Screening Commercial Onion Cultivars for Resistance to White Rot

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ABSTRACT

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Sixty-four North American and European cultivars of dry-bulb, sweet Spanish, pickling, and bunching onions were evaluated in a simple lattice design for resistance to *Sclerotium cepivorum*, the causal agent of white rot. The trial was conducted in Burnaby, British Columbia on organic muck soil with uniform high levels of added inoculum. Percent white rot infection, weights of total and healthy bulbs harvested, downy mildew infection levels, and sprouting during storage were measured. Significant differences in susceptibility and yield occurred. A correlation between low levels of downy mildew infection in the field and sprouting in storage was found. The same 64 cultivars also were evaluated for percent infection by white rot in a laboratory trial. There was an overall correlation (P = 0.05, r = 0.26) between percent infection in the field and laboratory trials, and this was significant at P = 0.01 (r = 0.39) when the 45 dry-bulb cultivars were analyzed separately. Percent infection in the field trial was significantly least (P = 0.05) for the cultivars Ailsa Craig, Dako, and Wolska. These three cultivars also were among those least infected in the laboratory trial.

Sclerotium cepivorum Berk., the causal agent of white rot of onion and other *Allium* spp., generally is of longstanding and worldwide distribution (15). In contrast, the disease was first recorded in the commercial onion growing areas of the Fraser Valley of British Columbia in 1970 (1). Provisions of the Provincial Plant Protection Act were utilized to prohibit further onion production on known infested fields as these occurred, but the pathogen has continued to spread (13). The literature suggests (3, 4, 5, 12) that white rot may become a major limitation to onion production in the Fraser Valley within a few years if the present infestations cannot be checked.

Chemical control has been attempted in many areas, but its effectiveness is limited (3, 4, 8, 9, 10, 11). Resistant cultivars would be useful, but at present none is known. A preliminary study of resistance to white rot in Peru (14) reported variation in the yielding abilities of onion cultivars in the presence of white rot. Similar studies in North America have been few and not widely publicized. This paper describes an evaluation of 64 onion cultivars in both field and laboratory trials in the presence of added inoculum of *S. cepivorum*.

MATERIALS AND METHODS

The field trial was carried out in Burnaby, British Columbia, on organic muck soil situated on a market vegetable farm on which white rot previously had occurred. The 64 onion (*Allium cepa* L.) cultivars tested were collected from commercial seed sources and included bulb, bunching, and pickling types grown in North America and Europe. Some seed companies provided thiram-treated seeds; we treated seeds of the remaining cultivars with thiram (tetramethylthiuramdisulfide) (Arasan 75, E.I. du Pont de Nemours, Wilmington, DE 19805, USA). Uniform levels of inoculum were placed in direct contact with each seed at planting. Inoculum consisted of sclerotia of *S. cepivorum* (isolated in 1975 from local field-grown onions) produced in sand-maize meal medium (7) and mixed with screened soil from the experimental field (3:40, v/v).

Cultivars were evaluated in an eight × eight simple lattice design. Individual treatment (cultivar) plots consisted of raised beds containing five rows (1.75 m long) spaced 25 cm apart. Inter-plot spacing parallel to rows was 40 cm, and alternately 0.5 and 1.0 m at right angles to the rows. Rows of holes were formed by pressing a board with protruding pegs (2 cm × 1 cm diameter, spaced 7.5 cm apart) into the surface of the prepared beds. Two seeds were placed in each hole and covered with approximately 4 cc of the soil-inoculum mixture, which contained 60-65 viable sclerotia per cubic centimeter.

First and second replications were seeded on 8 and 11 May 1976, respectively. Fertilization, weed control, and insect control were provided as prescribed for onions in the 1975 British Columbia Department of Agriculture Vegetable Production Guide (2), and were uniform for all treatments.

