Carrot Breeding to Develop and Introduce Improved Cultivars for California Producers

Annual Research Report to California Fresh Carrot Advisory Board
for March, 2015 to February, 2016

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. 1817 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 141 advanced baby, 41 cello, 95 novel color inbreds, and 592 new diverse base populations (for nematode resistance, length, flavor, and color) included in the trial. A summary of the characteristics of selected recent and unreleased USDA carrot inbreds developed and being used in the USDA program is presented in Table 1.

2. 65 cello and 99 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 11 baby, 4 cello, and 12 novel entries in the top 20 of their respective classes. This was the fourth year that we included nematode resistant inbreds as components to cut & peel hybrids among USDA entries, and among the 4 top cello hybrids from the USDA program, 3 had an inbred parent derived from nematode resistant backgrounds. This was our eleventh year to perform a specialty carrot trial that included 40 entries with unusual color or shape. Flavor evaluation was also performed for all entries.

3. Fifty-five inbreds are being tested further by seed companies (listed in Table 1). Nineteen of these are *Meloidogyne javanica* and/or *M. incognita* resistant inbreds 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

1. *Incorporating Resistance from South American Carrot Germplasm*
Studies we published demonstrate that the first nematode resistance gene to be extensively evaluated in carrot is *Mj-1* derived from 'Brasilia 1252'. *Mj-1* is on chromosome 8 and it controls the inheritance of the resistance to *Meloidogyne javanica* and also imparts partial resistance to *M. incognita.* We have also observed *Meloidogyne javanica* and *M. incognita* resistance from another strain of Brasilia ("Brasilia 1091'), and more recently from another South American cultivar – 'Uberlandia'. The *M. incognita* resistance from both 'Brasilia' strains is controlled, in part, by the *Mj-1* genetic region. In addition to *Mj-1*, a gene on chromosome 1 of South American carrots also contributes to *M. incognita* resistance. The importance of these genetic regions to developing *M. incognita* – resistant carrots has motivated our development of molecular markers to assist breeders in incorporating this resistance in new breeding stocks for California. With the sequence of the carrot genome in hand, numerous markers are now available to facilitate incorporation of multiple nematode resistance genes. To accompany the release of 'Brasilia'-derived germplasm to the seed industry (Table 3), we have published information on markers (Parsons et al. Molec. Br., 2015).

   At the Kearney Station 732 diverse seed sources were grown by Dr. Roberts on *Meloidogyne incognita* infested soil, with a subset on *Meloidogyne javanica*, and with adjacent susceptible check plots throughout both fields. Harvest was in October and included a field day with industry invited to attend. Inbreds derived from resistance sources mentioned above were resistant and sub-populations of selected roots were sent to Madison for seed increase. These included intercrosses of all sources of resistance with each other, and with good-flavored and long carrots adapted for production in California are at F_4 to F_9 generations. Several selections have excellent resistance (both *M. javanica* and *M. incognita* resistance scores of 0-1, see Dr. Roberts' report) and suitable length, smoothness, and flavor. Several more advanced generations were selected entries had excellent resistance to both *M. incognita* (MiR) and *M. javanica* (MjR). Several of these same breeding stocks were also grown in the DREC trials, where they had length, smoothness, color, and flavor suitable for California production. These inbreds are derived from an *Mj-1* single source of resistance or combinations of *Mj-1* and the chromosome 1 resistance backcrossed into an unrelated, dark orange, good flavor, long, smooth inbred. This confirms that strong nematode resistance can be bred into diverse genetic backgrounds adapted for production in California without compromising

resistance. Seed of these inbreds is released (Table 3) and has been distributed to all of the major seed companies breeding carrots for the North American market, as well as to other carrot researchers.

We invited the carrot seed industry to submit entries for evaluation of nematode resistance, in the Kearney Station 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

Additional sources of resistance beyond 'Brasilia 1252' (MJ) and 'Brasilia 1091' (1091) noted above have been derived from Syria ('Homs' HM), China ('Ping Ding' PD), Australia ('Western Red' WR), Europe ('Scarlet Fancy' × 'Favourite', SFF; and 'Nantes Fancy', NF) and are being genetically mapped and characterized. A second major gene, *Mj-2*, accounts for part of the 'Ping Ding' resistance, and it is on the same chromosome as *Mj-1*, but 30- 35 cM away (Ali et al. J. Hered., 2014). Field evaluation of resistance derived from all these sources was tested at both the Kearney Station and in the greenhouses by Dr. Roberts. Like MJ derivatives, these resistance sources also had variable levels of resistance among inbreds being developed from them, with inbred scores ranging from roughly 1 to 5. Scores of 2 and above reduce marketable yield significantly. MJ, BR, SFF, HM and PD selections had high levels of resistance, and all sources had individual roots with scores of 1 or less. Resistance from Homs (HM) in particular has been strong, and this was observed again in the last year. Homs has nematode resistance genes at or near the *Mj-1* BR resistance gene on chromosome 8, but also has additional resistance genes on chromosomes 1, 2 (2 genes) and 9. SFF has a resistance gene at or near the *Mj-1* BR resistance gene on chromosome 8, and also has an additional resistance gene on chromosome 4 (Table 4). The chromosome 9 resistance from HM is particularly strong, as is the chromosome 4 resistance from SFF. The discovery of resistance genes on chromosomes 1, 2, and 8 from unrelated genetic sources may indicate multiple alleles for the same genes (since they map to similar regions of these three chromosomes), or perhaps reflect genes linked but not allelic, since resistance genes are often clustered in other plants. In fact, we recently found that carrot has over 600 putative resistance genes (potentially imparting resistance to numerous pathogens, not just nematodes) and several are in a cluster at or near the *Mj-1* BR resistance gene on chromosome 8 (publication in press). These different genes apparently have a cumulative effect in strengthening resistance, to complement those for *Mj-1*, but it is not yet clear whether resistance genes from all four chromosomes need to be combined to provide the strongest resistance, or whether certain alleles or closely linked genes from one genetic source (e.g. *Mj-1* on chromosome 8 from 'Brasilia') are stronger than those from an unrelated source (e.g. the SFF and HM resistance genes also on chromosome

8, and mapped closely to *Mj-1*). The development of new combinations of genes and alleles was initiated in the last year to help clarify our understanding of how these multiple genes can best be combined to confer durable nematode resistance.

