

CROP: Carrot (*Daucus carota* subsp. *sativus* (Hoffm.) Arcang.)

PEST: Cavity spot (*Pythium intermedium* de Bary, *Pythium irregulare* Buisman, *Pythium sulcatum* Pratt & Mitchell, *Pythium sylvaticum* W.A. Campbell & J.W. Hendrix, *Pythium ultimum* Trow and *Pythium violae* Chesters & C.J. Hickman)

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TITLE: EVALUATION OF CARROT BREEDING LINES FOR SUSCEPTIBILITY TO CAVITY SPOT, 2017

MATERIALS: USDA experimental carrot breeding lines, commercial cultivars Cellobunch, Envy (Seminis), Atomic Red and Purple Haze (Johnny's Select Seeds), UpperCut, HoneySnax and Maverick (Nunhems), CR1706 and Triton (Sakata)

METHODS: The trial was conducted on organic soil (pH \approx 5.7, organic matter \approx 72.1%) naturally infested with *Pythium* spp. at the Muck Crops Research Station, Holland Marsh, Ontario. Carrots were direct seeded (\approx 70 seeds/m) onto raised beds using a push cone seeder on 7 June. A randomized complete block design with four replicates per treatment was used. Each experimental unit consisted of one row, 6 m in length, spaced 66 cm apart. On 11 July, plots were rated on a 0 to 5 scale for plant stand where 0 = < 5 carrots, 1 = very poor, 2 = poor, 3 = good, 4 = very good and 5 = excellent stand. On 2 and 13 October, plots were visually assessed for: leaf blight, (0-5 scale where 0= no blight to 5= leaf/ petiole necrosis), and bolting, (0-3 scale where 3 = more than 50% flowering, 2 = 5 to 49%, 1 = <5% and 0 = no flowering). On 26 and 27 October, 50 carrots from each replicate were harvested, placed into cold storage, and assessed for cavity spot on 7-16 November. Carrots were washed in a small drum washer and assessed for the percent that were forked and were visually examined for cavity spot lesions. Carrots were sorted into classes based on the size of the largest lesion (measured as horizontal width). The six classes were: 0 = no disease, 1 = very light (< 1 mm), 2 = light (1-2 mm), 3 = medium (3-5 mm), 4 = heavy (6-10 mm), and 5 = very heavy (> 10 mm). The disease severity index (DSI) was determined using the above classes and the following equation:

$$DSI = \frac{\sum [(class\ no.) (no.\ of\ carrots\ in\ each\ class)]}{(total\ no.\ carrots\ per\ sample) (no.\ classes - 1)} \times 100$$

Compared to the previous 10 year average, air temperatures in 2017 were average for June (18.1°C), July (20.7°C), August (19.4°C) and above average for September (17.7°C) and October (11.6°C). The 10 year average temperatures were: June 18.7°C, July 21.0°C, August 20.1°C, September 16.1°C and October 9.7°C. Monthly rainfall was above the 10 year average for June (206 mm) and October (82 mm) and below average for July (70 mm), August (60 mm) and September (38 mm). The 10-year rainfall averages were: June 83 mm, July 92 mm, August 73 mm, September 68 mm and October 67 mm.

Data for DSI and disease incidence were analyzed using ANOVA in Proc Mixed using SAS 9.4 (SAS Institute, Cary, NC). All other data were analyzed using the General Analysis of Variance function of Statistics V.10. Means separation was obtained using Fisher's Protected LSD test with $P = 0.05$ level of significance.

RESULTS: as presented in Tables 1, 2 & 3

CONCLUSIONS: In 2017, the weather was drier in August and September than average and cavity spot incidence and severity were lower in the standard cultivars than in previous years. A wide range of susceptibility to cavity spot was observed among the lines tested (Table 1). Several orange lines including CS736 (1137A), and CS732 (1137B -F₂M₅) had low cavity spot in 2017 and are consistent with results from previous years. The parent lines 1137, 5367 and 6526 had low cavity spot in the trials from past years and

overall, crosses with these parents also had low cavity spot, although there were some exceptions. Similarly, parent lines 2205 and 5494 had high levels of cavity spot in previous trials and crosses with these parents tended to have high cavity spot. For instance CS 724, which is 2205B had the highest cavity spot (100% incidence and 73.6 % DSI). Again there were a few lines that did not fit this trend.

