

Carrot Breeding to Develop and Introduce Improved Cultivars for California Producers

Annual Research Report to California Fresh Carrot Advisory Board
for March, 2018 to February, 2019

Principal Investigator:

P.W. Simon, USDA/ARS, Horticulture Department, University of Wisconsin-Madison,
WI

Cooperating personnel:

J. Nunez, Vegetable/Plant Pathology Farm Advisor, Kern County, U.C. Coop. Ext.

P. Roberts, Nematologist, UC Riverside

M.R. McDonald, Plant Pathologist, University of Guelph, Ontario, Canada

I. Goldman, Breeder, University of Wisconsin, Madison

Growers, shippers, seed producers

A. Field Trial of USDA Breeding Stocks and Hybrids for California

1. 1645 USDA experimental breeding entries (inbreds, new crosses, segregating populations, unadapted and undomesticated material) were grown at the Desert Research and Extension Center (DREC). Yield components evaluated include root length, shape, sprangles (forking, presumably due to soil compaction, perhaps pythium), smoothness, tip shape, and length, uniformity, premature bolting, vigor, earliness, and powdery mildew. Quality components include color, smoothness, flavor (sweetness and harshness), texture, and nutritional value (carotene and anthocyanin pigment levels). There were 89 advanced baby, 42 cello, 111 novel color inbreds, and 726 new diverse base populations (for nematode and pythium resistance, length, flavor, and color) included in the trial. A summary of the characteristics of selected recent unreleased USDA carrot inbreds developed and being used in the USDA program is presented in Table 1.
2. 57 cello and 65 baby USDA and seed company hybrids were grown at DREC and evaluated visually by carrot growers, seed producers, and researchers and each given a composite rating (Table 2). New USDA hybrids performed well in the trials with 8 baby, 6 cello and 5 novel entries in the top 20 of their respective classes. This was the seventh year that we included nematode resistant inbreds as components to cello and cut & peel hybrids among USDA entries, and among the 15 top baby hybrids from the USDA program, 6 had an inbred parent derived from nematode resistant backgrounds, among the 15 top cello hybrids from the USDA program, 10 had at least one inbred parent derived from nematode resistant backgrounds and 2 had all three resistant parents. This was our fourteenth year to perform a specialty carrot trial that included 15 entries with novel color or shape. Flavor evaluation was also performed for all entries.

3. 59 inbreds or populations representing programatic scope are described in Table 1, of which 14 are being tested further by seed companies. Fifteen of these are *Meloidogyne javanica* and/or *M. incognita* resistant inbreds and 5 are cavity spot resistant, and are included in evaluations in infected fields reported below.
4. Joe Nunez also performed field trials including USDA experimental hybrids and populations. Please refer to his report for those results.

B. Breeding for Nematode-Resistant Carrots

Incorporating Resistance from 'Brasilia' Germplasm

A significant effort continues to be made in evaluating the scope of nematode resistance derived from the Brazilian open-pollinated carrot 'Brasilia'. The *Mj-1* derived from 'Brasilia 1252' (MJ) is on chromosome 8 and it controls the inheritance of the resistance to *Meloidogyne javanica* and also imparts partial resistance to *M. incognita*. Another strain of Brasilia ("Brasilia 1091' (1091)), also has resistance to nematodes and is included in genetic and breeding studies.

In addition to *Mj-1*, a gene on chromosome 1 of 'Brasilia' also contributes to *M. incognita* resistance, and additional MiR QTLs occur on chromosomes 4 and 6 in 'Brasilia 1252' derivatives. The relative value of these genes is being evaluated in derivatives of these genetic stocks, including the development of molecular markers to track resistance genes during the breeding process.

At the Kearney Research Center 772 diverse seed sources were grown by Dr. Roberts on *Meloidogyne incognita* and *Meloidogyne javanica* infested fields including adjacent susceptible check plots throughout both fields. Harvest was in August and included a field day with industry invited to attend. Inbreds derived from resistance sources were selected and sent to Madison for seed increase. These included intercrosses of all sources of resistance, and with good-flavored and long carrots adapted for production in California. Some of these derivatives are at the F₁₀ generation with very good resistance. These same breeding stocks were also grown in the DREC trials, where they had length, smoothness, color, and flavor suitable for California production.

We invited the carrot seed industry to submit entries for evaluation of nematode resistance, in the Kearney Research Center infested fields. Multiple entries were received from 4 seed companies and evaluated. The full range of resistance ratings was observed, and resistance scores of 0 and/or 1 were observed in entries from several seed companies.