Segregating populations incorporating combinations of resistance, or intercrossing resistance into long, high color, good flavor susceptible backgrounds have been established and advanced in the breeding program, and most combinations of resistance are being tested (Table 5). We have produced seed of several F_2 through F_6 populations that combine multiple sources of resistance. Inheritance studies underway provide basic scientific information and the basis for development of molecular markers which seed companies and our program can use to incorporate resistance into carrot germplasm backgrounds adapted for California. Seed was sent to Dr. Roberts for testing plants grown in greenhouses and inoculated with nematode eggs. Resistant and susceptible roots were selected and are used for seed production in Wisconsin. Resistance data gathered to date for segregating populations is provided in Dr. Roberts' report.

Of the crosses within and between these multiple sources of resistance, populations with a high incidence of strong *Meloidogyne incognita* resistance (MiR) were observed. F_2 average scores were low (0-1) in several populations (see trial data in Dr. Roberts' report) from field trials at the Kearney Station (esp. among plots 116-133), combining MJ with HM, NF with HM, MJ with PD, and HM with SFF, suggesting that most of the derivative plants from these populations would be expected to have a relatively high level of nematode resistance. Currently greenhouse seed production is underway in the greenhouse for selected roots from the Kearney trials with MiR scores of 2.0 or less. These materials will be used to determine if multigenic resistance can be widely incorporated into carrots for California production with limited use of nematicides.

Seed samples of F_3, F_4 , and F_5 derivatives were generated in the last year to be evaluated for resistance segregation patterns in a new promising sources of resistance from the wild carrots -*Daucus carota* ssp. *gaedecii* PI 478883 and Ames 31193; and wild *Daucus carota* ssp. *carota*, SS109, from Amador, CA, and from another source of resistance discovered in cultivated carrots in the South American (open-pollinated cultivar 'Uberlandia'). Derivatives of PI 478883 and SS109 grow poorly due to a genetic disorder referred to as hybrid breakdown that occurs in some derivatives of genetically wide crosses of many plant and animal species. These are quite wide crosses and hybrid breakdown in carrot manifests itself as slow growth, distorted leaves flowers, and frequently extreme male and female sterility. Nematode resistance scores from these two sources generally ranged from 2 to 3. Given the difficulty of advancing segregating generations due to hybrid breakdown, these resistance sources will be dropped from future study. 'Uberlandia' derivatives also had resistance scores in the range of 2-3 (plots 279-281; see Kearney results in Dr. Roberts' report)

and had robust overall growth. Seed stocks derived from 'Uberlandia' will be evaluated to determine if resistance is due to the same genes already identified, or whether additional nematode resistance genes occur in carrots.

Greenhouse evaluation of carrots proven to have strong Mi resistance in previous collaborative research were evaluated for resistance response when exposed to several new nematode strains and species by Dr. Roberts (see his report) and selected roots were sent to Wisconsin. Seed production and molecular marker evaluation is underway to generate seed, including self-pollinations and crosses to susceptible carrots for future progeny analysis and genetic analysis.

D. Identifying Genetic Sources of Cavity Spot Resistance

Based upon the wide range of disease response by Dr. McDonald in previous evaluations, eight crosses were made last year between resistant and susceptible inbred plants, and also among resistant plants were grown in our DREC trials. Seed from the first segregating populations will be tested in 2016 by Dr. McDonald to begin to study the inheritance of cavity spot resistance.

Carrot seed samples of a diverse collection of USDA inbreds beyond those she had evaluated previously were provided to Dr. McDonald in 2015 to confirm her previous observations and to identify additional genetic sources of cavity spot resistance. Seed from two resistant sources that she had previously evaluated, B1137 and B5367, was evaluated by her in 2015 and cavity spot resistance scores were quite similar between the two years. Detailed results of those evaluations are found in Dr. McDonald's report. Roots of resistant plants from a wide genetic range of seed sources in those evaluations were shipped to Wisconsin and are being used in our winter 2015-2016 greenhouse seed production trials to develop seed stocks to determine the genetic basis of resistance and advance our breeding program for resistance based upon Dr. McDonald's field evaluations.
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E. Seed Production and Laboratory Analysis

1. Roots from California trials were sent to Wisconsin for seed production. Seed yields were average in our 85 cages and 800 breeding plot isolations in the summer, and average in 1648 greenhouse cages in the winter greenhouse. These roots were used to produce seed of 78 new experimental hybrids, and 289 new experimental breeding stocks for current and future testing.

2. Detailed flavor and texture evaluation was made on 103 populations and carotene was quantified in 39 of them to estimate nutritional value (see Table 1). Seed was sent to cooperators for testing. Of particular interest are nutritional properties in populations with elite nematode resistance. A range in color and nutritional value has been observed in these materials, indicating that nutritional

quality or flavor will not need to be sacrificed to incorporate nematode 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 as mentioned above. Seed production was above average. We produced 77 new F_1 intercrosses combining unrelated sources of resistance, 59 F_2 populations segregating for multiple sources of resistance in California-adapted background, and 142 inbreds to be tested for MI resistance. Large-scale seed production by industry collaborators of selected items will supplement seed supplies. These will be very valuable in future nematode resistance genetics and breeding.

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 produced 17 new F_1 intercrosses combining unrelated sources of resistance and generated the first F_2 populations segregating for resistance in California-adapted background. These will be very valuable in future nematode resistance genetics and breeding.

F. Evaluation of Carrot Germplasm and Advanced Selections for Alternaria Leaf Blight Resistance and Production Characteristics

Field evaluation of *Alternaria dauci* resistance was performed in Wisconsin. Resistance was observed in 341 wild and land race carrots, and in derivatives of several wild carrots crossed with modern cultivated inbreds. Several hybrids, backcrosses and testcrosses were made among these items for testing. Segregating populations are being tested for genetic studies discussed above. Molecular markers are being developed to track resistance. New genetic sources of resistance were mapped and crosses were made between these genetic stocks and inbreds adapted for production in California. Hybrid combinations are being developed for field testing.

G. Carrot Molecular Genetic Markers

1. With the carrot genome sequenced, we have identified hundreds of molecular markers linked to all major resistance QTL (Table 5). These markers are being used to select for nematode resistance in more diverse backgrounds and to identify candidate genes. Molecular markers associated with genes for alternaria resistance, early flowering, sugar and pigment content, root color, and components of carrot flavor are also being identified. Marker information is being shared with seed companies to facilitate their selection programs.