The percent of forked carrots ranged from 3% to 33 %. Forking was not correlated to cavity spot incidence or severity. Differences in leaf blight incidence was also observed among the lines tested. Several breeding lines (CS 703,725 and 710) had low leaf blight incidence similar to commercial cultivars Maverick, UpperCut and Honey Snax (Table 2). Germination and carrots stands varied greatly among the breeding lines, in some cases there were not enough carrots to assess for cavity spot or leaf blight (Table 3).

Table 1. Cavity spot incidence and severity index (DSI) and percent forked for carrot breeding lines from the University of Wisconsin grown at the Muck Crops Research Station, Holland Marsh, Ontario, 2017.

Cultivars	Pedigree	DSI ¹	Incidence (%)	% Forked
CS 740	P6306A x P6139B	0.3 a ²	1.6 a	33.6 b
CS 736	1131A	0.7 a	2.5 ab	5.4 a
Purple Haze		1.1 ab	4.1 abc	7.4 ab
Cellobunch		1.1 ab	5.1 a-e	4.8 a
CS 734	(6366 x 2226) x 1131 ²	1.4 abc	4.1 abc	6.2 ab
CS 735	7162A x 1131	1.5 abc	4.3 a-d	14.6 ab
UpperCut		1.7 abc	4.0 abc	11.1 ab
CS 737	(6139A x 6245B) x 6308B	2.3 a-d	7.2 a-f	21.6 ab
CS 732	1131B - F ₂ M ₅	2.9 a-d	7.3 a-f	10.6 ab
CS 721	(6366 x 2226) x 5367 ²	3.0 a-d	8.9 a-g	14.5 ab
CS 713	Nb4001A x Nb65526B	3.3 a-d	10.5 a-i	5.8 ab
CS 717	(7241 x 2566L) x 5367	3.3 a-d	12.8 a-j	10.3 ab
CS 707	(7241 x 2566L) x 6526	3.6 a-d	11.6 a-i	6.8 ab
Envy		3.6 a-d	8.1 a-f	6.9 ab
CS 720	(6366 x 2226) x 5367	3.9 a-d	10.4 a-h	14.3 ab
CS 731	1131 - F ₂ M ₃	4.4 a-d	9.3 a-g	7.1 ab
CS 753	1129	4.5 a-d	12.8 a-j	11.4 ab
CS 710	(6366 x 2226) x 6526	5.2 a-e	13.9 a-k	22.8 ab
CS 716	(7254 x EFM) x 5367 ²	7.5 a-e	24.1 a-m	25.5 ab
CS 704	(6366 x 2226) x 5494	7.7 a-f	22.6 a-m	13.2 ab
CS 739	6139A x 6245B	7.8 a-f	26.4 a-m	16.8 ab
CR1706		7.9 a-f	17.9 a-k	4.9 a
CS 705	Nb6526B	8.3 a-f	27.4 b-n	13.3 ab
Triton		8.7 a-f	19.9 a-l	5.0 b
Maverick		8.8 a-f	19.7 a-l	10.6 ab
HoneySnax		8.9 a-f	19.5 a-l	12.4 ab
Atomic Red		9.2 a-g	17.7 a-k	18.5 ab
CS 711	[(8531MjRA x 3999MjRB) x (BR x 6274)] x 6526MjRB	9.2 a-g	21.9 a-m	15.4 ab
CS 730	1131 - F ₂ M ₂	9.5 a-g	17.6 a-k	11.5 ab
CS 712	[(5280A x 6366B) x 6526B] x 6526B	9.8 a-g	23.6 a-m	5.6 ab
CS 754	1137	10.2 a-g	22.0 a-m	10.4 ab
CS 750	Nb4001B	10.5 a-g	20.6 a-l	7.9 ab
CS 703	(5280 x 6366 ²) x 5494	10.7 a-g	27.9 b-n	11.1 ab