C. Establishing Carrot Populations with Nematode Resistance from Other Germplasm Sources

In addition to the ‘Brasilia 1252’ (MJ) and ‘Brasilia 1091’ (1091) noted above, diverse sources of nematode resistance have also been identified in carrots from Syria (‘Homs’ HM), China (‘Ping Ding’ PD), Australia (‘Western Red’ WR), Europe (‘Scarlet Fancy’ × ‘Favourite’, SFF; and ‘Nantes Fancy’, NF) and more recently another Brazilian carrot “Uberlandia’ (UB) and an African carrot (‘CM’). To determine if additional genomic regions control nematode resistance, resistance gene locations are being mapped and resistance characterized. A second major gene on the same chromosome as *Mj-1*, *Mj-2*, accounts for part of the ‘Ping Ding’ resistance and several additional genes conferring resistance to *Meloidogyne incognita* have been mapped (Parsons et al., 2015). Combinations of resistance genes from MJ with HM and with SFF are particularly promising (Table 3) and these combinations accounted for part of the materials sent back to Madison from the Kearney harvest for seed increase and crossing this winter, although combinations from most sources of resistance were represented in those breeding stocks.

Crosses to evaluate and incorporate nematode resistance genes from the UB and CM sources are in early stages and not yet included in Table 3. Plants from these gene sources were grown in the greenhouse and evaluated by Dr. Roberts with a focus on characterizing the genetic basis of resistance. Greenhouse trials included these early generation combinations, as well as selected advanced generation materials.

D. Identifying Genetic Sources of Cavity Spot Resistance

Dr. McDonald evaluated cavity spot resistance in trials this year, and those results are described in her report. Roots of resistant plants Dr. McDonald’s evaluations were shipped to Wisconsin and are being used in our winter 2018-2019 greenhouse seed production nursery to develop seed stocks for future genetic analysis of disease resistance and advance resistant stocks in our breeding program. Resistance scores for materials that had been evaluated previously generally held up again this past year. Based on previous evaluations of resistance in inbreds and their hybrid combinations, a focus was placed on developing a series of hybrid combinations to perform a diallel analysis. Seed for those hybrids is currently being produced in the greenhouse with plans to begin that evaluation in the field in 2019 and 2020. Inbreds and hybrids with adequate seed supply will also be evaluated in collaborative trials in CA with Drs. Sidhu and Nunez, and in WA with Dr. du Toit.

E. Evaluation of Carrot Germplasm and Advanced Selections for Alternaria Leaf Blight Resistance

Field evaluation of *Alternaria dauci* resistance was performed in Wisconsin. Disease symptoms developed were quite severe with wet late summer growing conditions. Resistance was scored in 121 breeding populations as well as in 694 open-pollinated cultivars. Hybrids, backcrosses and testcrosses were generated among these items for future testing. Disease scores were generally consistent with previous evaluations. Best resistance tends to occur in wild carrot but advanced derivatives of wild x cultivated crosses, like AR8576 noted in Table 1, are approaching commercial quality.

F. Seed Production and Laboratory Analysis

1. Roots from California trials were sent to Wisconsin for seed production. Seed yields were average to above average in 1410 greenhouse cages in the winter greenhouse, and poor in our 124 cages and 723 breeding plot isolations in the summer, due to record late summer rain. Summer seed production generated 17 new experimental hybrids, and 223 new experimental breeding stocks for current and future testing.
2. Detailed flavor and texture evaluation was made on individual carrots in 61 populations and carotene was quantified in 26 populations to estimate nutritional value (see Table 1). Seed was sent to cooperators for testing. Nutritional properties and flavor in populations with elite nematode resistance exhibited a range of flavor and nutritional value comparable to typical cello and baby breeding stocks lacking resistance, and several of the cavity spot resistant are among inbreds with the best flavor (1137, 5367) and nutritional value (1131) in the program (Table 1). These observations confirm that consumer quality need not be sacrificed when breeding for disease resistance.
3. Roots selected for nematode resistance from the field trials and from Dr. Roberts' greenhouse testing program were sent to Wisconsin for seed production where seed production was above average. We produced F₁ intercrosses with new sources of resistance and increased advanced derivatives. Large-scale seed production by industry collaborators of selected items supplemented seed supplies. Horticultural performance was evaluated at DREC and several lines were increased from those plots for future evaluation.
4. Roots selected for cavity spot resistance from the field trials of Dr. McDonald's testing program were sent to Wisconsin for seed production as mentioned above. Seed production was above average. We increased seed of promising selections and produced new F₁ intercrosses combining unrelated sources of resistance. F₃ families were also generated, and horticultural performance was evaluated at DREC. Seed was produced from selected roots for future cavity spot resistance genetics and breeding.

G. Carrot Molecular Genetic Markers

Genetic mapping populations were evaluated to map molecular markers in 7 populations segregating for nematode resistance and in 3 crosses between inbreds that were resistant and susceptible for cavity spot resistance. Flavor variation was evaluated in 6 of these populations to generate better molecular markers for this important trait. Genotyping-by-sequencing was used to generate genome-wide and fine linkage maps. Marker information is being shared with seed companies as it is published to facilitate their selection programs.