Table 1. Selected USDA Carrot Breeding Lines

Inbred	Source	Color	Smooth-ness	Flavor	Length cm	Industry Testing	Tip	Use	Other Traits	Remarks
Orange Cello, Cut & Peel, Nematode Resistant										
1111	7241 × 5280	4	4	3	15	x	Intermediate	CP, Cello	Sprangles =5	Good Combining Ability, Released
1138	HTDS/HRS	3	3	3	14	x	Blunt +	CP, Cello		Good CP Pollinator
Nb1175	8483 × 9256					x		Cello		Nematode, SC'10 Mi=1.0, 8th Place Finish 2014 E.C.
Nb1386	8483 × 9256							Nematode Res.	MjR, MiR	Kearney'13 Mi *and* Mj =0 or 1, S.C.'14 Mi and Mj =0,1 or 2
Nb1391	8483 × 9256					x		Nematode Res.	MjR, MiR	Nematode, Kearney'13 Mi *and* Mj =0 or 1
L1397	FN2-9 × 2302							CP		High Rank Hybrid 2013 E.C.
L1408	FN2-9 × 2302				28			CP		High Rank Hybrid 2013 E.C.
2126	2566 × 3475	3	4	4	15	x	Blunt	CP, Cello	Sprangles =5	Good Hybrid Seed Parent
2144	3180 × 6274	4	4	3	20	x	Blunt	CP	Sprangles =5	Good Hybrid Seed Parent
Nb2155	BR × 6274							Cello		S.C.'14 Mi and Mj =0 or 1
Nb2159	BR × 6274					x		Nematode Res.	MjR, MiR	
Nb2160	BR × 6274							Nematode Res.	MjR, MiR	Nematode, Kearney'13 Mi *and* Mj =0 or 1
Nb2167	BR × 6274							Nematode Res.	MjR, MiR	S.C.'14 Mi and Mj =0 or 1
Nh2168	Homs							Nematode Res.	MjR, MiR	S.C.'14 Mi and Mj =0 or 1; Released
Nhb2189	HM × (BR × 6274)							Nematode Res.	MjR, MiR	Nematode, Kearney'13 Mi *and* Mj =0 or 1, S.C.'14 Mi and Mj =0 or 1
Nb2195	BR × 6274							Nematode Res.	MjR, MiR	S.C.'14 Mi and Mj =0 or 1
Nb2205	BR × 6274							Nematode Res.	MjR, MiR	Kearney'13 Mi *and* Mj =0 or 1, S.C.'14 Mi and Mj =0 or 1
Nb2246	BR × 6274							Nematode Res.	MjR, MiR	Nematode, Kearney'13 Mi *and* Mj =0 or 1
Nb2285	BR × 6274							Nematode Res.	MjR, MiR	S.C.'14 Mi and Mj =0
L2301	FN2-9 × 9304			4	29			CP		3rd and 4th Place Finish 2013 E.C. High Rank Hybrid 2015 E.C.
Nbh2306	HM × (B × 6)							Nematode Res.	MjR, MiR	Nematode, Kearney'13 Mi *and* Mj =0 or 1, S.C.'14 Mi and Mj =0 or 2
2327	5280 × HCM				27	x	Blunt	CP, Cello		3rd Place Finish 2014 E.C., High Rank Hybrid 2015 E.C.
L2574	FN2-9 × 2302				34			CP		High Rank Hybrid 2012 and 2013 E.C.
L2575	FN2-9 × 2302				27	x		CP		High Rank Hybrid 2012 and 2013 E.C.
L2576	FN2-9 × 2302				33			CP		High Rank Hybrid 2012, and 2015 E.C.
L2577	FN2-9 × 2302				29			CP		High Rank Hybrid 2012 E.C.
3035	2126 × 2144	4	4	4.5	15	x	Intermediate	CP, Cello		Good Combining Ability, High Rank Hybrid 2015 E.C.
3308	LRSurrey × HCM					x		Cello		Dark Orange
3309	LRSurrey × HCM					x		Cello		Dark Orange
Nb3353	BR × 6274							Nematode Res.	MjR, MiR	
3363	(Camberly × S.B146Nts) × 9256B					x		Cello		Dark Orange

1=Worst, 5 = Best; CP = Cut and Peel type; BR= Brasilia; MjR = *M. javanica* resistance, MiR = *M.incognita* resistance; S.C.= South Coast; E.C.= El Centro

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

Inbred	Source	Color	Smooth-ness	Flavor	Length cm	Industry Testing	Tip	Use	Other Traits	Remarks
Nb3725	FN2-9 × 2302							CP		
Nb3999	BR × 6274					x				High Rank Hybrid 2015 E.C., Released
Nb4001	BR × 6274					x				Released
Nb4002	BR × 6274					x				Released
Nb4005	BR × 6274	3	4	3.5	22	x	Internediate	CP		Flavor Select, S.C.'14 Mi and Mj =0 or 1
L4168	FN2-9 × 9304					x		CP		Very Long
Nb4216	USDA inbred × (BR × 6274)					x		Cello	MjR, MiR	
Ns4222	SFF							Cello	MjR, MiR	Very Good Flavor
Nb4228	8483 × 9256						Blunt	Cello	MjR, MiR	
Nbh4234	(HM × (Bx6)) × FS							Nematode Res.	MjR, MiR	
Nw4453	WR × (FN2-9 × 2302)						Nantes	Cello		
Ns4467	SFF							Cello		
Nb4591	BR × 6274	3	4	3.5	17			Nematode Res.	MjR, MiR	
L4622	FN2-9 × 2302							CP		High Rank Hybrid 2014 E.C., High Rank Hybrid 2015 E.C.
L4623	FN2-9 × 2302							CP		High Rank Hybrid 2014 E.C., High Rank Hybrid 2015 E.C.
L5133	(FN2-9 × 9304) × FS							CP, Cello		Dark Orange
L5134	FN2-9 × 2302							CP, Cello		Dark Orange
Ns5154	SFF					x		Nematode Res.	MjR, MiR	Released
Nb5169	BR × 6274	3	3.5	4.5	18			Nematode Res.	MjR, MiR	
Nb5192	BR × 6274	3	4.5	4.5	20			Nematode Res.	MjR, MiR	S.C.'14 Mi and Mj =0 or 1
5497	5238 × 6274	4	5	4	17		Tapered	Flvr. Improvement		Flavor Select
6038	5280 × HCM	4	3.5	4+	21	x	Tapered	CP	Dark orange	Long Flavor Select
L6203	2566 × FN2-9	4	3.5	4+	22		Intermediate	CP		Long Flavor Select
Nb6509	BR × 6274							Cello	MjR, MiR	
Ns6520	SFF					x		Cello	MjR, MiR	
Nb6526	BR × 6274					x		CP, Cello	MjR, MiR	Good Combining Ability, Released
7003	(7262B × Trksh #2) × 9304							Cello		Orange Flavor Select
7241	8532 × FN2-9	3	4+	3	21	x	Intermediate	CP, Cello	Blck Crwn =R	Good Combining Ability
L7550	FN2-9 × 9304	4	3.5	4	29	x	Blunt	CP		Long Flavor Select, High Rank Hybrid 2015 E.C.
L7551	FN2-9 × 9304	4	3.5	4+	33	x	Tapered	CP		High Rank Hybrid 2013 and 2015 E.C.
L7553	FN2-9 × 9304	4	3.5	4	24	x	Tapered	CP		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; E.C.= El Centro

