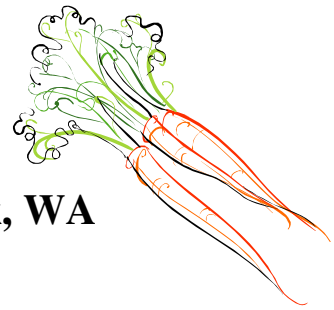

34th International Carrot Conference
26-28 July 2010, Red Lion Hotel, Kennewick, WA

Oral Presentation and Poster Session

Monday, 26th July 2010

11:00 am - 1:00 pm **Registration desk open**

1:00-1:15 pm **General announcements.** Lindsey du Toit, Vegetable Seed Pathologist and Co-chair of Organizing Committee, Washington State University, Mount Vernon, WA, USA.

Welcome. Randy Baldree, College of Agricultural, Human, & Natural Resource Sciences, Washington State University, Pullman, WA, USA.

1:15-4:00 pm **Opening Session: Carrot Production in the Pacific Northwest USA**

1:15-1:45 **Carrot breeding.** Roger Freeman, Nunhems, Brooks, OR, USA.

1:45-2:15 **Hybrid carrot seed production in central Oregon.** Mike Weber, Managing Partner, Central Oregon Seeds, Inc., Madras, OR, USA

2:15-2:45 **Nutrient use and requirements of carrots grown for seed.** John Hart, Soil Scientist, Department of Crop and Soil Science, Oregon State University, Corvallis, OR, USA.

2:45-3:00 pm **Break with refreshments**

3:00-3:30 **Carrot root crop production in the Pacific Northwest USA.** Jim Klaustermeyer, Klaustermeyer Farms, Basin City, WA, USA.

3:30-4:00 **40 years of organic carrot production in the Pacific Northwest.** Nash Huber, Nash's Organic Produce, Sequim, WA, USA.

4:00-5:00 pm **Carrot Pests and Diseases**

4:00-4:20 **An experimental approach in controlled conditions for understanding biofumigation effects at the succession scale on *Rhizoctonia solani* expression on carrots.** Françoise Montfort, François Collin, Emile LeMarchand, Stéphanie Morliere, Sylvain Poggi, Institut National de la Recherche (INRA), France.

4:20-4:40 **Evaluation of systemic induced resistance for suppression of *Xanthomonas hortorum* pv. *carotae* in carrot seed crops.** Bo-Ming Wu, Oregon State University, Madras, OR, USA.

4::40-5:00 **Influence of fungicides and cultivar on development of cavity spot of carrot.** Mary Ruth McDonald, Kevin Vander Kooi, Michael Tesfaendrias and Catarina Saude, University of Guelph, Ontario, Canada.

6:00-8:30 pm **Banquet at the Red Lion Hotel**

History of the Columbia Basin Irrigation Project. Guest speaker, Mick Qualls, Qualls Ag Laboratory, Ephrata, WA, USA.

Tuesday, 27th July

8:00-8:40 am **Carrot Pests and Diseases (Continued)**

8:00-8:20 **Can insecticide seed treatments protect carrots from damage by carrot weevil and carrot rust fly?** Mary Ruth McDonald and Kevin Vander Kooi, University of Guelph, Ontario, Canada

8:20-8:40 **Evaluation of biological and botanical nematicides for the control of root-knot nematodes of carrots.** Joe Nunez, University of California Kerney Co. Extension, Bakersfield, CA, USA.

8:40-9:40 am **Carrot Production and Marketing**

8:40-9:00 **Carrot production in southern Africa.** Vincent Sequeira, Greenway Farms, Tarlton, South Africa.

9:00-9:20 **Residual phosphorous influence on carrot productivity in African humid tropics.** Ojo Olubiyi David, HiHort, Ibadan, Nigeria.

9:20-9:40 **The sensory quality of carrots: Effects of some cultural factors.** François Villeneuve, Centre Technique Interprofessionnel des Fruits et Légumes, France.

9:40-10:00 am **Break with refreshments**

10:00-11:00 am **Carrot Breeding and Genetics**

10:00-10:20 **Carotenoid gene nucleotide diversity reflects carrot history and selection.** J. Clotault, E. Geoffriau, C. Dubois-Laurent, S. Huet, V. Soufflet-Freslon, M. Briard, and D. Peltier. INHP and Université Angers, UMR GenHort, Angers, France.