Table 1. Selected USDA Carrot Breeding Lines

Inbred	Source	Color	Smoothness	Flavor	Length cm	Industry Testing	Tip	Use	Other Traits	Remarks
Orange Cello, Cut & Peel Inbreds and Breeding stocks										
1131	Long Red surrey x HCM	5	3	2	16	x	Taper	Cavity Spot Res.		Best Cavity Spot Resistance; high carotene
1137	Good Flavor Mass	3	4	5	13	x	Intermedia	Cavity Spot Res.		Good cello parent; excellent flavor
1138	HTDS/HRS	3	3	3	14	x	Blunt +	Cello		Good cello pollinator
Nb1175	8483 x 9256	4		3	28	x		Cello	MjR, MiR	Strong nem res S.C.'10; High rank hybrid 2014 DREC
Nb1391	8483 x 9256	4		4	27	x		Nematode Res.	MjR, MiR	Strong nematode resistance Kearney 2013, '16
1401	FN2-9 x 2302	4		4	23	x		Cello		Cello parent
L1408	FN2-9 x 2302	4		4	28	x		CP		High Rank Hybrid 2013, '16, '17, '18 DREC
2126	2566 x 3475	3	4	4	15	x	Blunt	CP, Cello	Sprangles =5	Good Hybrid Seed Parent
2144	3180 x 6274	4	4	3	20	x	Blunt	Cavity Spot Res.	Sprangles =5	Good Hybrid Seed Parent
Nb2155	BR x 6274	4		4	22			Cello	MjR, MiR	Strong nematode resistance S.C.'14, Kearney '16
Nb2159	BR x 6274	3		3	22	x		Nematode Res.	MjR, MiR	Strong nematode resistance, Kearney 2015
Npw 2191	PD x WR	3		3	18	x		Nematode Res.	MjR, MiR	Strong nematode resistance, Kearney 2016
Nb2195	BR x 6274	3		4	24			Nematode Res.	MjR, MiR	Strong nematode resistance S.C.'14
Nb2205	BR x 6274	4		4	23	x		Nematode Res.	MjR, MiR	Strong nematode resistance Kearney'13, S.C.'14
2226	HTDS/LRS	4		3	25	x		Cavity Spot Res.		Cello parent
L2301	FN2-9 x 9304	4		4	29			CP		High rank hybrid 2013, '15 DREC
Nbh2306	HM x (B x 6)	4	5	4	24			CP, Nematode Res	MjR, MiR	Strong nem res Kearney'13, '16; '18 S.C.'14high rank '18 DREC
2327	5280 x HCM	5		3	27	x	Blunt	CP, Cello		High rank hybrid 2014, '15 DREC
L2575	FN2-9 x 2302	4		4	34	x		CP		High rank hybrid 2012, '13, '16, 17 DREC
L2577	FN2-9 x 2302	4		4	29	x		CP		High rank hybrid 2013, 17 DREC
3035	2126 x 2144	4	4	4.5	15	x	Intermedia	CP, Cello		Good Combining Ability, High rank hybrid 2015 DREC
Nb3271	BR x 6274	3		4	21	x		Nematode Res.		Strong nematode resistance, Kearney 2015
Nb3284	Nb8483 x 9256	4		4	24			Nematode Res.		Strong nematode resistance, Kearney 2014, '16
F3513	EFM	3		4.5	17	x		Cello flavor		Good flavor cello
L4622	FN2-9 x 2302	4		4	27			CP		High rank hybrid 2014, '15 DREC
C5133	(FN2-9 x 9304) x FS	4.5	3.5	3.5	19	x		High color		Dark orange parent
Nb5192	BR x 6274	4	4.5	4.5	20	x		Nematode Res.	MjR, MiR	Strong nematode resistance, Kearney 2014, '16
F5367	EFM	3		4	17	x		Cavity Spot Res.		Cello pollinator; excellent flavor
L6191	2566 x FN2-9	4	3.5	4+	24		Intermedia	Cello		Long ,Flavor Select

1=Worst, 5 = Best; CP = Cut and Peel type; BR= Brasilia; MjR = M. javanica resistance, MiR = M.incognita resistance; S.C.= South Coast; DREC= Desert Res. Ext. Center

Nb, Nh, Np, Ns, Nw = nematode resistance gene sources 'Brasilia', 'Homs', 'Ping Ding', 'SFF', 'Western Red'