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

Inbred	Source	Color	Smooth-ness	Flavor	Length cm	Industry Testing	Tip	Use	Other Traits	Remarks
7808	HTDS/HRS					x		Cello		Flavor Select High Rank Hybrid 2015 E.C.
8378	5238 × 5280	5	4	3	21		Intermediate	Cello		Dark Orange
Nb8478	BR × 6274			3.5			Blunt	Nematode Res.	MjR, MiR	Nematode Res.
Nb8483	BR × 6274	3	3	4+	18	x	Blunt	CP, Cello	MjR, MiR	Good Combining Ability; MjR, MiR+
Nb8495	BR × 6274							Nematode Res.	MjR, MiR	S.C.'14 Mi and Mj =0 or 1
Nb8503	BR × 6274					x		Nematode Res.	MjR, MiR	Released
Nb8524	BR × 6274	4	3	3	19	x	Blunt	Cello	MjR, MiR	Good Combining Ability; MjR, MiR+, S.C.'14 Mi and Mj =0 or 1.5
Nb8531	BR × 6274	4	3	3	19		Blunt	General Use	MjR, MiR	Good Combining Ability
8535	Flavor Selections			4.5			Intermediate	Flvr. Improvement		Elite Flavor Inbred
Nb8542	BR × 6274	3	3	4+	15	x	Blunt	CP, Cello	MjR, MiR	Good Combining Ability; MjR, MiR+
AR8576	4367 × D.carota Ger.			4			Intermediate	Alternaria Res.		Medium Orange, Alternaria Resistant
9256	5238 × 5280					x		Cello		
Nb9296	(FN2-9 × 2566) × 8503					x		Cello	MjR, MiR	Flavor Select, S.C.'14 Mi and Mj =0 or 1
Nb9297	8483 × 9256					x		Cello	MjR, MiR	5th and 7th Place Finish 2014, S.C.'14 Mi and Mj =0
Nb9321	8542 × FS							Cello	MjR, MiR	Flavor Select
Nb9322	8483 × 9256			4			Blunt	CP	MjR, MiR	CP
Nb9324	8503 × Long					x		CP, Cello	MjR, MiR	S.C.'14 Mi and Mj =0 or 1
L9785	FN2-9 × 2302			4	30	x	Blunt	CP		1st Place Finish 2009 and 2013 E.C., High Rank 2015 E.C.
L9788	FN2-9 × 2302						Blunt	CP		High Rank Hybrid 2013 and 2015 E.C.
L9791	FN2-9 × 2302			4	24	x	Blunt	CP		13th Place Finish 2009 E.C.
Speciality Colors and Nematode Resistant										
P0114	Red × 7262					x	Blunt	Specialty		Purple
R0148	PI 432903					x	Blunt	Specialty	Nantes	Red Flavor Select, High Rank 2015 E.C.
P0252	HM					x		Nematode Res.	MjR, MiR	Purple Yellow; Nematode, Kearney'13 Mi *and* Mj =0 or 1
P0159	7262 × 2566					x		Specialty		Purple, Flavor Select
P0175	(Trksh × 7262B) × Best Flavor							Specialty		Purple Orange
P0191	Ping Ding							Specialty		Purple Yellow Flavor Select; Nematode Res.
P0252	Homs							Specialty		Purple Yellow Flavor Select; S.C.'14 Mi and Mj =0 or 1
P1129	9304 × PI					x		Specialty		Purple Orange; Flavor Select
Nb1175	8483 × 9256							Specialty		Nematode Res.

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

Inbred	Source	Color	Smooth-ness	Flavor	Length cm	Industry Testing	Tip	Use	Other Traits	Remarks
Npw2191	PD × WR							Nematode Res.	MjR, MiR	Purple; Nematode, Kearney'13 Mi/Mj =0/1, S.C.'14 Mi/Mj =0/1
PR2356	7262 × 432903							Specialty		Purple Red; Flavor Select
W2383	BCVTHT × Wwortel			3				Specialty		White
Y3429	JOD × W. Belgian							Specialty		Dark Yellow, Flavor Select
Npw4217	(PD × PI326011) × WR							Nematode Res.	MjR, MiR	Purple
Npw4268	PD × WR							Nematode Res.	MjR, MiR	Purple
R4294	Red × 7262					x		Specialty		Red, Flavor Select
Y4310	JOD × W. Belgian							Specialty Cello		Yellow
Npw4458	(PD × PI326011) × WR							Specialty		Purple Orange, Flavor Select
Npw5182	(PD × PI326011) × WR							Nematode Res.	MjR, MiR	Pale Purple Orange, Flavor Select, Mi Score =0
R5646	Red × 7262					x		Specialty		Red, Flavor Select
P5887	Trksh × 7262			4				Specialty		Purple, Flavor Select
R6139	PI 432903			3.5		x		Specialty		Red, Flavor Select
R6216	Flavor × Red			4				Specialty		Red, Flavor Select
P6220	Trksh × 7262			4		x	Taper	Specialty		Purple, Flavor Select
PR6245	7262 × PI 432903			3.5		x	Blunt	Specialty		Purple Red
R6254	432906PRC × 319858JP			4			Blunt	Specialty		Red, Flavor Select
R6259	432906PRC × 319858JP							Specialty		Red, Flavor Select
P6264	Trksh × 7262			4			Intermediate	Specialty		Purple, Flavor Select
R6345	Red PI's			3.5			Intermediate	Specialty		Red Imperator
P6360	(Trksh × 7262) × Best Flavor					x		Specialty		Purple, High Rank 2015 E.C.
R6636	(432906PRC × 319858,432903) × FS					x		Specialty		Red
R6637	432906PRC × 319858JP			4.5			Blunt	Specialty	Nantes	Red
R7245	432906PRC × 319858JP			4		x		Specialty		Red, Flavor Select
R8193	432906PRC × 319858JP							Specialty		Red, Flavor Select
R8197	432906 × 319858							Specialty		High Rank 2013 and 2015 Novel E.C.
R8201	PI 432903					x		Specialty		Red; 1st Place Finish 2013 E.C., 6th 7th Place Finish 2014 E.C.
P8255	7262 × 2566					x		Specialty		Purple
P8492	Ping Ding × PI 326011			4				Nematode Res.	MjR, MiR	Purple, Nematode Res.
Nh8502	Homs			3		x	Blunt	Nematode Res.	MjR, MiR	Purple, Kearney'13 Mi and Mj =0 or 1
Y8519	Trksh × 7262			3		x	Intermediate	Specialty		Yellow Imperator
Y9244	(2566 × Trksh) × 5280			4			Blunt	CP		Yellow

