Response of Sweet Spanish Onion Cultivars and Numbered Hybrids to Basal Rot and Pink Root

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ABSTRACT

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Yellow sweet Spanish onion cultivars and numbered hybrids were evaluated for disease resistance, bulb yield, and bulb size in field trials on a soil heavily infested with the pathogens that cause pink root and basal rot. Hybrid lines exhibited lower incidence of basal rot and pink root than named cultivars in both 1990 and 1991. Resistance to basal rot was not closely related to level of pink root infection. Hybrids that exhibited a low level of pink root infection had the healthiest roots and produced the highest bulb yields. Extensive replacement of infected roots with healthy new roots was a common characteristic of pink root–resistant hybrids. Adoption of numbered onion hybrids resistant to pink root and basal rot could reduce the current dependence on fumigation as the primary control method for these soilborne diseases.

Additional keywords: *Allium cepa,* disease resistance, *Fusarium oxysporum* f. sp. *cepae, Phoma terrestris*

Onion (*Allium cepa* L.) is one of the most economically important vegetable crops in the Pacific Northwest. Idaho and Oregon together produce over 30% of the U.S. storage onion crop, in addition to some onions for processing and export (5). Most of the onions grown in the region are long-day, sweet Spanish hybrids. Onions provide a profitable rotation alternative for area farmers. Onion production often involves high inputs of fertilizers and pesticides, and is subject to significant losses in yield and quality due to several diseases in field and storage.

Pink root, caused by *Phoma terrestris* E.M. Hans. (=*Pyrenochaeta terrestris*), and basal rot, caused by *Fusarium oxysporum* Schlechtend.:Fr. f. sp. *cepae* (H.N. Hans.) W.C. Snyder & H.N. Hans., are the two most serious soilborne diseases of onions in the region. The occurrence of both pink root and basal rot together appear to cause more losses in yield and quality than either disease alone. Both of these pathogens attack the onion root system, causing collapse and eventual death of the roots. The reduction in root volume can decrease the plant's ability to obtain nutrients and water from the soil. Many growers increase nitrogen and water application rates to compensate for the reduced root volume caused by pink root and basal rot. This practice increases the risk of leaching nitrate below the root zone and may lead to contamination of groundwater. Onion genotypes that can maintain a healthier root system could lead to more efficient and economical use of nitrogen and water in the production system.

Crop rotation and soil fumigation are the most common methods of controlling pink root and basal rot (19). However, long crop rotations are not economically feasible in some farm management systems (12). Fumigation, although effective, may not be economical in all situations because of the high cost (8). Fumigation can account for approximately 11% of the total cost of producing onions in Idaho (4). Additionally, the high cost of registration for use on a minor crop, such as onions, may limit fumigant availability in the future.

Resistant onion cultivars offer one of the best nonchemical means for controlling soilborne diseases. Several cultivars of yellow globe onions have resistance to basal rot (1,14,18), but basal rot resistant and susceptible cultivars were found to be equally susceptible to pink root (14). However, in the Midwest, onion cultivars exhibiting resistance to basal rot also tended to yield well in plots infested with both *F. oxysporum* and *P. terrestris* (11). While short-day onion cultivars have been routinely screened for disease resistance (17), only a few long-day sweet Spanish onion hybrids have been evaluated for disease resistance (7,11,16). In the field, symptoms of pink root and basal rot are not usually apparent during early stages of plant growth when temperatures are below optimum for growth of these two pathogens. Yet disease resistance evaluations are frequently done on seedling onions grown in the greenhouse (9,15). Consequently, there is not always a high correlation between greenhouse and field evaluations for disease resistance (10). Private breeding programs in the northwestern United States are releasing many new sweet Spanish onion cultivars with purported resistance to either basal rot or pink root. However, there has been no comparative evaluation of these new cultivars for their disease resistance under field conditions. Our studies were conducted: (i) to evaluate the level of pink root and basal rot resistance in locally adapted sweet Spanish onion cultivars and numbered hybrids developed by seed companies, and (ii) to determine if susceptibility to pink root is correlated to incidence of basal rot.