10:20-10:40 **Is quantitative resistance qualitative? An example with two Alternaria leaf blight resistant carrot genotypes and four resistance assessment techniques.** Romain Berruyer, University of Angers, France.

10:40-11:00 **The search for new *Meloidogyne incognita* nematode resistance.** Joshua D. Parsons[1], William C. Matthews[2], Philip A. Roberts[2], Philipp W. Simon[1,3]. [1]University of Wisconsin-Madison, Madison, WI, USA; [2]University of California, Riverside, CA; [3]USDA-ARS, Madison, WI, USA.

11:00 am-Noon **View Carrot Posters with Authors**

Poster 1. Antioxidant content of carrots with different pigments grown in Ontario, Canada. Chanli Hu, Rong Cao, and Mary Ruth McDonald, University of Guelph, Ontario, Canada.

Poster 2. Efficacy of Scholar (fludioxonil) for control of Sclerotinia rot of carrot in cold storage. Mary Ruth McDonald and Kevin Vander Kooi, University of Guelph, Ontario, Canada.

Poster 3. Regional ascospore detection correlates to disease incidence providing accurate timing for disease management of Sclerotinia rot of carrot. M. Parker, Mary Ruth McDonald and G.J. Boland, University of Guelph, Guelph, Ontario, Canada.

Poster 4. Diversity of volatile and non-volatile compounds in a gene bank collection of cultivated carrot. Thomas Nothnagel, Institute for Breeding Research on Horticultural and Fruit Crops, Quedlinburg, Germany.

Poster 5. Heterosis for quality traits in ems based hybrids of tropical carrot (*Daucus carota* L.). Nouri Kushlaf, Indian Agricultural Research Institute, New Delhi, India.

12:00-1:30 pm **Lunch provided at the Red Lion Hotel**

1:30-3:10 pm Carrot Breeding and Genetics (Continued)

1:30-1:50 **Development and analysis of SSR and SNP markers for a carrot mapping population.** Pimchanok Satapoomin[1] and P.W. Simon[2]; [1]University of Wisconsin, Madison, WI, USA; [2]USDA-ARS, Madison, WI, USA.

1:50-2:10 **Genetic analysis of prominent lateral root formation in carrot.** Syed Salim Shah[1] and Philipp W. Simon[2]; [1]University of Wisconsin, Madison, WI, USA; [2]USDA-ARS, Madison, WI, USA.

2:10-2:30 **Analysis of phytoene desaturase (PDS) during the development of root and leaf tissue of the *Rp* mutant in carrot (*Daucus carota*).** Megan J. Bowman[1], Anne E. Atkins[1], Irwin L. Goldman[1], and Philipp W. Simon[2]; [1]University of Wisconsin, Madison, WI, USA; [2]USDA-ARS, Madison, WI, USA.

2:30-2:50 **Progress in the deployment of nutrient-rich nematode resistant carrots to benefit growers, consumers, and the environment.** Philipp W. Simon[1] and Philip A. Roberts[2]; [1]USDA-ARS, Madison, WI, USA; [2]University of California, Riverside, CA, USA.

2:50-3:10 **Isolation of cold responsive genes in carrot by suppression subtractive hybridization.** Rajeev Kumar Sarma, Anandhan Sivalingam, Mani Chandra Harish, Dhivya Selvaraj, Varghese Philipose Inchakalody, Zakwan Ahmed, and Ramalingam Sathishkumar, Bharathiar University, Coimbatore, India.

3:10-3:30 pm **Break with refreshments**

3:30-4:30 pm Carrot Breeding and Genetics (Continued)

3:30-3:50 **Evaluation of vernalization requirement in different carrot populations.** María S. Alessandro[1], Claudio R. Galmarini[2], and Philipp W. Simon[3]; [1]Instituto Nacional de Tecnologia Agropecuaria, La Consulta, Mendoza, Argentina; [2]UNCuyo y CONICET, Argentina; [3]USDA-ARS, Madison, WI, USA.

3:50-4:10 **Unlocking the potential of genebank carrot collections: creating a carrot diversity set as a research and pre-breeding resource.** Charlotte Allender, Ann Baker and Dave Pink, University of Warwick, Warwick, UK.