1=Worst, 5 = Best; CP = Cut and Peel type; BR= Brasilia; MjR = *M. javanica* resistance, MiR = *M.incognita* resistance; S.C.= South Coast; E.C.= El Centro

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

Table 2. USDA Carrot Trial Results, DREC 2015

USDA California Carrot Trials 2015

Entry	Pedigree or Name	Source	Number of Judges Placing in Class 1	2	3	4	5	Mean[1]	Rank	Flavor[2] H	S
Cello Trial											
C501	Dominion	Seminis		1	13	1		3.00		4	4
C502	Choctaw	Nunhems		1	1.5	10	3.5	4.00		4	4
C503	FCR-13212	Sakata	1	3	15.5	3	1.5	3.04	21	4	4
C504	(6366 x 5238) x 1175 ☆	310-4		18	4	2		2.33	52	4	4
C505	SV2214DL	Seminis		2	12	10		3.33	8	4	4
C506	(8542 x 8524) x 4002 ☆☆☆	117-3	2	12.5	8	1.5		2.38	49	4	4
C507	BX 3005	Bejo		2.5	10.5	9	2	3.44	5	4	4
C508	(6253 x 2144) x 2306 ☆	248-5	3	9.5	9.5	2		2.44	44	4	4
C509	NUN 85021	Nunhems	1	5	10	6	2	3.13	14	4	4
C510	S.C. x 9297B ☆	B111-4		1	15.5	7.5		3.27	11	4	4
C511	(5280 x 6366) x 7254	752-3		1.5	5.5	9.5	7.5	3.96	1	4	4
C512	VH198	Vilmorin		6.5	12.5	5		2.94	27	3.5	4
C513	KXPC-404	Integra		7.5	9	7	0.5	3.02	24	4	4
C514	(8531 x 3999) x 2289 ☆☆	316-5	2	8	7	6	1	2.83	33	4	4
C515	BX 1144	Bejo	2	14.5	6	1.5		2.29	55	4	4
C516	(6038 x 2327) x 1131	309-3	1	11	10	1.5	0.5	2.56	40	4	4
C517	2327 x 2289	B122-3	3	10	9.5	1.5		2.40	47	3.5	4
C518	(8495 x 9324) x 2289 ☆☆	316-4	2	6	9	7		2.88	30	4	4
C519	Maverick	Nunhems		5.5	8.5	8	2	3.27	12	4	4
C520	(7254 x 9788) x 3999	058-5	2	6	10	6		2.83	34	4	4
C521	2327 x 2303	B123-3	7.5	13.5	2.5	0.5		1.83	63	4	4
C522	(8531 x 3999) x 6526 ☆☆☆	086-5	1	1.5	17.5	3.5	0.5	3.04	22	4	4
C523	VH231	Vilmorin	1	3.5	12	7.5		3.08	16	4	4
C524	(3035 x 3999) x 2327 ☆	259-3		5.5	11.5	7		3.06	18	4	4
C525	FCR-14361	Sakata	1	2	6.5	14.5		3.44	6	3.5	4
C526	FCR-12069	Sakata		5	12	7		3.08	17	4	4
C527	(7553 x 2327) x 9297	474-2	3	11.5	7.5	2		2.35	51	4	4
C528	KXPC-405	Integra		10	11	2	1	2.75	36	4	4
C529	(8233 x 7553) x 9297 ☆	474-3	2	11	8	2	1	2.54	41	4	4
C530	(7550 x 7808) x 9297 ☆	474-4	1	3	13.5	6.5		3.06	19	4	4
C531	Trooper	Nunhems		3	14.5	5.5	1	3.19	13	3.5	4
C532	(7808 x 9304) x 9297 ☆	474-5		5.5	15.5	3		2.90	29	4	4.5
C533	KXPC-020	Integra	2	12.5	8	1.5		2.38	50	4	4
C534	(7550 x 1111) x 2735	426-5	8	7.5	6.5	1	1	2.15	57	4	4
C535	Bull Dog	Nunhems	2	9	9	3	1	2.67	38	4	4
C536	(7550 x 7808) x 3271 ☆	428-2	2	14.5	5.5	2		2.31	53	4	4
C537	T1A x 9297 ☆	B111-3	5	8	9.5	1.5		2.31	54	4	4
C538	FCR-13215	Sakata		7	11	6		2.96	25	4	4
C539	S.C. x 1175 ☆	B120-3	5	15.5	1.5	2		2.02	62	4	4
C540	(7550 x 7808) x 3999 ☆	430-2	1	9.5	7.5	4	2	2.85	32	4.5	4
C541	VH182	Vilmorin	8	9	5	1.5	0.5	2.06	61	4	4
C542	(7550 x 5238) x 4216 ☆	433-2	3	11	7.5	2.5		2.40	48	4	4
C543	Istanbul	Bejo	2	5.5	13.5	3		2.73	37	4	4
C544	(7808 x 9304) x 4228 ☆	436-2	5	12	6	1		2.13	60	4	4
C545	(7550 x 7808) x 3999 ☆	431-2	2	10.5	6.5	4	1	2.65	39	4	4
C546	SV4128DL	Seminis	1	2	6.5	13.5	1	3.48	3	4	4
C547	KXPC-403	Integra	1	2.5	11.5	6.5	2.5	3.29	10	4	4
C548	(7550 x 5238) x 3271 ☆	428-3		8	10	6		2.92	28	3.5	3
C549	Rebel	Nunhems	1	0.5	8	10.5	4	3.67	2	4	4
C550	(8524 x 3999) x 3271 ☆☆☆	428-4	1	13.5	6.5	3		2.48	43	4	4
C551	CR2289	Seminis		8	9	7		2.96	26	4	4

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USDA California Carrot Trials 2015