CS 738	(6139A x 6245B) x 6523B	11.3 a-g	34.8 h-o	10.9 ab
CS 755	2144B x 6139B	11.5 a-g	30.5 e-n	11.6 ab
CS 702	(9304 x 2566L) x 5494	13.4 a-h	27.9 b-n	10.3 ab
CS 723	2327	15.3 b-i	31.1 f-n	20.9 ab
CS 706	6526	15.6 b-i	29.6 d-n	6.2 ab
CS 727	(6366 x 2226) x 2205	15.9 c-i	32.1 f-n	9.9 ab
CS 752	Nb4001B – F ₃ M ₂ SM	16.0 c-i	28.8 c-n	20.7 ab
CS 714	S.C. x 6526B ²	16.3 d-i	38.6 k-o	5.1 a
CS 715	5367	19.3 e-i	34.0 g-o	12.2 ab
CS 749	(6366 x 2226) x 5494 ³	19.7 e-i	35.9 i-o	4.2 a
CS 701	5494	22.4 f-j	43.5 l-p	3.3 a
CS 756		23.7 g-k	38.0 j-o	31.3 ab
CS 748	(6366 x 2226) x 5494 ²	26.4 h-k	46.2 mnop	4.6 a
CS 729	(6366A x 2226B) x 2205 ²	28.3 ijk	52.1 nop	11.7 ab
CS 751	Nb40001B – F ₃ M ₄	34.7 jk	58.3 opq	14.1 ab
CS 728	2205	38.1 kl	64.6 pq	21.2 ab
CS 733	1131B – F ₁ X ₂ M ₃ SM ₄	49.7 l	81.5 qr	15.3 ab
CS 724	2205B	73.6 m	100.0 r	8.1 ab

¹Disease Severity Index (DSI) was determined using the following equation:

$$DSI = \frac{\sum [(class\ no.) (no.\ of\ carrots\ in\ each\ class)]}{(total\ no.\ carrots\ per\ sample) (no.\ classes - 1)} \times 100$$

²Numbers in a column followed by the same letter are not significantly different at $P= 0.05$, Fisher's Protected LSD test.

Table 2. Blight severity and bolting ratings made on (date), for carrot breeding lines from the University of Wisconsin grown at the Muck Crops Research Station, Holland Marsh, Ontario, 2017

Field name	Pedigree	Leaf Blight Rating ¹	Seeders ²
CS 703	(5280 x 6366 ²) x 5494	0.4 a ³	0.0 a
CS 725	(6366 x 2226) x 2205	0.4 a	0.0 a
CS 710	(6366 x 2226) x 6526	0.4 a	0.3 ab
Maverick		0.4 a	0.3 ab
UpperCut		0.5 ab	0.0 a
HoneySnax		0.5 ab	0.0 a
CR1706		0.5 ab	0.0 a
CS 739	6139A x 6245B	0.5 ab	0.3 ab
CS 719	(6253 x 2144) x 5367	0.5 ab	0.3 ab
CS 717	(7241 x 2566L) x 5367	0.5 ab	0.3 ab
CS 726	(6253 x 2144) x 2205	0.5 ab	0.5 abc
CS 713	Nb4001A x Nb6526B	0.5 ab	0.5 abc
CS 709	(2566 x 6253) x 6526	0.5 ab	0.8 bc
CS 705	Nb6526B	0.5 ab	2.0 e
Cellobunch		0.6 abc	0.0 a
CS 752	Nb4001B - F ₃ M ₂ SM	0.6 abc	0.0 a
CS 742	5494A	0.6 abc	0.0 a
CS 741	5494	0.6 abc	0.0 a
CS 715	5367	0.6 abc	0.0 a
CS 708	5367A x 2566B	0.6 abc	0.0 a
CS 701	5494	0.6 abc	0.0 a
CS 716	(7254 x EFM) x 5367 ²	0.6 abc	0.0a