MATERIALS AND METHODS

Studies were conducted in 1990 and 1991 at the Oregon State University Malheur Experiment Station in Ontario, Oregon, on a field that had a high incidence of pink root and basal rot in previous years. Infested soil from a local source had been added to the field approximately 20 years ago to build up the pathogen populations. The soil is an Owyhee silt loam (coarse-silty, mixed, mesic Xerollic Cambrothids) with less than 1% organic matter. Onions grown in this field in 1989 exhibited 11% incidence of basal rot and extensive pink root at the time of harvest.

The experiment was designed as a randomized complete block with five replicates. Individual plots were four rows wide (2.2 m) by 7.6 m in length. Raw seed of six cultivars and six numbered hybrids of yellow sweet Spanish onions was planted on 13 April 1990. The seed was treated with thiram (tetramethylthiuram disulfide) for control of damping-off of seedlings. Plots were seeded at a rate of 12 viable seeds per 30 cm of row. After emergence, seedlings were thinned by hand to four plants per 30 cm of row. Plots were fertilized with 224 kg ha^{-1} of nitrogen at the three- to four-leaf stage. Plots were furrow irrigated during the season. Weeds were controlled by a combination of herbicides, cultivation, and hand-weeding. Onion thrips were controlled with insecticides as needed. Foliar diseases were not observed during the season, and no fungicide sprays were applied.

Visual ratings of pink root severity and root health were conducted on 10 September. Foliage of all onion cultivars and numbered hybrids was upright, and bulbs were mostly 5 to 7 cm in diameter at

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sampling. Pink root severity and root health were evaluated on a 20-bulb sample from the outside rows of each plot according to the method of Levy and Gornik (13). Onions from the entire length of the middle two rows of each plot were harvested on 3 October. Each bulb was examined for symptoms of basal rot, and bulb size and weight were recorded. Average bulb weight was calculated by dividing total weight of bulbs by the number of bulbs. All symptomless bulbs were placed in storage at 5°C and 70% relative humidity until 3 December, when incidence of basal rot was recorded.

Plot size and cultural practices in 1991 were the same as in 1990. Eight of the cultivars and numbered hybrids evaluated in the 1990 trial were also included in the 1991 trial. Raw seed of five cultivars and 15 numbered hybrids of yellow sweet Spanish onions were planted on 4 April. Visual ratings of pink root severity and root health were made on 26 August on a 20-bulb sample from the outside rows of each plot. Onions from the entire length of the middle two rows of each plot were harvested on 2 October. Each bulb was examined for symptoms of basal rot, and the number and weight of bulbs were recorded.

Data for each year were subjected to analysis of variance and mean separation with the MSTAT statistical program (6). Data for the eight cultivars and numbered hybrids included in both years of the trials were combined and subjected to analysis of variance to evaluate the consistency of results between years. Orthogonal contrasts were utilized to compare the mean disease reaction and agronomic characteristics of cultivars with those of numbered hybrids.

RESULTS

In 1990, numbered hybrids exhibited less basal rot and pink root than the cultivars, but they also produced a lower proportion of bulbs in the over 7.5 cm diameter size class (Table 1). SR2316-3 tended to have a lower number of bulbs infected with basal rot and severe pink root than did other numbered hybrids or cultivars. SunRe 1463 produced higher total yields than other numbered hybrids or cultivars and also tended to produce the highest proportion of large-diameter bulbs. Cultivars and numbered hybrids that produced the highest total yields also tended to produce a high proportion of large-diameter bulbs.

Incidence of basal rot in the 12 cultivars and numbered hybrids in the 1990 trial was not significantly correlated with susceptibility to pink root (r = 0.377). The proportion of bulbs exhibiting severe pink root symptoms was negatively correlated with both root health rating (r = –0.943, P < 0.01) and total yield (r = -0.648, P < 0.05).