4:10-4:30 **Carrot chromosomes and linkage groups.** Marina Iovene[1], Pablo F. Cavagnaro[2], Philipp W. Simon[3]; [1]University of Wisconsin, Madison, WI, USA; [2]CONICET and INTA-EEA La Consulta, Mendoza, Argentina; [3]USDA-ARS, Madison, WI, USA.

4:30-4:45 pm: **Wrap-up & Planning for Next International Carrot Conference**

4:45-5:30 pm: Discussion Groups

Carrot breeding
Carrot diseases and pests
Carrot production
Carrot marketing
Others

6:00 pm: **Dinner 'on your own'**

Wednesday, 28th July

8:00-4:00 pm Field Tour

Buses depart from the Red Lion Hotel promptly at 8:00 am and return by approximately 4 pm. The tour through the southern Columbia Basin of Washington State, a semi-arid region of extensive, high-value, irrigated agriculture, will include stops at **processing carrot crops, carrot seed crops, and the Washington State University carrot cultivar demonstration**. Lunch will be provided.

ABSTRACTS: ORAL PRESENTATIONS

Opening Session: Carrot Production in the Pacific Northwest USA

Carrot Breeding

Roger Freeman

Nunhems, Brooks, OR, USA

Hybrid Carrot Seed Production in Central Oregon

Mike Weber

Managing Partner, Central Oregon Seeds, Inc., Madras, OR, USA

Nutrient Use and Requirements of Carrots Grown for Seed

John Hart

Department of Crop and Soil Science, Oregon State University, Corvallis, OR, USA

Plant nutrition is balancing nutrient supply with plant demand. To satisfy plant demand, supplementation of soil nutrient supply is necessary for carrot root and seed production. The primary nutrient applied for both root and seed production is nitrogen with relatively routine phosphorus and potassium application for root production. At harvest, the aboveground biomass for an Oregon seed carrot crop contains between 200 to 250 kg N/ha with 20 kg/ha of this amount in the seed. French production of Nantes-type carrots for seed are reported to contain less N in aboveground biomass, 170 kg/ha. In contrast, a carrot root yield of 60 to 80 Mg/ha contains 225 to 350 kg N/ha. Even though the N concentration is similar in roots and tops, 1.5 to 2 mg/kg, the N content in roots is about three times greater compared to tops due to much greater root mass. Potassium content of seed carrot crops is approximately the same as the N content. The K content of root carrot crops can be as much as double the N content. P content of both types of carrot crops is about 10% of the N content. Seed carrots in Oregon accumulate N rapidly during May and June. All N is in the plant by early August or 5 to 6 weeks before harvest. The peak N uptake rate of 2.5 to 3.5 kg/ha occurs in late June. Time of N application recommended in France and Oregon are similar with the first application as the crop begins to grow in the spring. Additional N should be added before flowering. Maximum P uptake occurs about the same time as N. Potassium uptake slightly precedes N accumulation. In spite of accumulating more than 200 kg N/ha in a seed carrot crop, N rate for seed production is maximized at rates below 100 kg/ha. A primary factor is rotation. In central Oregon, carrot seed is commonly planted after bluegrass seed production. Cool season grass roots contain 75 to 100 kg N/ha that mineralizes as roots and crowns decompose. The longevity of a seed carrot crop allows efficient utilization of soil supplied N. Excess N is detrimental to carrot seed yield. Seed yield decreased almost 30% as N application rate increased from 55 to 100 kg N/ha in an Oregon trial with commercially grown Nantes type hybrid seed carrots. Additionally, seed size from the primary umbel also decreased with the same N rate increase. Soil N supply for carrot seed production is critical as little supplemental N is required in many rotations and excess N reduces seed yield. Application of 50 to 75 kg N/ha is usually adequate for carrot seed production in central Oregon.