Entry	Pedigree or Name	Source	Number of Judges Placing in Class 1	2	3	4	5	Mean[1]	Rank	Flavor[2] H	S
Cello Trial — Continued											
C552	(7808 x 9304) x 2306 ☆	421-5	2	12	7.5	2.5		2.44	45	4	4
C553	BX 1133	Bejo	3	7	6	7.5	0.5	2.81	35	3	4
C554	(7550 x 1111) x 9786	476-2	6	12.5	2.5	2	1	2.15	58	2.5	4
C555	VH180	Vilmorin	2	10.5	10.5	1		2.44	46	4	4
C556	FCR-12080	Sakata	4	6.5	10	3.5		2.54	42	3.5	3.5
C557	Choctaw	Nunhems		6	9	9		3.13	15	4	4
C558	(7550 x 2327) x 9786	476-3	6	10.5	4.5	1.5	0.5	2.13	59	4	4
C559	SCR-8457 Nantes	Sakata		2	11	9		3.32	9	4	4
C560	FCR-14406 Nantes	Sakata	3	12	5.5	1.5		2.25	56	4	4
C561	FCR-14395 Nantes	Sakata	2	3	10.5	5.5	1	3.02	23	4	4
C562	FCR-14376 Nantes	Sakata		4	8.5	7.5	2	3.34	7	4	4
C563	SCR-8431 Nantes	Sakata		0.5	12	8	1.5	3.48	4	4	4
C564	FCR-14384 Nantes	Sakata		7	11	4		2.86	31	4	4
C565	FCR-14413 Nantes	Sakata	1	4.5	8	5.5	1	3.05	20	4	4

[1] Mean based on average of 24 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

USDA California Carrot Trials 2015

Entry	Pedigree or Name	Source	Number of Judges Placing in Class 1	2	3	4	5	Mean[1]	Rank	Flavor[2] H	S
Baby Cut & Peel Trial											
B501	Propeel	Seminis		1	8	8		3.41		3.5	4
B502	UpperCut	Nunhems		1.5	6.5	8	2	3.58		4	4
B503	(7551 x 1131) x 9788	477-2		2.5	9	11.5	2	3.52	4	4	4
B504	VH210	Vilmorin		2.5	15	7.5		3.20	14	4	4
B505	9253 x 9788[2]	477-5		3	7	11.5	3.5	3.62	3	3.5	4
B506	KXPC-520	Integra		1	7.5	10.5	6	3.86	1	4	4
B507	(7550 x 2327) x 9786	476-4	1	7	12.5	3.5	1	2.86	31	3.5	4
B508	(9253 x 7551) x 6191	491-4	1	4	12.5	6.5	1	3.10	17	4	4
B509	(7254 x 7551) x 6191	491-5	2	9	12.5	1.5		2.54	55	4	4
B510	VH180	Vilmorin		4	9.5	8.5	3	3.42	7	4	4
B511	(7550 x 2327) x 9786	476-5	1	2	11.5	9.5	1	3.30	11	4	3.5
B512	(9253 x 7551) x 2576	425-3		7.5	14	3.5		2.84	33	4	4
B513	KXPC-107	Integra	1	7.5	11.5	4	1	2.86	32	4	4.5
B514	(9253 x 7551) x 2576	425-4		1	14.5	9.5		3.34	8	4	4
B515	Propeel	Seminis		1	8	14.5	1.5	3.66	2	4	4
B516	(9253 x 9788) x 2576	425-5	3	10	9	3		2.48	57	3	4
B517	(S.C. x 9788) x 2306 ☆	421-3	11	8	3.5	0.5	2	1.98	86	4	4
B518	CandySnax	Nunhems	1	4	6.5	13	0.5	3.32	9	4	4
B519	(9253 x 7551) x 1401	412-5	10	10	5			1.80	95	4	4
B520	VH238	Vilmorin	4	9.5	9	1.5	1	2.44	62	4	4
B521	(9253 x 7551) x 0569	405-5	2	9.5	9.5	4		2.62	49	3	3.5
B522	FCR-13164	Sakata	3	10	9	3		2.48	58	4	4
B523	(S.C. x 9788) x 6191	491-2		7.5	12.5	5		2.90	29	3	4.5
B524	(9253 x 7551) x 6191	491-3	1	7	11	5	1	2.92	27	4	4
B525	(6253 x 2144) x 1386	109-5	3	13.5	6.5	2		2.30	71	4	4
B526	(6253 x 6333) x 2574	156-4	3	11	9	2		2.40	64	4	3.5
B527	(9253 x 7551) x 2576	158-4	4	14	7			2.12	83	4	4
B528	(9253 x 9788) x 2575	157-5	6	15	4			1.92	91	4	4
B529	(6253 x 6333) x 2577	159-3	6	11.5	7	0.5		2.08	84	4	4
B530	HoneySnax	Nunhems	3	10	10	2		2.44	63	4	3.5
B531	(9253 x 9788) x 2574	156-6	1	9	12.5	1.5	1	2.70	42	4	4
B532	(2144 x 6253) x 2575	157-3	1	9	10.5	4.5		2.74	39	4	4
B533	(S.C. x 9788) x 6190	490-2	7	12.5	4.5	1		1.98	87	4	4
B534	(S.C. x 9788) x 4622	363-3		4.5	11.5	9		3.18	15	4	4
B535	KXPC-577	Integra	1	3	6.5	11.5	3	3.50	5	4	4
B536	(7553 x 2327) x 4623	362-4	2	9	10	3	1	2.68	45	4	3.5
B537	(9253 x 7551) x 6190	490-3	5	10.5	8	1.5		2.24	77	3	3.5
B538	SV2765DC	Seminis	2	5.5	9.5	8		2.94	25	4.5	4
B539	(9253 x 7551) x 6190	490-4	1	6	15.5	2.5		2.78	36	4	4
B540	FCR-12042	Sakata	3	6.5	10.5	5		2.70	43	4	4.5
B541	(7254 x 7551) x 6190	490-5	2	12.5	7	3.5		2.48	59	3.5	4
B542	KXPC-306	Integra	3	13.5	7.5	1		2.26	76	4	4
B543	(7551 x 1131) x 9785	475-3	2	6	12	5		2.80	35	4	4
B544	VH182	Vilmorin	1	5	11.5	7.5		3.02	22	3	4
B545	(S.C. x 9788) x 9785	475-4	1	1.5	8.5	12.5	1.5	3.48	6	4	4
B546	(9253 x 7551) x 9785	475-5		2.5	15	5.5	2	3.28	12	4	4
B547	NUN 85931	Nunhems	2	5.5	8	7	2.5	3.10	18	4	4.5
B548	(7551 x 1131) x 4168	432-2	4	6	12.5	2.5		2.54	56	4	4
B549	FCR-13169	Sakata	1	6	10.5	7.5		2.98	23	3.5	4
B550	(S.C. x 9788) x 4168	432-4	10	5	5	5		2.20	80	4	4
B551	(9253 x 7551) x 4168	432-5	7	16	2			1.80	96	4	4