Table 1 (cont.). Selected USDA Carrot Breeding Lines

Inbred	Source	Color	Smoothness	Flavor	Length cm	Industry Testing	Tip	Use	Other Traits	Remarks
Orange Cello, Cut & Peel Inbreds and Breeding stocks										
7241	8532 x FN2-9	3	4+	3	21	x	Intermediate	Cello	Blck Crwn =R	Good Combining Ability
L7550	FN2-9 x 9304	4	3.5	4	29	x	Blunt	CP		Long Flavor Select, High rank hybrid 2015, '16 DREC
7808	HTDS/HRS	3		3	19	x		Cello		Flavor Select, High rank hybrid 2015 DREC
Nh8502	Homs	3		3	15	x		Nematode Res.	MjR, MiR	Strong nematode resistance, Kearney 2016
Nb9324	8503 x Long	3		4	23	x		CP, Cello	MjR, MiR	S.C.'14 Mi and Mj =0 or 1
L9785	FN2-9 x 2302	4		4	30	x	Blunt	CP		High rank hybrid 2009, '13, '15 DREC
L9786	FN2-9 x 2302	4		4	31			CP		High rank hybrid 2015, '16 DREC
L9788	FN2-9 x 2302	4		4	29		Blunt	CP		High rank hybrid 2013, '15 DREC
L9791	FN2-9 x 2302	4		4	24	x	Blunt	CP		High rank hybrid 2009 DREC
Novel Colored Breeding Stocks and Gene Sources										
P0114	Red x 7262			4		x	Blunt	Specialty		Purple
R0148	PI 432903			3		x	Blunt	Specialty	Nantes	Red Flavor Select, High rank entry 2015 DREC
P0252	Homs			3		x		Nematode Res.	MjR, MiR	Purple Yellow; Strong nem res Kearney'13 '18
P1129	9304 x PI			4		x		Specialty		Purple Orange; Flavor Select
Y1246	(2566 x FN2-9) x white			4		x		Specialty		Yellow; Flavor Select
W2383	BCVTHT x Wwortel			5		x		Specialty		White
Y3429	JOD x W. Belgian			4		x		Specialty		Dark Yellow, Flavor Select
R4294	Red x 7262			4		x		Specialty		Red, Flavor Select
Y4310	JOD x W. Belgian			4				Specialty Cello		Yellow
R5646	Red x 7262			3		x		Specialty		Red, Flavor Select
P6220	Trksh x 7262			4		x	Taper	Specialty		Purple, Flavor Select
PR6245	(7262 x Trksh) x Flavor			3.5		x	Blunt	Specialty		Purple Red
P6360	(Trksh x 7262) x Best Flavor			4		x		Specialty		Purple, High rank entry 2015 DREC
P6423	PD x Pi132601			4		x		Specialty		Purple
R6636	(432906PRC x 319858,432903) x FS			4		x		Specialty		Red
R6637	432906PRC x 319858JP			4.5		x	Blunt	Specialty	Nantes	Red
R8201	PI 432903			4		x		Specialty		Red; High rank entry 2013, '14 DREC
Y8519	Trksh x 7262			3		x	Intermediate	Specialty		Yellow Imperator

1=Worst, 5 = Best; CP = Cut and Peel type; BR= Brasilia; MjR = M. javanica resistance, MiR = M.incognita resistance; S.C.= South Coast; DREC= Desert Res. Ext. Center

Nb, Nh, Np, Ns, Nw = nematode resistance gene sources 'Brasilia', 'Homs', 'Ping Ding', 'SFF', 'Western Red'

Table 2. USDA Carrot Trial Results, DREC 2018 (Cello Trial, page 1)