Carrot Root Crop Production in the Pacific Northwest USA

Jim Klaustermeyer

Klaustermeyer Farms, Basin City, WA, USA

40 Years of Organic Carrot Production in the Pacific Northwest USA

Nash Huber

Nash's Organic Produce, Sequim, WA, USA

Nash Huber has been farming organic produce, grains, and seed in the Sequim-Dungeness Valley on the northeast corner of the Olympic Peninsula in Washington State since 1979. Currently, he and his team of young farmers cultivate 400 acres - 150 in grain and 150 in diverse vegetables, fruits, and berries - and raise a 100+ herd of hogs and 300-400 laying hens. They also raise more than half the farm's seed, including carrot seed. The farm sells 50% of its products wholesale and 50% direct at farmers markets. Direct marketing is increasing as more people become aware of the nutritional benefits and great taste of local food. Every year, 15% of the vegetable land is devoted to carrots, but carrots are responsible for about 40% of the farm's annual gross income. The excellent flavor and tenderness of Nash's carrots are due to the unique climate of the Valley - mild, moist winters and dry summers - and the alluvial soils that are enhanced by comprehensive, organic soil management practices, including cover crops, crop rotations, and extensive composting, through which the organic matter in the soils has increased to 4-5%. The mineral-rich irrigation water from the Dungeness River adds to the carrots' sweet flavor and delightful crunch and texture. Most years, Nash harvests his carrots from mid-July through March. They fill an important niche market in the Puget Sound region, for a great-tasting, organic carrot that is locally grown and available to customers at stores like PCC Natural Markets, as well as farmers markets in Sequim, Port Angeles, Port Townsend, Kingston, U-District, and Ballard.

Session: Carrot Pests and Diseases

An Experimental Approach in Controlled Conditions for Understanding Biofumigation Effects at the Succession Scale on *Rhizoctonia solani* Expression on Carrots

Françoise Montfort, François Collin, Emile LeMarchand, Stéphanie Morliere, and Sylvain Poggi
Institut National de la Recherche (INRA), UMR BiO3P, BP 35327,
F 35653 Le Rheu cedex, France

Soil-borne diseases are of major concern in field vegetables production, and their management is still strongly dependent on chemical soil fumigants. To build integrated crop strategies, the crop succession scale offers opportunities of inter-crops management between two commercial crops. Particularly, there is now an increasing interest in biofumigation, which consists in growing some *Brassicaceae* species, then crushing them at flowering stage and incorporating them into soil. First, an *in vitro* experiment is conducted to compare the toxicity of volatile compounds contained in crushed above-ground parts of two *Brassica juncea* lines, highly different in their glucosinolates profiles, on various soil-borne fungi: two pathogenic species (*Pythium sulcatum* and *Rhizoctonia solani)*, and one antagonistic species (*Trichoderma atroviride)*. Besides, a one-year succession 'inter-crop period – carrot crop –inter-crop period – carrot crop' is carried out in large containers, with biofumigation by these 2 lines of mustard conducted during inter-crop period and compared to bare soil. Effects induced on *R. solani* AG2-2 by biofumigation, in soil amended or not by *T atroviride,* are assessed by means of soil inoculum potential experiments, pathogen-ADN quantification and, finally, assessments of incidence and severity of disease on mature carrots. Differences in toxicity *in vitro* are attributed to the level of sinigrin of the studied lines; among the fungi species, *Trichoderma atroviride* is clearly shown to be less sensitive than the two pathogens. In greenhouse, even when mustard is attacked by *R. solani* (spring conditions), a significant decrease in soil inoculum potential is observed all through the succession, whatever the line of mustard. No significant effect of *T. atroviride* is demonstrated. A strong and highly significant reduction of incidence and severity of the disease on mature carrots is observed at the end of the experiment.

Evaluation of Systemic Induced Resistance for Suppression of *Xanthomonas hortorum* pv. *carotae* in Carrot Seed Crops

Bo-Ming Wu[1], Rhonda Simmons[1], Ken Johnson[2], and Lindsey du Toit[3]

[1]Oregon State University, Madras, OR, USA
[2]Oregon State University, Corvallis, OR, USA
[3]Washington State University Mount Vernon NWREC, Mount Vernon, WA, USA

Bacterial blight caused by *Xanthomonas hortorum* pv. *carotae* (*Xhc*) is the most important pest to the carrot seed industry in the Pacific Northwest USA. Copper-containing products such as ManKocide are applied regularly to carrot seed crops in the Pacific Northwest in an attempt to prevent contamination of seed by *Xhc*, but the effect of this treatment is typically poor to fair. Other alternative chemical strategies, including foliar applications of Actigard, also have shown limited efficacy. A recent report showed that a root drench with Actigard, an inducer of systemic acquired resistance (SAR), offered 4 months of good protection against bacterial canker of citrus, whereas a corresponding foliar treatment provided partial protection for only a week. A preliminary study we conducted demonstrated that a root drench with Actigard significantly reduced colonization of carrots leaves inoculated with *Xhc*. Since drip irrigation has become a widely adopted cultural management tool to suppress contamination of carrot seed by *Xhc* in the semi-arid production areas of central Oregon and central Washington, it provides an ideal method by which to introduce SAR inducers to carrot seed crops via the roots. Therefore, we are conducting greenhouse and field experiments to evaluate this approach as an alternative tactic for management of bacterial blight in carrot seed crops. Greenhouse and field trials are currently being conducted in central Oregon, the most important carrot seed production area in the U.S. Preliminary results will be presented during the meeting.

