
B3350B	Res	11	17	6	1,345
MSU5785B	Res	33	16	1	1,793
LSD 0.05			21		

^y Res = resistant; Sus = susceptible based on seedling evaluation (M. Havey and P. Simon, *personal communication*).

^z Maturity rating scale was 0 = no tops have fallen, 1 = 1 to 10% down, 2 = 11 to 20% down, etc., up to 10 = 90 to 100% down, 11 = 100% down plus <33% leaves brown, 12 = 33 to 67% leaves brown, and 13 = >67% leaves brown.

performed on yield and severity with PROC ANOVA (complete block design) or PROC GLM (incomplete block design) (SAS Institute, Cary, NC). If $P > F$ was less than 0.10, means were compared with Fisher's least significant difference (LSD). The influences on yield from pink root alone (linear regression) or from pink root and relative maturity (multiple regression) were examined.

RESULTS

Yates and Genesee counties (1987). In Yates County, no pink root symptoms were

seen on plants sampled 21 May. After incubation on filter paper or wheat-straw agar, some roots turned pink, indicating that *P. terrestris* had infected the plants. On 13 June, plants had six true leaves. Pink roots were visible at the time of sampling, and in many cultivars a majority of the plants were symptomatic (Table 1). However, less than 10% of the root tissue had turned pink.

Sweet Sandwich was resistant both early in the season, as indicated by low incidence, and late in the season, as indicated by low severity of pink root. Bronze Re-

serve was the most susceptible entry, as indicated by high early-season incidence and high late-season severity of pink root symptoms. Keepsweet II was the highest-yielding entry and also was fairly resistant.

In the Yates County experiment, the relationship between mean pink root severity and mean yield fit the linear regression model with one dependent variable. The regression line, $Y = 1524.7 - 8.6$ (pink root severity), was highly significant at $P = 0.002$ ($R^2 = 0.50$). Multiple regression with both dependent variables (pink root severity and maturity) resulted in the equation $Y = 1550.7 - 8.4$ (pink root severity) $- 3.6$ (maturity), significant at $P = 0.01$ ($R^2 = 0.50$).

In Genesee County experiment 1, pink root symptoms were seen in only a small proportion of the plants sampled on 13 June, and less than 10% of the root tissue was symptomatic (Table 2). Even on 1 July (data not shown), the maximum pink root incidence was 38% of the plants sampled, and the maximum severity was 10%. Disease severity ratings agree with the expected levels of resistance and susceptibility, except that line B1834B had high levels of pink root on August 18 and was rated "resistant." Line B1834B was also more mature than the other entries, which may explain its high disease levels. The USDA breeding line MSU5785B had the fewest pink roots on 18 August. Pink root severity was not correlated with yield for the entries in this experiment.

In Genesee County experiment 2, Spartan Banner 80 (Pet) had the lowest percentage of pink roots but was also the latest-maturing cultivar and had the lowest yield (Table 3).

Genesee County (1989). The six most resistant entries were from the USDA breeding program, but only line (MSU-

Table 3. Pink root incidence, severity, maturity and yield of onion cultivars in the 1987 Genesee Co., NY, experiment 2

Entry	Seed source ^y	Pink root incidence (%) (June 13)	Pink root severity (%) (Aug. 18)	Maturity ^z	Yield (kg/ha)
Ontario M	As	33	64	7	19,838
Downing Yellow Globe	As	17	55	9	21,519
Saturn	Pet	0	52	7	23,313
Spartan Banner 80	Pet	33	35	1	12,553
LSD 0.05			23		3,770

^y See text for definition of abbreviations.

^z Maturity rating scale was 0 = no tops have fallen, 1 = 1 to 10% down, 2 = 11 to 20% down, etc., up to 10 = 90 to 100% down, 11 = 100% down plus <33% leaves brown, 12 = 33 to 67% leaves brown, and 13 = >67% leaves brown.