The trial was harvested on 22 September 1976, and harvest weights were determined after the bulbs had been air-dried for 4 wk. Data reported here include percent infection overall and in harvested bulbs; downy mildew rating; weight of healthy bulbs harvested and percent by

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weight of large, medium, boiler, and cull bulbs; and percent of healthy bulbs which sprouted after 4 wk of storage. Bulb grades are based on diameters: jumbo>7.62 cm, large 5.71-7.62 cm, medium 4.44-5.71 cm, boiler 3.17-4.44 cm, and cull<3.17 cm.

Percent infection overall was calculated as:

$$\frac{\text{no. of plants emerged} - \text{no. of healthy bulbs harvested}}{\text{no. of plants emerged}} \times 100.$$

Percent infection in harvested bulbs was calculated similarly on the basis of numbers of total and healthy bulbs harvested. The downy mildew rating was based on a relative scale ranging from one (tops dead) to 10 (no apparent infection), and was derived from a single late-season evaluation (120 days after seeding) when the disease was well established. All data were collected from the middle three rows of each plot only, excluding two guard plants at the ends of each row.

Soil in the trial field was nearly black in color, with a pH of 5.2 (determined on thick suspension of soil in 0.01 M $CaCl_2$). Meterological data were recorded in the center of the field. Air temperature (30 cm above ground) during the trial ranged from 7-27 C, and soil temperature (10 cm below the surface) ranged from 3-30 C. For the period from mid-June through August the mean daily ranges for air and soil temperatures were 14-22 C and 20-25 C, respectively. Rainfall totalled 283 mm during the trial, and daily averages for the months of May through September were 4.8, 2.3, 1.0, 3.2, and 1.6 mm, respectively.

The same 64 cultivars also were tested in a replicated trial in a growth chamber at 15 C, with a 16-hr photoperiod (15,000 lux at plant height). Cultivars were grown in plastic pots of soil taken from the field trial area. Five holes per pot were made, and three seeds per hole were added and covered with 4 cc of inoculum per hole. The inoculum was part of the same mixture used for the field trial. The pots were watered weekly. Number of infected plants was determined 17 weeks after seeding, and percent infection overall was calculated as described above.

All data were subjected to statistical analyses (6). Arcsine transformation was followed where necessary before analyzing the data. Duncan's multiple range test, $P = 0.05$ was used to compare different cultivars.

RESULTS

Under field conditions percent white rot infection overall was greater in the 19 green bunching, pickling, and sweet Spanish types (69 - 99%, mean 85%) than in the 45 dry-bulb storage types tested (22 - 89%, mean 64%) (Table 1). Infection was significantly ($P = 0.05$) least (22 - 28%) in the cultivars Ailsa Craig, Dako, and Wolska.

Microscopic examination of randomly selected dead plants indicated that virtually all plants that died before harvest were infected with, and presumably killed by, white rot. Comparison of the percent infection overall and in harvested bulbs indicates that the cultivars differed considerably in the proportion of infected plants which died. This may be due to different times of infection, or to varying capacity of infected plants to survive.