In 1991, numbered hybrids exhibited a lower incidence of basal rot and pink root than the cultivars (Table 2). Four of the 15

Table 1. Basal rot incidence, pink root severity, root health, yield, and bulb size distribution of 12 yellow sweet Spanish onion cultivars and numbered hybrids in 1990

	Basal rot[u] incidence (%)	Pink root[v] severity (0 to 3)	Incidence[w] pink root (%)	Root[x] rating (1 to 5)	Yield (t/ha)	Size[y] distribution (% > 7.5 cm)
Cultivar						
Oro Grande	4.7 b-e[z]	2.5 ab	77 ab	1.3 cd	32.5 c-e	64 ab
Cache	5.3 b-e	2.8 ab	81 a	1.4 b-d	32.8 c-e	40 c
Golden Cascade	6.1 a-e	2.8 ab	77 ab	1.3 cd	33.6 de	47 bc
Valdez	8.3 a-c	2.3 ab	45 b-d	1.7 ab	44.9 b	68 a
Cima	8.8 ab	2.6 ab	68 a-c	1.5 b-d	30.5 de	42 c
Winner	9.3 a	2.7 ab	72 ab	1.5 b-d	38.9 b-d	68 a
Mean	7.1	2.6	70	1.5	35.5	55
Numbered hybrid						
SR2316-3	2.5 e	1.9 c	35 d	2.0 a	43.6 bc	64 ab
SR2311-4	4.1 de	2.6 ab	70 ab	1.4 b-d	37.9 b-d	36 c
SunRe 1473	4.3 c-e	2.5 ab	57 a-d	1.5 b-d	42.0 bc	39 c
PSR 57289	4.9 b-e	2.5 ab	57 a-d	1.6 bc	22.8 e	3 d
XPH 3326	7.4 a-d	2.9 a	83 a	1.2 d	32.8 c-e	42 c
SunRe 1463	7.4 a-d	2.3 bc	38 cd	1.7 ab	55.4 a	80 a
Mean	5.1	2.4	57	1.6	39.1	44
Contrast						
Cultivar vs. hybrid ($P > F$)	0.008	0.185	0.020	0.124	0.075	0.007

[u] Percentage (by number) of total bulbs in each plot with basal rot.
[v] 0 = no disease, 1= <10% roots dark pink; 2 = 10 to 50% roots dark pink; 3 => 50% roots dark pink.
[w] Percentage (by number) of bulbs rated 3 for pink root severity.
[x] 1 = few roots, mostly dead; 2 = few roots, mostly healthy; 3 = moderate roots, mostly healthy; 4 = many roots, mostly healthy; 5 = many roots, all healthy.
[y] Percentage (by weight) of bulbs greater than 7.5 cm in diameter.
[z] Means followed by the same letter are not significantly different at P = 0.05 level by Duncan's multiple range test. Values are means of five replicates.

Table 2. Basal rot incidence, pink root severity, root health, yield, and size distribution of 20 yellow sweet Spanish onion cultivars and numbered hybrids in 1991