Table 4. Pink root severity, and onion maturity and yield, for onion cultigens in Genesee Co., NY, during 1989

Entry	Seed source ^y	Pink root severity (%) (Sept. 14)	Maturity ^z	Yield (kg/ha)
Cuprum	Sun	96	11	40,797
6105B	USDA	96	12	26,899
(B2354x B7728) × B2419	USDA	96	12	40,013
Paragon	Sun	95	12	33,848
B7728B	USDA	94	12	23,761
MSU5718B	USDA	94	11	35,585
NY Early	St	94	11	63,325
Keepsweet II	A&C	94	10	40,069
B1834B	USDA	94	12	18,157
Sunex 1492	Sun	93	11	46,121
(B3350 × B2380) × B2419	USDA	93	12	35,137
B2368B	USDA	92	12	18,661
Class Pak	F-M	92	10	39,564
(B1750 × B1828) × B3350	USDA	92	12	34,689
B3350B	USDA	91	12	10,984
MSU8155B	USDA	91	10	23,145
NY Early	Sun	90	11	52,902
(B1750 × B1731) × B1717	USDA	90	12	38,668
Sentinel	HM	90	10	46,569
B2352B	USDA	89	11	16,196
B6123B	USDA	87	8	31,663
Bullseye	F-M	86	8	46,962
Kodiak	HM	85	9	37,435
Sweet Sandwich	A&C	85	8	46,793
MSU826B	USDA	83	11	22,080
Spartan Banner 80	A&C	82	10	42,815
(MSU5718A × MSU8155B) × B6123B	USDA	82	9	58,954
B1717B	USDA	80	11	30,374
MSU611B	USDA	71	10	16,644
B2419B	USDA	71	10	19,782
B1750B	USDA	67	11	14,458
MSU5785B	USDA	65	9	15,691
LSD 0.05		14		9,841

^y See text for definition of abbreviations.

^z Maturity rating scale was 0 = no tops have fallen, 1 = 1 to 10% down, 2 = 11 to 20% down, etc., up to 10 = 91 to 100% down, 11 = 100% down plus <33% leaves brown, 12 = 33 to 67% leaves brown, and 13 = >67% leaves brown, except 11 = 100% down and <50% brown and 12 = 100% down and >50% brown.

Table 5. Pink root severity and yield for onion breeding lines in Genesee Co., NY, during 1990

Entry	Pink root severity (%) (Aug. 1) ^z	Yield (kg/ha)
W448A	62 a	13,660
W441A × W448B	45 b	27,897
W447A × W448B	41 bc	24,798
W429A × W448B	34 cd	26,899
W446A	33 d	17,442
W446A × W448B	31 d	19,754
W447A	30 de	18,493
B1847A	29 de	21,435
B1834B	29 de	16,654
MSU5785B	27 de	1,261
B1717B	23 ef	19,124
W434A	22 ef	24,939
MSU611B	19 f	6,025
B2419B	19 f	8,757
B1794B	17 fg	19,754
MSU6693B	11 g	Not harvested
LSD 0.05	7	

^z Means followed by the same letter are not significantly different according to Fisher's least significant difference test ($P < 0.05$).

5718A × MSU8155B) × B6123B had an acceptable yield (Table 4). Spartan Banner 80 and Sweet Sandwich were the most resistant of the commercial varieties, as was true in the 1987 experiments. Multiple regression with both dependent variables (pink root and maturity) resulted in a line significant at $P = 0.002$, with $R^2 = 0.35$. The equation is: Yield = 203.2 + 16.8 (pink root severity) – 101.3 (maturity). The entries from the USDA onion breeding program were selected for resistance to pink root, but some of them had significantly lower yields because of inbreeding. This may explain why entries with more pink root had better yields.

Yates and Genesee counties (1990). The most resistant lines were W447A in Yates County (Table 5) and MSU6693 in Genesee County (Table 6). The most susceptible entry in both experiments was W448A. In both experiments, there was no significant correlation between yield and pink root rating.

DISCUSSION

When onion plants were sampled at the three-leaf stage (6 to 8 weeks after planting), no pink roots were visible. After incubation on blotter paper or wheat-straw agar, some roots turned pink. This indicated that *P. terrestris* infects plants early in the growing season, even under relatively cool spring growing conditions. This also suggests that *P. terrestris* is present in the root tissue before pink color is visible. The isolates of *P. terrestris* recovered in this study did not form pycnidia in culture, so identification was based on symptoms in the host plant, colony morphology on culture media, and pink color on wheat-straw agar.