The number of plants emerged 3 wk after planting

TABLE 1. Data from cultivar trials on onion white rot

Onion types, cultivars, and seed sources	Field Infection[a] Overall (%)	Field Infection[a] Harvest (%)	Plants[b] (No.)	Yield[c] (Tons/ha)	Grade[d] L (%)	Grade[d] M (%)	Grade[d] B (%)	Grade[d] C (%)	Sprout[e] (%)	Mildew score[f]	Lab[g] inf. (%)
Dry-Bulb Storage Types											
Ailsa Craig[i]	22.13	20.10	62.0	36.97	43	26	26	5	60.89	3.97	32.50
Dako[o]	23.90	12.36	110.5	36.14	51	44	4	1	9.67	2.53	38.75
Wolska[o]	27.39	14.90	124.5	35.23	32	59	8	1	15.05	3.49	47.22
Autumn Splendor[i]	43.22	25.09	101.0	18.71	12	60	26	2	2.17	2.46	54.28
Super Elite[h]	46.77	24.52	125.0	29.72	19	34	41	6	9.52	1.53	54.16
Idol[o]	49.70	16.12	106.5	27.29	55	21	21	3	46.04	7.01	41.66
Stuttgarter[h]	51.34	22.60	119.5	26.84	42	52	5	1	15.49	2.51	45.00
Early Yellow Globe[i]	51.90	29.82	102.0	28.88	41	45	13	1	9.69	1.54	47.22
America[n]	52.84	29.39	91.0	21.52	24	56	19	1	3.55	2.53	50.00
Yellow Globe Danvers[i]	54.23	20.21	75.0	24.73	60	26	12	2	22.45	2.47	43.75
Mustang[n]	54.46	44.45	126.5	19.24	32	51	15	2	6.98	1.53	68.89
Golden Mosque[h]	56.08	14.28	116.5	26.40	44	45	9	2	30.34	3.54	35.00
Festival[m]	57.60	26.18	118.0	29.09	33	54	11	2	2.58	1.49	73.21
Hybrid 556-L[n]	57.87	50.25	134.0	26.19	12	51	35	2	23.83	2.49	45.00
Prime Beauty[m]	62.28	44.63	134.5	15.95	0	22	59	19	1.06	2.47	73.86
Elite[h]	62.36	48.31	128.0	32.06	8	56	35	1	33.87	1.50	54.55
Zewska[o]	62.75	55.04	125.5	31.17	33	57	9	1	27.36	3.50	54.76
Spartan Banner[h]	63.21	43.43	118.0	25.08	20	60	9	11	23.88	3.50	58.33
Aristocrat[h]	63.55	30.48	103.5	18.37	28	47	21	4	10.20	2.47	50.00
Canada Granite[h]	63.97	34.45	108.5	21.30	23	59	16	2	13.18	3.47	50.00
Autumn Spice[h]	66.77	44.23	110.0	24.66	39	48	13	0	2.75	1.53	47.62
Rawska[o]	67.02	38.21	128.0	23.98	36	55	7	2	8.77	3.51	46.66

(continued on following page)

TABLE 1. (Continued)