	Basal rot[u] incidence (%)	Pink root[v] severity (0 to 3)	Incidence[w] pink root (%)	Root[x] rating (1 to 5)	Yield (t/ha)	Size[y] distribution (% > 7.5 cm)
Cultivar						
Sweet Amber	2.6 e-g[z]	2.0 b-e	19 c-e	2.6 b-f	69.4 b-f	80 b-g
Cache	5.4 c-g	2.1 a-e	26 b-d	2.4 e-g	64.4 c-g	81 a-f
Golden Cascade	6.7 c-e	2.5 a	52 a	2.1 g	51.7 fg	61 hi
Oro Grande	9.4 bc	2.3 ab	41 ab	2.3 fg	47.0 g	73 d-g
Valdez	17.4 a	2.1 a-d	32 bc	2.4 d-g	57.1 e-g	78 c-g
Mean	8.3	2.2	34	2.4	58.0	75
Numbered hybrid						
SR2308-2	1.0 g	2.3 a-c	31 bc	2.3 fg	80.4 a-c	76 d-g
SR2316-3	1.4 g	1.7 ef	17 c-e	3.0 ab	56.4 e-g	54 i
SR2311-4	1.6 fg	2.1 a-e	4 e	2.4 e-g	61.4 d-g	70 f-h
SR2630	1.8 fg	1.8 d-f	10 de	2.7 a-f	86.4 ab	91 ab
SunRe1463	1.9 fg	1.9 b-f	18 c-e	2.8 a-e	72.4 b-e	83 a-e
AX2250	3.0 d-g	1.7 d-f	11 c-e	2.6 b-f	69.3 b-f	85 a-d
SunRe1473	3.1 d-g	1.8 c-f	10 c-e	2.8 a-e	56.7 e-g	68 gh
AX1849	3.4 d-g	1.9 b-f	17 c-e	2.5 c-g	80.6 a-c	82 a-e
AX1846	3.7 d-g	1.6 f	0 e	3.0 a-c	91.1 a	89 a-c
SunRe1465	4.3 d-g	1.7 d-f	4 e	2.7 a-f	77.8 a-d	90 a-c
AX1852	5.6 cd-g	2.0 b-f	13 c-e	2.7 a-f	93.7 a	92 a
AX2246	6.3 c-f	1.8 c-f	11 c-e	3.0 a-c	94.1 a	92 a
PSR72488	6.8 c-e	1.8 c-f	6 de	3.1 a	59.0 e-g	90 a-c
SR2308-4	7.4 b-d	1.9 b-f	15 c-e	2.4 e-g	48.3 g	72 e-g
PSR72788	11.1 b	1.9 d-f	16 c-e	2.9 a-d	54.9 e-g	90 a-c
Mean	4.2	1.9	12	2.7	72.1	82
Contrast						
Cultivar vs. hybrid ($P > F$)	0.000	0.000	0.000	0.000	0.000	0.000

[u] Percentage (by number) of total bulbs in each plot with basal rot.
[v] 0 = no disease, 1= <10% roots dark pink; 2 = 10 to 50% roots dark pink; 3 => 50% roots dark pink.
[w] Percentage (by number) of bulbs rated 3 for pink root severity.
[x] 1 = few roots, mostly dead; 2 = few roots, mostly healthy; 3 = moderate roots, mostly healthy; 4 = many roots, mostly healthy; 5 = many roots, all healthy.
[y] Percentage (by weight) of bulbs greater than 7.5 cm in diameter.
[z] Means followed by the same letter are not significantly different at P = 0.05 level by Duncan's multiple range test. Values are means of five replicates.

numbered hybrids had basal rot incidence of less than 2%, while the cultivar Valdez exhibited greater than 17% basal rot. Among the cultivars, Sweet Amber had the lowest incidence of basal rot. Pink root severity was 2.0 or higher in all cultivars. In contrast, all the numbered hybrids except SR2308-2 and SR2311-4 had pink root severity ratings of 2.0 or less. While SR2308-2 was the only numbered hybrid with more than 20% of the bulbs exhibiting severe pink root, all of the cultivars except Sweet Amber had more than 20% bulbs with severe pink root.

Root health ratings, total yield, and proportion of large-diameter bulbs were all higher in numbered hybrids than in the five cultivars (Table 2). PSR72788, SR2316-3, AX1846, and AX2246 were the numbered hybrids that had root health ratings of 3.0 or higher. The Golden Cascade cultivar had the least healthy root system at the time of sampling. There was a wide range in yields, with AX2246, AX1846, and AX1852 tending to produce higher yields than all of the other numbered hybrids or cultivars.