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USDA California Carrot Trials 2015

Entry	Pedigree or Name	Source	Number of Judges Placing in Class 1	2	3	4	5	Mean[1]	Rank	Flavor[2] H	S
Baby Cut & Peel Trial — Continued											
B552	S.C. x 3724	B124-3	5	9.5	8	2.5		2.32	69	4	4
B553	(9256 x 7551) x 2304	247-4	7	12	6			1.96	89	4	4
B554	(8233 x 7553) x 3724	287-2	2	4.5	13	4.5	1	2.92	28	4	4
B555	FCR-11740	Sakata	6	8	10	1		2.24	78	4	4
B556	(9253 x 9788) x 2304	247-5		8.5	15	1.5		2.72	40	4	4
B557	VH133	Vilmorin		9	10	5.5	0.5	2.90	30	4	4
B558	(9253 x 9788) x 3725	289-2	8	10	6.5	0.5		1.98	88	4	4
B559	S.C. x 2301	245-2	6.5	9	7	2.5		2.22	79	4	4
B560	(S.C. x 9788) x 4623	362-2	3	7	12	3		2.60	50	4	4
B561	(5280 x 6366) x 1405	047-4	3	7.5	11	3.5		2.60	51	4	4
B562	VH214	Vilmorin	2	10.5	8.5	4		2.58	53	4	4
B563	(9253 x 9788) x 2301	245-5	5	10.5	6.5	3		2.30	72	4	4
B564	(9256 x 7551) x 2301	245-4		6	8	8	3	3.32	10	4	4
B565	UpperCut	Nunhems	2	9	8.5	5	0.5	2.72	41	4	4
B566	(S.C. x 9788) x 9253	356-4	3	11.5	9	1.5		2.36	68	4	4
B567	(9253 x 7551) x 2304	247-3	1	7	14	3		2.76	37	4	4
B568	KXPC-060	Integra	1	8	8.5	6	1.5	2.96	24	4	4
B569	(9253 x 9788) x 9785	286-7		5	13	6.5	0.5	3.10	19	4	4
B570	FCR-14350	Sakata	4	7	8	3	3	2.76	38	4	4
B571	(7553 x 2327) x 4623	362-3		5.5	9.5	8.5	1.5	3.24	13	4	4
B572	KXPC-222	Integra	3	6	12	4		2.68	46	4	4
B573	(S.C. x 9788) x 4622	363-5	2	8	13.5	1.5		2.58	54	3	3.5
B574	CR1640	Seminis	3.5	10.5	11			2.30	73	4	4
B575	(S.C. x 2327) x 9785	287-3	1	7	12	5		2.84	34	4	4
B576	KXPC-506	Integra	2	8.5	10	4	0.5	2.70	44	4	4
B577	(9256 x 7551) x 9785	286-5	4	10.5	9	1.5		2.32	70	4	4
B578	SlenderCut	Nunhems	3	3	8	10	1	3.12	16	4	4
B579	(9253 x 7551) x 2301	245-3	3	14.5	7	0.5		2.20	81	4	4
B580	(9253 x 7551) x 1391	110-3	10	10.5	3.5	1		1.82	94	4	4
B581	(2144 x 7553) x 1403	045-6	9.5	8.5	7			1.90	92	4	4
B582	(2144 x 2126) x 1397	039-2	4	10	11			2.28	74	4	4
B583	VH116	Vilmorin	5	8.5	8.5	2.5	0.5	2.40	65	4	4
B584	(6253 x 2144) x 1398	040-2	2	16	5	2		2.28	75	4	4
B585	CR1706	Seminis	1	6	10	7	1	3.04	21	4	4.5
B586	(6333 x 6366) x Lng	033-3	6	14	5			1.96	90	4	4
B587	CrispyCut	Nunhems	1	7	7.5	8.5	1	3.06	20	4	4
B588	(6333 x 6366) x 1397	039-4	2	11.5	9.5	2		2.46	61	4	4.5
B589	FCR-13181	Sakata	2	4	13	5.5	0.5	2.94	26	4.5	4
B590	(9256 x 7551) x 1405	047-6	2	8.5	11	3.5		2.64	48	4	4
B591	(9253 x 7551) x 1397	039-5	3	15	7			2.16	82	3.5	4
B592	(6253 x 2144) x 1397	039-3	5	8.5	8.5	3		2.38	66	4	4
B593	PS1441	Seminis	2	11.5	9	2.5		2.48	60	4	4
B594	S.C. x 9788[2]	477-3	2	9.5	10	3.5		2.60	52	4	4
B595	VH195	Vilmorin	3	4	16.5	1.5		2.66	47	4	4
B596	(9256 x 7551) x 9788	477-4	15	7.5	2	0.5		1.52	97	4	4
B597	KXPC-576	Integra	6	13.5	5	0.5		2.00	85	4	4
B598	(9253 x 9788) x 2577	159-5	9	11	4.5	0.5		1.86	93	4	4
B599	(6253 x 2144) x 9793	361-2	5	7.5	9	2.5		2.38	67	4	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