The USDA entries that were resistant at the seedling stage (M. Havey and P. Simon, *personal communication*) also were resistant when pink root was assessed near maturity in these studies. The most resistant line (defined as the entry showing the least pink root near harvest) was MSU-5785B in all three experiments in which it was included. After MSU5785B, entries B1717B and B3350B were the most resistant in both experiments in which they were included. All three of these entries

were rated as resistant in the seedling stage (M. Havey and P. Simon, *personal communication*).

The varieties that were expected to be resistant did have lower pink root severity. Spartan Banner 80 is advertised as pink root resistant, and our experiments over 3 years and in various locations confirmed this. Sweet Sandwich had been found to be pink root resistant in previous experiments (L. A. Ellerbrock, *unpublished data*) and again our experiments confirmed this. Both Sweet Sandwich [MSU5718A × MSU8155B) × MSU826B] and Spartan Banner 80 [(MSU611-1A × MSU611B) × MSU2399C] were released by the USDA and some of the parents (MSU611B, MSU8155B, MSU826B) were included in these studies.

All experiments were conducted in growers' fields, so yields were measured before growers harvested their crop. A few entries may have been slightly immature, but most entries were quite mature at harvest.

Onion roots were rated for pink root at several times during the growing season because the optimum time to compare symptom expression was not known. The last rating, with the largest sample, was taken near maturity. In two experiments, there was a positive correlation between pink root and maturity. This suggests that the optimum time to assess pink root severity is just before maturity, i.e., before leaf development stops and green leaves fall over, so disease severity is not affected by maturity. The root system should be large and functioning well. Rating pink root severity before maturity may result in a wider range of values, which will assist in distinguishing differences among entries. For example, in 1989 in Genesee County, when pink root ratings were performed on onions that were fairly mature, all ratings were at least 65%. This, plus the high within-treatment variability in symptoms, resulted in relatively few groups in the means separation test. In 1987 in Yates County, pink root ratings were performed on onions that were less mature. Pink root ratings were spread over a wider range and more differences were apparent.

In Yates County in 1987 there was a negative correlation between pink root and

yield. This suggests that more resistant cultivars yield better because of pink root resistance. However, a third factor, such as maturity, may affect both development of pink root symptoms and yield. This relationship was only valid in one experiment, in which all entries were commercial cultivars. More experiments are needed to determine cause and effect (if any) among maturity, yield, and resistance to pink root.

An ideal experiment would have compared the response of onions in the presence and absence of *P. terrestris*, all other factors being equal. Unfortunately, the only way to conduct a field experiment in the absence of *P. terrestris* is to fumigate the fields. However, fumigation is not a standard agricultural practice for many onion growers, and it often causes a growth response not explainable merely by the absence of pathogens. Comparison of onion cultivars to each other may be more informative than comparison to a pathogen-free control. For example, cultigens can be compared with Spartan Banner 80, which was included in most of these studies because it is widely grown in New York and is resistant to pink root. Field experiments that include both new breeding lines and standard commercial cultivars may provide a realistic evaluation of the commercial potential of the new germ plasm.

In conclusion, although early-season and late-season assessments of pink root resistance were in general agreement, high resistance did not always translate to high yields, probably because other factors also affect onion yield. Yield comparisons between inbred lines and hybrids are not valid. Although inbred lines were resistant, their yields were depressed due to inbreeding.

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Table 6. Pink root severity and onion maturity and yield for entries in Yates Co., NY, during 1990

Entry	Pink root severity (%) ^y	Maturity ^z	Yield (kg/ha)
W448A	27	6	11,628
W446A × W448B	27	9	27,179
W429A × W448B	26	10	27,530
W434A	25	3	13,870
W441A × W448B	23	10	32,084
W447A × W448B	21	8	19,124
W446A	21	6	13,590
W447A	15	4	6,305

^y Analysis of variance indicated no significant differences.

^z Maturity rating scale was 0 = no tops have fallen, 1 = 1 to 10% down, 2 = 11 to 20% down, etc., up to 10 = 91 to 100% down, 11 = 100% down plus <33% leaves brown, 12 = 33% to 67% leaves brown, and 13 = >67% leaves brown.

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