Onion types, cultivars and seed sources	Field Infection[a] Overall (%)	Field Infection[a] Harvest (%)	Plants[b] (No.)	Yield[c] (Tons/ha)	Grade[d] L (%)	Grade[d] M (%)	Grade[d] B (%)	Grade[d] C (%)	Sprout[e] (%)	Mildew score[f]	Lab[g] inf. (%)
Italian Red[i]	67.40	50.23	89.5	8.42	17	60	11	12	62.75	5.00	50.00
Nugget[h]	67.51	41.77	112.5	14.28	34	44	17	5	1.72	2.46	50.00
Southport Red Globe[h]	67.80	14.86	97.5	25.76	38	49	10	3	32.06	2.51	53.33
Kowaska[o]	68.15	46.53	129.5	21.43	46	40	11	3	24.70	2.50	42.22
Canada Maple[h]	68.58	58.52	141.5	28.03	10	63	26	1	0.00	1.49	38.75
Hickory[h]	69.05	51.57	127.5	22.31	2	51	44	3	6.01	1.47	51.82
Indian Queen[h]	69.93	56.21	91.0	14.64	35	42	19	4	30.88	2.99	45.00
Buccaneer[n]	69.95	60.07	117.0	23.37	33	45	18	4	1.72	1.50	52.27
Encore[h]	70.05	51.37	134.5	22.93	30	55	14	1	3.84	1.53	41.66
Nutmeg[n]	70.34	58.41	118.5	15.21	24	64	12	0	1.61	1.51	73.33
Spartan Era[h]	72.30	37.16	129.0	17.21	39	43	17	1	4.51	2.41	47.50
Stokes Exporter[h]	72.36	54.27	109.5	21.58	13	41	43	3	5.97	1.50	70.45
Red Withersfield[i]	72.57	58.75	98.0	11.49	65	19	13	3	40.25	3.99	83.33
Hybrid 1956[n]	73.26	49.70	103.5	21.14	68	28	3	1	1.93	1.51	43.75
Northern Oak[h]	75.20	46.97	104.5	20.09	35	51	11	3	10.60	2.46	52.77
Rocket[l]	75.47	57.27	110.5	18.94	29	59	10	2	4.54	1.49	68.33
Fawn Preview[m]	75.86	57.71	103.0	15.37	57	29	12	2	2.77	1.50	100.00
Hybrid 1426[n]	76.62	57.72	129.5	16.60	31	61	8	0	11.82	1.51	50.00
Yellow Ebenezer[h]	78.61	52.80	102.0	13.11	40	42	15	3	7.64	2.50	85.00
Golden Passport[m]	80.60	69.89	117.0	9.47	29	57	9	5	3.70	1.54	46.43
Storage King[h]	83.92	66.56	114.5	5.60	39	59	2	0	18.35	2.01	45.00
Copper Cache[m]	84.58	71.64	127.0	6.49	39	48	11	2	5.92	1.53	50.00
Improved Autumn Spice[h]	88.86	76.38	134.0	9.35	12	51	20	17	0.00	1.53	90.00
Sweet Spanish types											
White Sweet Spanish[h]	69.55	63.93	114.5	11.76	69	13	9	9	33.34	2.50	56.25
Chieftan[h]	77.10	57.00	122.5	6.13	6	27	47	20	72.87	4.47	58.75
Fiesta[h]	78.56	46.02	121.5	14.47	59	32	7	2	14.42	2.49	52.77
Riverside Sweet Spanish[h]	82.01	55.85	99.5	5.29	9	30	38	23	88.89	4.00	68.75
Gringo[h]	83.24	56.59	127.5	4.94	7	37	40	16	61.35	3.49	60.00
Sweet Spanish Utah[i]	94.21	76.45	139.5	1.17	0	0	61	39	56.82	2.99	52.27
Southport White Globe[h]	99.48	97.10	137.0	0.26	0	0	100	0	100.00	1.50	58.89
Pickling types											
Silver Queen[h]	74.06	54.66	94.5	10.25	28	55	3	14	84.58	2.51	47.22
Silverskin Pickling[j]	83.30	62.06	111.5	9.21	16	45	22	17	43.10	1.50	54.16
White Portugal[h]	89.23	72.02	113.0	3.92	0	77	21	2	19.64	1.53	47.22
Early Silverskin Pickling[i]	89.46	69.73	121.0	5.76	6	63	28	3	23.68	1.46	41.66
Barletta[h]	91.17	73.20	128.0	4.42	2	52	30	16	90.11	1.49	55.00
White Ebenezer[h]	93.15	89.41	134.0	4.37	0	91	5	4	0.56	1.51	90.00
Green Bunching types											
Stokes Early Mild Bunching[h]	75.41	67.25	77.5	6.62	0	38	50	12	60.29	3.47	77.50
Hardy White Bunching[h]	79.07	60.64	118.5	5.40	0	0	64	36	95.65	7.99	67.50
White Lisbon[h]	80.18	64.34	117.0	3.58	0	0	27	73	96.77	7.00	83.75
Beltsville Bunching[h]	87.00	68.53	95.0	2.29	0	0	19	81	97.62	7.00	75.00
Annual Bunching[k]	95.72	85.16	137.0	3.14	19	36	36	9	33.39	1.53	45.23
Southport White Globe Bunching[h]	96.45	94.45	128.5	2.12	0	97	3	0	100.00	1.50	48.18
S.E. of Mean	4.06	3.16		2.55					2.30	0.19	7.18

[a]See text for method of calculation.

[b]Mean number of plants emerged 3 wk after planting in middle three rows of plots; maximum possible = 150.

[c]Based on yield of healthy bulbs harvested and adjusted for cultivar differences in number of plants emerged 3 wk after planting (to the overall mean population of 115.3).

[d]Percent by weight of total yield of harvested healthy bulbs; grades based on bulb diameter: L = 5.71-7.62 cm, M = 4.44-5.71 cm, B = 3.17-4.44 cm, C < 3.17 cm.

[e]Percent of harvested healthy bulbs sprouted after 4 weeks of storage.

[f]Downy mildew score: 1 = tops dead,– 10 = no visible infection.