Each ☆ indicates that one parent is a nematode resistant line

USDA California Carrot Trials 2015

Entry	Pedigree or Name	Source	Number of Judges Placing in Class 1	2	3	4	5	Mean[1]	Rank	Flavor[2] H	S	Color
Novelty Trial												
T501	(7262 x 6308) x 6245	062-4	4	10	6	2	1	2.39	27	4	4	Purple
T502	NUN 89682	Nunhems		1	6	8.5	7.5	3.98	1	4	4	Purple
T503	1129 x 8438[2]	134-6	2	10	5	4.5	1.5	2.72	22	4	4.5	Purple
T504	(7262 x 6245) x 8197	067-5	4	13.5	3	2.5		2.17	37	3.5	4	Purple
T505	(7262 x 6360) x 6139	060-2	1	2	11	8	1	3.26	6	4	3	Purple
T506	8502 x 8438	277-3	8	8	4	2	1	2.13	38	3	4	Purple
T507	PurpleElite	Nunhems	1	5	5	9.5	2.5	3.33	5	4	4	Purple
T508	(S.C. x 6259) x 8197	273-4	2	6	7.5	7	0.5	2.91	14	2.5	4	Purple
T509	(6139 x 6245) x 6245	125-5		9.5	9	4.5		2.78	21	4	4	Purple
T510	Deep Purple	Bejo		7.5	6	9.5		3.09	8	3	4	Purple
T511	(7262 x Trksh) x 9304	656-1		6.5	13	3.5		2.87	18	3	4	Purple
T512	(S.C. x 6360) x 6307	065-3	3	13	3	2.5	1.5	2.41	26	3.5	4	Purple
T513	Purple Haze	Bejo	3	11	7	2		2.35	31	4	4	Purple
T514	(S.C. x 0148) x 8197	273-5	1	6.5	8.5	5.5	1.5	3.00	11	3.5	4	Purple
T515	Purple Sun	Bejo		5	9.5	6.5	2	3.24	7	4	4	Purple
T516	(1129 x 8522) x 8438	470-5	6	11	1	4	1	2.26	34	4	4.5	Purple
T517	(S.C. x 0148) x 8201	275-4	3	8.5	7	4.5		2.57	25	4	4	Red
T518	(S.C. x 6259) x 8201	131-2	2	8	7	4	2	2.83	19	4.5	4	Red
T519	Red S.C. x (0148 x 6220)	252-4	3	5.5	8.5	5	1	2.80	20	4	4	Red
T520	Red S.C. x (0148 x 6220)	252-2	3.5	6.5	8	3	2	2.72	23	3	4	Red
T521	(S.C. x 6220) x 8201	275-2	2	4	10.5	5	1.5	3.00	12	3	4	Red
T522	(S.C. x 6637) x 8197	067-3	1	4.5	11.5	5	1	3.02	10	4	4	Red
T523	(8197 x PI) x 8201[2]	131-3	4	10.5	7	1.5		2.26	35	4	4	Red
T524	(8197 x PI) x 8201	089-2	6.5	7	5.5	4		2.30	32	3	4	Red
T525	6253 x 8438	277-2	7	5	7.5	2.5	1	2.37	30	3.5	4	Red
T526	(S.C. x 6259) x 8201	275-3		8	9.5	5.5		2.89	16	4	4	Red
T527	8201 x 0148	101-4	2	3	12.5	4	1.5	3.00	13	4	4	Red
T528	(5280 x 6366) x Red	412-5	1	8.5	6.5	6	1	2.89	17	4	4	Red
T529	(2566 x 6253) x dY	310-2		2	7	11	3	3.65	2	4	4	Yellow
T530	(7254x8519) x (JODxW.Belgian)	032-2	4	11.5	4.5	2		2.20	36	4	4	Yellow
T531	JOD x W. Belgian	916-1	1	9.5	10.5	1	1	2.63	24	4	4	Yellow
T532	YellowBunch	Nunhems		5.5	12	4.5	1	3.04	9	4	4	Yellow
T533	CreamPak	Nunhems		1.5	9	11	1.5	3.54	3	4	4.5	Cream
T534	Mello Yello	Bejo		8.5	9	4.5	1	2.91	15	3.5	4	Yellow
T535	Yellowstone	Bejo	5	9.5	6	2	0.5	2.28	33	4	3.5	Yellow
T536	Rainbow	Bejo	9	6.5	6.5			1.89	40	3.5	4	Mix
T537	(dY x Z021) x 3271	428-5	10	4.5	7	1.5		2.00	39	4	4	Mix
T538	White Satin	Bejo	6	7.5	4	5.5		2.39	28	2.5	3.5	White
T539	(7808 x 9304) x 2383	423-2	5	8.5	6	2.5	1	2.39	29	3.5	4	White
T540	SnowMan	Nunhems		4.5	7.5	6	4	3.43	4	4	4	White

[1] Mean based on average of 23 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. USDA,ARS – UC Riverside jointly developed and released nematode resistant carrot germplasm derived from three diverse unrelated genetic backgrounds

Inbred	Source of Resistance	Generation	Remarks
Nb3999	'Br 1252'	F_3M	11-13 cm, orange, blunt
Nb4001	'Br 1252'	F_3M	14-16 cm, orange, blunt
Nb4002	'Br 1252'	F_3M	16-19 cm, orange, blunt
Nb6526	'Br 1252'	F_4	19-22 cm, orange, blunt
Nb8503	'Br 1252'	F_3M	11-12 cm, orange, blunt
Nh2168	'Homs'	F_7	14-17 cm, purple yellow/orange, blunt
Ns5154	'Scarlet Fancy' x 'Favourite'	F_6M	11-14 cm, orange, blunt

Research leading to the development of this germplasm was supported by CFCAB, USDA-SCRI, and USDA-OREI.

Table 4. Chromosomal location and contribution to resistance of carrot genes conferring *M. incognita* resistance from three genetic backgrounds

Background	Chromosome	Position (cM)	Contribution to Variation in Resistance (%)
'Brasilia'	1	67	6
'Brasilia'	8	42	14
'Homs'	1	35	4
'Homs'	2	43	8
'Homs'	2	63	34
'Homs'	8 (~*Mj-1*)	42	16
'Homs'	9 (2 genes?)	4	4
		10	18
'Scarlet Fancy' x 'Favourite'	4	33	13
'Scarlet Fancy' x 'Favourite'	8 (~*Mj-1*)	42	9

From Parsons et al., Molec. Br., 2015

Table 5. Progress in combining nematode resistance sources

	MJ	1091	WR	HM	PD	SFF	NF
MJ	--	*** 0-5	*** 1.5-3	*** 4-5.5	*** 0-5	** 3-6	*** 0-3
1091		--		*** 1-3	** 2-4	*** 0-2	* 1-4
WR			--	*** 1-2	*** 3.5-4	* 2-3	* 1-3
HM				--	*** 0-2	*** 0-2	** 1
PD					--		* 2-3
SFF						--	*** 0-1
NF							--
Susc. Long	*** 0-1	*** 0.5-2	*** 2-3	*** 0-1	*** 0-2	*** 0-1	
Susc. Flavor	*** 0-1	*** 0-2	* 2-3	*** 0-1	*** 0-1	*** 0-1	** 2-3
Susc. Other	*** 0-1			*** 0-1		*** 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 F_1, F_2, and F_3 or higher, respectively for *, **, and ***. Values below asterisks denote average MiR scores among several F_2 populations for a given cross among resistance sources (upper portion of the table), and best MiR scores among one or more F_1 hybrids with susceptible parents (lower portion of the table). Data is from South Coast and Kearney field trials.