USDA California Carrot Trials 2018											
Entry	Pedigree or Name	Source	Number of Judges Placing in Class					Mean ¹	Rank	Flavor ²	
			1	2	3	4	5			H	S
Entries Listed by Field Number											
C801	Maverick	Nunhems			5	8	2	3.80		4	4
C802	Nb2205A × Nb9297B	669-5	2	11	10	4	2	2.76	30	4	4
C803	FCR16578	Sakata		12.5	13	3.5		2.69	34	4	4
C804	KXPC-020	Integra		8	18.5	2	0.5	2.83	23	3.5	4
C805	(1111A × L3303B)×2144B	708-3	1	7	16	6		2.90	19	4	4
C806	SV2214DL	Seminis		4	12	9.5	4.5	3.48	6	4	4
C807	(2126A × Nb9297B)×2144B ☆	708-4	2	9.5	16	1.5	1	2.67	37	4	4
C808	Istanbul	Bejo		5	16	9		3.13	13	4	4
C809	(Nb8483A × Nb4216)×2144B ☆☆	708-5	2	12	13.5	2.5		2.55	38	4	4
C810	PV 5256	Pop Vriend	1	6.5	18	4.5		2.87	21	4	4
C811	(Nb8483A × Nb4216)×Nb3271B ☆☆☆	716-3		11	17	2		2.70	33	4	4
C812	Trooper	Nunhems		2	13	13	2	3.50	5	4	4
C813	(1138A × L3303B)×5367B	725-2		11.5	12.5	6		2.82	24	3.5	4
C814	FCR12073	Sakata	1	4.5	14.5	9	1	3.15	12	4	4
C815	(1111A × L3303B)×6116B	730-3		7.5	18.5	3	1	2.92	18	4	4
C816	NBC N850	Nunhems		0.5	8.5	15.5	5.5	3.87	1	3.5	4
C817	SVDL1522	Seminis		2.5	11.5	9	7	3.68	3	4	4
C818	(Nb8483A × Nbh2306B)×6116B ☆☆	730-4	1	9	10.5	7.5	2	3.02	15	4	4
C819	PV 5116	Pop Vriend	2	10.5	10.5	6	1	2.78	28	4	4
C820	(Nb8483A × Nb4216)×6116B ☆☆	730-5	4	13.5	8.5	4		2.42	44	4	4
C821	SVDL6430	Seminis		1.5	15.5	8	5	3.55	4	4	4
C822	(7808A × 9304B)×F7119B	748-2	6.5	12.5	6.5	1.5	3	2.40	47	4	4
C823	(Nb8483A×Nbh2306B)×F7120B ☆☆	749-2	16	2	1.5	0.5		1.33	56		
C824	PV 5304	Pop Vriend	2	12.5	7.5	3	4	2.81	27	4	4
C825	(5280A × 6116B)×F7723B	764-2	10.5	11.5	5	3		2.02	54	3.5	4
C826	FCR12070	Sakata	2	10	10	4	4	2.93	17	4	4
C827	(2126A×Nb9297B)×F7142B	750-4	6	13	6.5	1.5	3	2.42	45	4	4
C828	PV 5303	Pop Vriend	6	16.5	2	2.5	3	2.33	49	4	4
C829	(Nb8483A×Nbh2306B)×F7142B ☆☆	750-5	2	15	6	2	5	2.77	29	4	4
C830	(1138A × L3303B)×F7723B	764-4	5	10.5	8.5	5	1	2.55	39	4	4
C831	EaglePak	Nunhems	5	13.5	7.5	2	2	2.42	46	4	4
C832	(Nb8483A × Nb4216)×F7723B ☆☆	764-6	20	5	1	1	2	1.62	55	4	4
C833	(2126A × L3303B)×F7723B	764-5	8	10	9	2	1	2.27	50	4	4
C834	SV4128DL	Seminis		2.5	14.5	9	4	3.48	7	4	4
C835	(1138A×L3303B)×F7737B	765-3		5.5	15.5	7	2	3.18	11	4	4
C836	3058	Bejo		10	11	4.5	4.5	3.12	14	4	4
C837	FCR12089	Sakata		8.5	13.5	7	1	3.02	16	4	4
C838	(1138A×7808B)×F7737B	765-4	2	9.5	13.5	5		2.72	32	4	4
C839	Maverick	Nunhems		4.5	12	9.5	4	3.43	9	4	4
C840	Rebel	Nunhems		4.5	14	10.5	1	3.27	10	4	4
C841	(Nb2205A×Nb9297B)×F7737B ☆☆	765-5	1	10.5	12.5	5	1	2.82	25	4	4
C842	PV 5102	Pop Vriend	2	11.5	15.5	1		2.52	41	4	4
C843	(Nb8483A×Nbh2306B)×F7738B ☆☆	766-3	1	8	16.5	4.5		2.82	26	4	4

Continues next page

Table 2 (cont.). USDA Carrot Trial Results, DREC 2018 (Cello Trial, page 2)

USDA California Carrot Trials 2018											
Entry	Pedigree or Name	Source	Number of Judges Placing in Class					Mean ¹	Rank	Flavor ²	
			1	2	3	4	5			H	S
Cello Trial — Continued											
C844	KXPC-404	Integra	1		7.5	17.5	4	3.78	2	4	4
C845	(1111A×2226B)×F7738B	766-4	4	16.5	8.5	1		2.22	52	4	4
C846	PV 5077	Pop Vriend	5	14.5	8.5	2		2.25	51	4	4
C847	(5280A×Nbh2306B)×F7738B ☆	766-5	3	13.5	9.5	3	1	2.52	42	4	4
C848	Bull Dog	Nunhems	4	15	5	5	1	2.47	43	4	4
C849	FCR16552	Sakata	7	11.5	11.5			2.15	53	4.5	4
C850	(2126A×L3303B)×Npbw7261B ☆	788-3	4	10	9.5	4.5	2	2.68	35	4	4
C851	NUN 85192	Nunhems	3	14	12.5	0.5		2.35	48	4	4
C852	(2144A×Nb9297B)×Npbw7261B ☆☆	788-4	3	12.5	9.5	5		2.55	40	4	4
C853	(5280A×Nbh2306B)×Npbw7261B ☆☆☆	788-5		1	16.5	9.5	3	3.48	8	4	4
C854	(Nb2205A×Nb9297B)×Npbw7261B ☆☆☆	788-6	1	14	8	3	4	2.83	22	4	4
C855	FCR16573	Sakata	4	7.5	12.5	6		2.68	36	4	4
C856	SVDL7627	Seminis	2	7.5	16.5	4		2.75	31	4	4
C857	(L1406A×L0567B)×Nbh2306B ☆	789-2	1	7.5	15.5	6		2.88	20	4	4

¹ Mean based on average of 30 judges: 1 = unacceptable, 2 = poor, 3 = fair, 4 = good, 5 = excellent.