CS 735	7262A x 1131	0.6 abc	0.3 ab
CS 707	(7241 x 2566L) x 6526	0.6 abc	0.3 ab
CS 718	(9304 x 5238) x 5367	0.6 abc	0.5 abc
CS 736	1131A	0.6 abc	0.8 bc
CS 732	1131B F ₂ M ₅	0.6 abc	0.8 bc
CS 714	S.C. x 6526B ²	0.6 abc	0.8 bc
CS 756		0.6 abc	1.5 de
CS 711	[(8531MjRA x 3999MjRB) x (BR x 6274)] x 6526MjRB	0.6 abc	1.8 e
CS 738	(6139A x 6245B) x 6523B	0.6 abc	3.0 f
CS 722	7245B	0.63 abcd	0.1 ab
CS 745	(6366 x 6333) x 5494	0.63 abcd	0.4 abc
Envy		0.8 abcd	0.0 a
CS 747	5494B - F ₃ M ₃	0.8 abcd	0.0 a
CS 754	1137	0.8 abcd	0.3 ab
CS 731	1131 - F ₂ M ₃	0.8 abcd	0.3 ab
CS 723	2327	0.8 abcd	0.3 ab
CS 712	[(5280A x 6366B) x 6526B] x 6526B	0.8 abcd	0.8 bc
Triton		0.9 abcde	0.0 a
CS 748	(6366 x 2226) x 5494 ²	0.9 abcde	0.0 a
CS 727	(6366 x 2226) x 2205	0.9 abcde	0.0 a
CS 721	(6366 x 2226) x 5367 ²	0.9 abcde	0.0 a
CS 753	1129	0.9 abcde	0.3 ab
CS 743	(5280 x 5238) x 5494	0.9 abcde	0.3 ab
CS 744	5494B - F ₃ M ₅	0.9 abcde	0.8 bc
CS 730	1131 - F ₂ M ₂	0.9 abcde	0.8 bc
Purple Haze		0.9 abcde	1.8 e
CS 750	Nb4001B	1.0 abcdef	0.0 a
CS 746	(6333 x 8483MjR-B) x 5494	1.0 abcdef	0.0 a
CS 720	(6366 x 2226) x 5367	1.0 abcdef	0.0 a
CS 704	(6366 x 2226) x 5494	1.0 abcdef	0.0 a
CS 733	1131B - F ₁ X ₂ M ₃ SM ₄	1.0 abcdef	0.3 ab
Atomic Red		1.0 abcdef	0.5 abc
CS 702	(9304 x 2566L) x 5494	1.1 bcdef	0.3 ab
CS 706	6526	1.1 bcdef	0.5 abc
CS 729	(6366A x 2226B) x 2205 ²	1.3 cdef	0.0 a
CS 734	(6366 x 2226) x 1131 ²	1.3 cdef	0.3 ab
CS 751	Nb4001B - F ₃ M ₄	1.3 cdef	1.0 cd
CS 755	2144B x 6139B	1.4 defg	1.8 e
CS 728	2205	1.5 efg	0.0 a
CS 749	(6366 x 2226) x 5494 ³	1.5 efg	0.3 ab
CS 740	P6306A x P6139B	1.5 efg	1.5 de
CS 724	2205B	1.6 fg	0.3 ab

¹ Leaf blight was rated on a 0-5 scale where 0 = no blight, 1 = 1-10% leaf area blighted, 2 = 11-25% leaf/petiole blighted, 3 = 26-50% leaf/petiole blighted, 4 = >75% leaf/petiole area blighted, 5 = leaf/petiole necrosis

² Bolting was rated on a comparatively 0-3 scale where: 0 = no seeder, 1 < 5%, 2 = 5 – 20%, 3 > 50 %

³ Numbers in a column followed by the same letter are not significantly different at P=0.05, Fisher's Protected LSD test.

Table 3. Plant stands on 11 July and the sample size for final cavity spot assessment for breeding lines from University of Wisconsin grown at the Muck Crops Research Station, Holland Marsh, Ontario, 2017.