[g]Percent infection overall for trial in controlled environment chamber.

[h]Stokes Seeds Ltd., St. Catharines, Ontario, Canada.

[i]Buckerfield Ltd., Vancouver, British Columbia, Canada.

[j]A. E. McKenzie Co., Ltd., Weston, Ontario, Canada.

[k]Steele-Briggs, Subsidiary of A. E. McKenzie Co., Ltd.

[l]Asgrow-Seed Co. of Canada, Ltd., Bradford, Ontario, Canada.

[m]Ferry-Morse Seed Co., Mountain View, CA. 94040 USA.

[n]Jos. Harris Co., Inc., Rochester, NY 14624 USA.

[o]J. E. Ohlsens Enke., 2630 Taastrup, Denmark.

varied among the cultivars. Tests in the laboratory indicated that the white rot inoculum used in the trials had no effect on seedling emergence, and variation of this character thus is attributed to cultivar and/or seed lot characteristics. Yield data in Table 1 are calculated from the healthy bulbs harvested, and are adjusted for cultivar differences in number of plants emerged 3 wk after planting (to the overall mean population of 115.3). The best-yielding cultivars in the presence of uniform high levels of white rot inoculum were Ailsa Craig, Dako, Wolska, Elite, Zewska, Super Elite, and Early Yellow Globe ($P = 0.05$). Adjustment assumes that bulb weight would be unaffected by variations in plant populations within the range of adjustment, and probably overrates cultivars with extreme adjustment, such as Ailsa Craig. With or without adjustment, yield was not necessarily inversely proportional to percent infection or vice versa.

Correlation between infection levels in the laboratory and in the field for the 64 cultivars was significant at $P = 0.05$ ($r = 0.26$). When the 45 dry-bulb cultivars were analyzed separately the correlation was significant at $P = 0.01$ ($r = 0.39$). No correlation existed between laboratory and field infection levels for pickling, bunching, and sweet Spanish cultivars when each group was analyzed separately.

Downy mildew was least severe in Hardy White Bunching, Idol, Beltsville Bunching, and White Lisbon. The apparent resistance of these cultivars differed in nature. Leaves of White Lisbon and Idol were attacked and killed and new leaves appeared quickly, whereas the leaves of Hardy White Bunching and Beltsville Bunching were little affected by downy mildew. An unexpected correlation ($P = 0.01$, $r = 0.57$) was found between the downy mildew ratings and percent of sprouted bulbs after 4 wk of storage for the 64 cultivars. All cultivars with low incidence of downy mildew had relatively high sprouting percentages.

DISCUSSION

The primary objective of this study was to evaluate the yield capacity and disease levels of onion cultivars in the presence of inoculum of the white rot fungus. Significant differences were observed, and these are undoubtedly the combined result of inherent genetic potential for yield, sensitivity to white rot, and adaption to climate, soil type, and management practice. Differences in percent infection that occurred for some of the cultivars between the field and laboratory trials are likely due to differences in environmental factors.

None of the 64 cultivars was immune to infection by white rot. Percent infection under field conditions was significantly less in Ailsa Craig, Dako, and Wolska than in the remaining cultivars; these three cultivars also were among those least infected in the laboratory trial. Considering the uniform conditions of these trials and the fact that viable inoculum was placed in contact with every seed at planting it is unlikely that differences in percent infection among the cultivars are due to disease escape. On the other hand, why did some plants remain totally free of infection? Are the seed lots variable for resistance to white rot? We are attempting to self-pollinate plants from bulbs of several of the cultivars which remained noninfected and plan to compare their progeny with the original seed lots of the parents for resistance to white rot.

This study demonstrates that commercial onion cultivars differ significantly in susceptibility and yield capacity in the presence of uniform, high levels of inoculum of the white rot fungus. These two characters are not necessarily inversely proportional. Cultivar differences in susceptibility must be interpreted with attention to the undefined effects of different environmental conditions, possible variations of the pathogen, and the possibility that individual seed lots of cultivars may be variable for resistance to white rot.

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