² Flavor (1 judge):

H = Harshness: 1=Very harsh, 5=Very mild;

S = Sweetness: 1=Not sweet, 5=Very sweet

Each ☆ indicates that one parent is a nematode resistant line

Table 2 (cont.). USDA Carrot Trial Results, DREC 2018 (Baby Trial, Page 1)

USDA California Carrot Trials 2018											
Entry	Pedigree or Name	Source	Number of Judges Placing in Class					Mean ¹	Rank	Flavor ²	
			1	2	3	4	5			H	S
Baby Cut & Peel Trial											
B801	UpperCut	Nunhems	1	4	6	7		3.06		4	4
B802	Propeel	Seminis	1	5	6.5	5.5		2.92		4	4
B803	Imperial Cuts	Integra	2	11	6			2.21		4	4
B804	(9253A x L7551B) x L2576B	425-4	1	17	10.5	0.5		2.36	52	4	4
B805	SVDC4193	Seminis		10	9.5	9.5		2.98	32	4	4
B806	(S.C. x L9788B) x L9785B	475-4		6	14	9		3.10	24	4	4
B807	PV 5193	Pop Vriend	2	12.5	9.5	5		2.60	44	4	4
B808	(L7550A x 2327B) x L9786B	476-5		5	14.5	9.5		3.16	22	4	4
B809	CrispyCut	Nunhems		10	10	6.5	2.5	3.05	30	4	4
B810	PS 1441	Seminis		8	16	5		2.90	36	4	4
B811	L14082A x L2577B	620-3	1	9	13.5	5.5		2.81	40	4	4
B812	L1406A x L0567B ²	704-2	4	13.5	8.5	3		2.36	53	4	4
B813	Starr	Integra	14.5	6.5	3	1	4	2.09	58	4	4
B814	PV 5280	Pop Vriend	3.5	12	7.5	5	1	2.59	45	4	4
B815	(L14082A x L9793B) x L2577B	713-4	1	2.5	14.5	9	2	3.29	21	4	4
B816	NUN 85936	Nunhems	1	4.5	9	13.5	1	3.31	20	4	4
B817	(L7550A x L1408B) x L2577B	713-5	11	10	5	2	1	2.03	59	4	4
B818	(L2304A x L2576B) x L3303B	717-3	2.5	8.5	14	4		2.67	43	4	4
B819	(L1406A x L0567B) x L7118B	747-4	6	13.5	8.5	1		2.16	57	4	4
B820	FCR15457	Sakata	2	5.5	14.5	7		2.91	35	4	4
B821	(L1408A x L9793B) x L7118B	747-3	1	12.5	14.5	1		2.53	48	4	4
B822	FCR15458	Sakata	1	4.5	16.5	7		3.02	31	4	4
B823	NUN 85931	Nunhems	1	7	17	4		2.83	38	4	4
B824	(L7550A x L1408B) x L7118B	747-5	1	10	12.5	5.5		2.78	42	4	4
B825	KXPC-506	Integra	3	10	12.5	3.5		2.57	46	4	4
B826	(L1408A x L9793B) x L7553B	763-3			9.5	16	3.5	3.79	6	4	4
B827	KXPC-576	Integra		1	3	18	7	4.07	1	4	4
B828	(L1406A x L0567B) x L7553B	763-4			11.5	13.5	4	3.74	8	3	4
B829	PV 5192	Pop Vriend	1	12	10	3	3	2.83	39	4	4
B830	UpperCut	Nunhems		6	9.5	4.5	9	3.57	12	4	4
B831	(L7550A x L1408B) x L7553B	763-5		1	17.5	8.5	2	3.40	16	4	4
B832	SlenderCut	Nunhems		1	9.5	14	4.5	3.76	7	4	4.5
B833	(L7550A x L1408B) x Nbh2306B ☆	790-3		2	16.5	6.5	4	3.43	13	4	4
B834	PV 5146	Pop Vriend	4	11	11	2	1	2.48	49	4	4
B835	(L9785A x L2576B) x Nbh2306B ☆	790-4			14	10	5	3.69	10	4	4
B836	FCR15514	Sakata		1	5.5	15	7.5	4.00	2	4	4
B837	CR1706	Seminis			6	19.5	3.5	3.91	3	4	4
B838	Imperial Cuts	Integra		6	16	6	1	3.07	29	4	4
B839	(L1406A x L0567B) x Nbh2306B ☆	790-5		5	17	6	1	3.10	25	4	4
B840	NUN 85933	Nunhems		1	7.5	18.5	2	3.74	9	4	4.5
B841	(L9793A x L3726B) x Nbh2306B ☆	790-6		1	18	9	1	3.34	18	4	4
B842	FCR17710	Sakata		5	9	13	2	3.41	14	4	4
B843	SV2765DC	Seminis		5	8	15	1	3.41	15	4	4
B844	(L7550A x L1408B) x Nbh2306B ☆	791-3		2.5	15.5	9	2	3.36	17	4	4
B845	KXPC-520	Integra		1.5	6	15	6.5	3.91	4	4	4
B846	SVDC1978	Seminis	1		14	9	5	3.59	11	4	4
B847	(L9785A x L2576B) x Nbh2306B ☆	791-4		5.5	15	7.5		3.07	28	4	4
B848	PV 5041	Pop Vriend	4	15.5	8.5	1		2.22	56	4	4