There was no significant correlation between pink root severity and basal rot incidence among the 20 cultivars and numbered hybrids in the 1991 trial ($r = 0.267$). The proportion of bulbs severely infected with pink root was negatively correlated with root health ($r = -0.813$, $P < 0.01$), yield ($r = -0.452$, $P < 0.05$), and size distribution ($r = -0.488$, $P < 0.05$). Onion cultivars and numbered hybrids with healthy root systems produced a greater proportion of large-diameter bulbs at harvest ($r = 0.565$, $P < 0.01$). Total yields and proportion of large-diameter bulbs were also positively correlated ($r = 0.645$, $P < 0.01$).

Analysis of variance for the data from the eight cultivars and hybrids included in both years of the trial indicated that pink root severity was significantly higher ($P < 0.05$) and root health, yield, and the proportion of large-diameter bulbs were lower in 1990 than in 1991 ($P < 0.01$). Incidence of basal rot was the only parameter unaffected by trial year. Differences among cultivars and numbered hybrids in pink root severity, root health, and yield were consistent over years (Tables 1 and 2). There was a significant interaction between years and cultivars for the incidence of basal rot ($P < 0.01$). The numbered hybrids all expressed less basal rot in 1991 than in 1990, while cultivars Valdez and Oro Grande had a higher incidence of basal rot in 1991. All numbered hybrids and cultivars produced a higher proportion of greater than 7.5-cm-diameter bulbs in 1991 than in 1990. However, SunRe 1473 and Cache exhibited a greater increase in proportion of large-size bulbs than did the other numbered hybrids and cultivars ($P < 0.05$).

DISCUSSION

These results indicate that breeding programs of seed companies are making progress toward development of yellow sweet Spanish onion cultivars with resistance to basal rot and pink root. Numbered hybrids generally exhibited less pink root and basal rot, while also maintaining a healthier root system than the cultivars. None of the numbered hybrids or cultivars were highly susceptible or immune to pink root or basal rot. Similar results have been reported by other researchers (7,14,16,18). Many of the numbered hybrids also performed well agronomically, producing high yields and a high proportion of large-diameter bulbs. Several of the numbered hybrids in this trial have since been released as cultivars and are commercially available.

Yellow sweet Spanish onion lines have not previously been evaluated extensively for resistance to soilborne diseases. Lacy and Roberts (11) identified a single sweet Spanish onion hybrid developed by Michigan State University with resistance to basal rot and pink root. Gorenz et al. (7) found that reaction of sweet Spanish hybrid lines to pink root ranged from highly susceptible to moderately resistant.

Previous research (11,17) showed that data from field trials could be used to identify onion cultivars and hybrid lines with resistance to soilborne diseases. Agronomic characteristics and disease reaction of the eight cultivars and numbered hybrids included in both years of this study were consistent from year to year, thereby enabling identification of disease-resistant yellow sweet Spanish cultivars that are locally adapted.

Incidence of basal rot was not closely related to pink root severity. For example, SR2308-2 had the lowest incidence of basal rot but had one of the highest pink root severity ratings (Table 2). Similar lack of relationship between susceptibility to basal rot and severity of pink root infection in onion cultivars was reported previously (14), although pink root infection has been observed to predispose onion bulbs to infection by *F. o.* f. sp. *cepa* (3).

Severe pink root incidence was associated with low yields in both years (Tables 1 and 2). However, absence of pink root late in the season may not adequately reflect the actual level of pink root resistance since resistance could be expressed as avoidance by early maturity before soil temperatures become optimum for the pathogen, reduced susceptibility of roots to the pathogen, or extensive replacement of infected roots with new healthy roots (13). The highly significant negative correlation between root health and pink root severity in this study indicates that extensive root replacement may be a common characteristic of pink root resistant cultivars and numbered hybrids. Pink root infection may not affect the yield of some onion cultivars because of extensive replacement of infected roots (2).

Availability of pink root and basal rot resistant onion cultivars could lead to significant changes in some of the current production practices. Soil fumigation may become unnecessary, and a substantial reduction in fertilizer and irrigation applications may be realized, as the healthy root systems of these cultivars are less likely to restrict nutrient and water uptake.

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