Seed Source	Stand Rating ¹	Avg # Carrots Assessed for Cavity Spot
Cellobunch	4.8 a ²	50.3
CR1706	4.0 ab	47.5
CS 736	1131A	3.4 bc
UpperCut		3.4 bc
Envy		3.3 bcd
HoneySnax		3.3 bcd
CS 737	(6139A x 6245B) x 6308B	3.3 bcd
CS 738	(6139A x 6245B) x 6523B	3.1 cde
Maverick		3.0 cdef
CS 723	2327	3.0 cdef
Purple haze		3.0 cdef
CS 750	Nb4001B	2.9 cdefg
Triton		2.9 cdefg
CS 734	(6366 x 2226) x 1131 ²	2.6 cdefgh
CS 729	(6366A x 2226B) x 2205 ²	2.5 defghi
CS 756		2.5 defghi
CS 755	2144B x 6139B	2.4 efghij
CS 707	(7241 x 2566L) x 6526	2.4 efghij
CS 751	Nb4001B – F ₃ M ₄	2.3 fghijk
CS 731	1131 - F ₃ M ₃	2.3 fghijk
CS 739	6139A x 6245B	2.3 fghijk
CS 720	(6366 x 2226) x 5367	2.1 ghijkl
CS 721	(6366 x 2226) x 5367 ²	2.1 ghijkl
Atomic Red		2.1 ghijkl
CS 702	(9304 x 2566L) x 5494	2.1 ghijkl
CS 728	2205	2.1 ghijkl
CS 703	(5280 x 6366 ²) x 5494	1.9 hijklm
CS 714	S.C. x 6526B ²	1.8 ijklmn
CS 735	7262A x 1131	1.8 ijklmn
CS 732	1131B – F ₂ M ₅	1.8 ijklmn
CS 740	P6306A x P6139B	1.8 ijklmn
CS 705	Nb6526B	1.6 jklmn
CS 748	(63666 x 2226) x 5494 ²	1.6 jklmn
CS 753	1129	1.6 jklmn
CS 717	(7241 x 2566L) x 5367	1.5 klmno
CS 726	(6253 x 2144) x 2205	1.5 klmno
CS 752	Nb4001B – F ₃ M ₂ SM	1.5 klmno
CS 730	1131 – F ₂ M ₂	1.5 klmno
CS 711	[(8531MjRA x 3999MjRB) x (BR x 6274)] x 6526MjRB	1.4 lmno
CS 733	1131B – F ₁ X ₂ M ₃ SM ₄	1.4 lmno
CS 713	Nb4001A x Nb6526B	1.3 mnop

CS 712	[(5280A x 6366B)×6526B] × 6526B	1.3 mnop	25.8
CS 749	(6366 x 2226) x 5494 ³	1.3 mnop	23.8
CS 716	(7254 x EFM) x 5367 ²	1.1 mnop	12.0
CS 701	5494	1.1 mnop	26.3
CS 727	(6366 x 2226) x 2205	1.1 mnop	12.8
CS 704	(6366 x 2226) x 5494	1.1 nopq	22.5
CS 710	(6366 x 2226) x 6526	1.0 nopq	10.3
CS 706	6526	1.0 nopq	19.3
CS 724	2205B	1.0 nopq	17.8
CS 718	(9304 x 5238) x 5367	0.8 opqr	0
CS 754	1137	0.8 opqr	10.8
CS 715	5367	0.8 opqr	10.0
CS 708	5367A x 2566B	0.5 pqr	0
CS 719	(6253 x 6144) x 5367	0.5 pqr	0
CS 745	(6366 x 6333) x 5494	0.5 pqr	0
CS 709	(2566 x 6253) x 6526	0.5 pqr	0
CS 746	(6333 x 8483MjR-B) x 5494	0.5 pqr	0
CS 743	(5280 x 5238) x 5494	0.3 qr	0
CS 742	5494A	0.3 qr	0
CS 722	7245B	0.3 qr	0
CS 747	5494B - F ₃ M ₃	0.3 qr	0
CS 744	5494B - F ₃ M ₅	0.3 qr	0
CS 725	(6366 x 2226) x 2205	0.0 r	0
CS 741	5494	0.0 r	0

¹ Stands were rated using a 0-5 scale where: 0 = < 10%, 1 = 11-30%, 2 = 31-50%, 4 = 51-80%, 5 = 81-100% of expected carrots in a 6 meter row.

² Numbers in a column followed by the same letter are not significantly different at $P= 0.05$, Fisher's Protected LSD test.

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