Continues next page

Table 2 (cont.). USDA Carrot Trial Results, DREC 2018 (Baby Trial Page 2)

USDA California Carrot Trials 2018											
Entry	Pedigree or Name	Source	Number of Judges Placing in Class					Mean ¹	Rank	Flavor ²	
			1	2	3	4	5			H	S
Baby Cut & Peel Trial — Continued											
B849	(L1406A×L0567B)×Nbh2306B ☆	791-5	2	13.5	11.5	2		2.47	50	4	4
B850	Propeel	Seminis	5	10.5	10.5	2		2.34	54	4	4
B851	HoneySnax	Nunhems		11.5	10.5	6		2.80	41	4	4
B852	(L9793A×L3726B)×Nbh2306B ☆	791-6		6	16.5	5.5		2.98	33	4	4
B853	FCR17723	Sakata		6	14.5	6.5	1	3.09	26	4	4
B854	KXPC-516	Integra	3	4.5	12	8.5		2.93	34	4	4
B855	L1406A × L0567B	B101-2	2	5	7	9.5	4.5	3.34	19	4	4.5
B856	FCR15456	Sakata		1	8	14	5	3.82	5	4	4
B857	PV 5145	Pop Vriend	1	9	14	1	3	2.86	37	4	4
B858	(9253A×9788B)×L9786B	776-3	8	14	2	1	1	1.96	61		
B859	(L1406A×L0567B)×L9786B	776-4	4	13	6	2	3	2.54	47		
B860	(L9785A×L2576B)×L9786B	776-5	14	4	2	3	2	2.00	60		
B861	(L7550A×L1408B)×L9786B	776-6	14	6	2	1	2	1.84	62		
B862	(L2304A×L2576B)×L9793B	778-3	3	4	11	6.5	3.5	3.13	23		
B863	(L1406A×L0567B)×L9793B	778-4	7	8	9	2	2	2.43	51		
B864	(L9785A×L2576B)×L9793B	778-5	9	9	6	1	3	2.29	55		
B865	(L7550A×L1408B)×L9793B	778-6	3	3	12.5	7.5	2	3.09	27		

¹ Mean based on average of 29 judges: 1 = unacceptable, 2 = poor, 3 = fair, 4 = good, 5 = excellent.
² Flavor (1 judge):
H = Harshness: 1=Very harsh, 5=Very mild;
S = Sweetness: 1=Not sweet, 5=Very sweet

Each ☆ indicates that one parent is a nematode resistant line

Table 2 (cont.). USDA Carrot Trial Results, DREC 2018 (Novel Carrot Trial)

USDA California Carrot Trials 2018												
Entry	Pedigree or Name	Source	Number of Judges Placing in Class					Mean ¹	Rank	Flavor ²		Color
			1	2	3	4	5			H	S	
Novelty Trial												
T801	CreamPak	Nunhems			6	8.5	10.5	4.18	2	4	4.5	
T802	Deep Purple	Bejo	2	8	10.5	3.5	1	2.74	32	4	4	
T803	Malbec	Seminis		2	11.5	8.5	3	3.50	11	3	4	
T804	P6279A×P8438B	770-2	11	10	1	2	1	1.88	38	4	4	
T805	KXPC-588	Integra			3	14	8	4.20	1	4	4.5	
T806	PV 5221	Pop Vriend	1	1.5	10.5	7	5	3.54	10	4	4	
T807	(R8201A×R6093B)×R7294B	755-3	3	7	9	4	2	2.80	28	4	4	
T808	Yellowstone	Bejo	1	11	8	4	1	2.72	33	4	4	
T809	PD x PI326011	B309-1	3	2	10	6	4	3.24	20	3.5	4	
T810	Ruby Queen	Nunhems		3	9.5	6.5	5	3.56	9	4	4	
T811	Mello Yello	Bejo		12	6	5	2	2.88	26	4	4	
T812	(R8201A×R6093B)×R7297B	756-4		6	10	7	2	3.20	21	4	4	
T813	White Satin	Bejo	2	4.5	13	3.5	2	2.96	25	4	4	
T814	P1129B	B103-1	3	7	9.5	3	2.5	2.80	29	4	4	
T815	Rainbow	Bejo	2	8	9	3	2	2.79	30	4	4	
T816	PV 5134	Pop Vriend	1	2.5	10.5	8	3	3.38	14	4	4	
T817	R4294B	B113-1		3	13	4	5	3.44	13	4	4	
T818	Deep Purple	Bejo		3	11	7	4	3.48	12	4	4	
T819	Snow Man	Nunhems		2.5	5	10.5	7	3.88	5	4	4	
T820	Y1246B	B114-1		3.5	11.5	9	1	3.30	17	4	4	
T821	PV 5059	Pop Vriend	1	2	13	7	2	3.28	18	4	4	
T822	YellowBunch	Nunhems		1	9.5	10.5	4	3.70	6	4	4	
T823	(PR2347A×Purple Red)×PR7299B	757-2	5	11	4	3	2	2.44	35	4	4	
T824	PurpleElite	Nunhems	2	2.5	12.5	6	2	3.14	22	4	4	
T825	(P.S.C.×PR2356B)×PR7299B	757-3	6	8	7	4		2.36	36	4	4	
T826	NBC PU 5463	Nunhems	2	8.5	6.5	7	1	2.86	27	3	4	
T827	R6636B	S364-1		6	15	2	2	3.00	24	3.5	4	
T828	PV 5288	Pop Vriend		2	10	9	4	3.60	7	4	4	
T829	CreamPak	Nunhems		1	4.5	11	8.5	4.08	3	4	4	
T830	Y5654B	B105-1	3	10	6	2	4	2.76	31	4.5	4	
T831	RZ_1	Rijk Zwaan	1	2.5	12.5	5	4	3.34	15	4	4	
T832	Y5665	B106-1	7	10	4	1	3	2.32	37	4	4	
T833	PV 5215	Pop Vriend	1	2.5	14.5	3	4	3.26	19	4	4	
T834	(Nb8483A×Nbh2306B)×Npw2191B	518-2	3	13	3.5	2.5	3	2.58	34	4	4	
T835	Purple Sun	Bejo	1	4	13.5	4.5	2	3.10	23	3	4	
T836	(R6220A×R6304)×R8201B	768-2	1	3	12.5	3.5	5	3.34	16	3.5	4	
T837	PV 5284	Pop Vriend	1	1.5	8	10.5	4	3.60	8	4	4	
T838	R6220B	B104-1			7	12.5	5.5	3.94	4	3	4	

¹ Mean based on average of 25 judges: 1 = unacceptable, 2 = poor, 3 = fair, 4 = good, 5 = excellent.

² Flavor (1 judge): H = Harshness: 1=Very harsh, 5=Very mild;
S = Sweetness: 1=Not sweet, 5=Very sweet

Table 3. Progress in combining nematode resistance sources

	MJ	1091	WR	HM	PD	SFF	NF
MJ	--	*** 0-5	*** 1-3	*** 0-2	*** 0-5	*** 0-1.5	*** 0-3
1091		--		*** 0-3	** 2-4	*** 0-2	* 1-4
WR			--	*** 0-2	*** 3.5-4	*** 2-3	* 1-3
HM				--	*** 0-2.5	*** 0-2	** 0-2
PD					--	* 1-3	** 2-3
SFF						--	*** 0-1.5
NF							--
Susc. Long	*** 0-1	*** 0.5-2	*** 2-3	*** 0-1	*** 0-2	*** 0-1	*** 1-3
Susc. Flavor	*** 0-1	*** 0-2	*** 2-3	*** 0-1	*** 0-1	*** 0-1	*** 2-3
Susc. Other	*** 0-1			*** 0-1	** 2-4	*** 0-1	

MJ = *Mj-1* from 'Brasilia 1252'

1091 = Resistance from 'Brasilia 1091'

WR = Resistance from 'Western Red'

HM = Resistance from 'Homs'

PD = Resistance from 'Ping Ding'

SFF = Resistance from 'Scarlet Fancy × Favourite'

NF = Resistance from 'Nantes Fancy'

Asterisks denote intercross generations at F₁, F₂, and F₃ or higher, respectively for *, **, and ***. Values below asterisks denote average MiR scores among several F₂ populations for a given cross among resistance sources (upper portion of the table), and best MiR scores among one or more F₁ hybrids with susceptible parents (lower portion of the table). Data is from South Coast and Kearney field trials.