Influence of Fungicides and Cultivar on Development of Cavity Spot of Carrot

Mary Ruth McDonald[1], Kevin Vander Kooi[1], Michael Tesfaendrias[1], and Catarina Saude[2]

[1]Department of Plant Agriculture, University of Guelph, Muck Crops Research Station, Kettleby Ontario, L0G 1J0, Canada
[2]Department of Plant Agriculture, University of Guelph, Simcoe, Ontario, Canada

Cavity spot of carrot, caused by several species of Pythium, is an important soilborne disease of carrots in many parts of the world including Canada and the United States. Field trials were conducted in the Holland/Bradford Marsh region of Ontario from 2002 to 2009 to identify differences in susceptibility to cavity spot among carrots with different pigments. Trials were conducted in 2008 and 2009 to determine the efficacy of fungicide Ranman® 400SC (cyazofamid 34.5%) on cavity spot incidence and severity. Carrots were assessed 12 to 14 weeks after seeding and again 18 to 20 weeks after seeding to determine 'early' and 'late' symptom expression. Rainfall and temperature data were collected within 100 m of the plots. Some carrots with purple pigments, such as Purple Haze, had consistently lover levels of cavity spot. Cavity spot was lower on susceptible cultivars in years with low rainfall, and were high in 2008 and 2009 where high levels of rain occurred in June and July. An increase in cavity spot incidence and severity late in the season varied with cultivar and year. Application of Ranman 400SC within 3 days or 14 days after seeding suppressed cavity spot more effectively under moderate disease pressure than high disease pressure.

Can Insecticide Seed Treatments Protect Carrots from Damage by Carrot Weevil and Carrot Rust Fly?

Mary Ruth McDonald and Kevin Vander Kooi

Department of Plant Agriculture, University of Guelph, Muck Crops Research Station, Kettleby Ontario, L0G 1J0, Canada

Carrot rust fly (*Psila rosea* (Fabricius)) and carrot weevil (*Listronotus oregonensis*(LeConte)) are major insect pests of carrots grown on muck soils in eastern Canada. The carrot rust fly has two generations per year; adults emerge at 329 and 1399 day degress at base 3 C. Carrot weevils have one generation per year, they overwinter as adults and begin depositing eggs at 138 daydegrees at base 7 C. Both pests deposit eggs on the soil at the base of carrot plants and the larvae feed on the roots. Populations of both insects are monitored as part of the local integrated pest management program. Foliar insecticde sprays are registered for both pests, but control of carrot rust fly can be erractic. Insecticide seed treatments could be an efficient method of reducing the damage caused by the larvae. Insecticide seed treatments spinosad, thiamethoxam and clothianidin were evaluated in field trials in the Holland Marsh, Ontario, from 2007-2009. In 2007, spinosad (3.75 and 7.5 mg ai/100g seed) and clothianidin (5.6 and 7.5 mg a.i.) reduced carrot weevil damage. In 2008, thiamethoxam (2.5 and 3.75 mg a.i.), spinosad (7.5 mg a.i.) and clothianidin plus imidachloprid (3:1 at 11.25 mg a.i total) suppressed carrot rust fly damage. Rust fly damage was high in 2009 and there were no significant differences among treatments. Spinosad shows promise for suppression of both pests.

Evaluation of Biological and Botanical Nematicides for the Control of Root-Knot Nematodes of Carrots

Joe Nunez

University of California Kerney Co. Extension, Bakersfield, CA, USA

Nematodes are likely the number one pest of carrots grown in California, particularly root knot nematodes. Currently the preferred method of control of nematodes for carrots is with the use of pre-plant soil fumigants. New fumigant regulations have been put in place to restrict the emissions of volatile organic compounds (VOC) from the use of soil fumigants. These regulations include limits on the amount of soil fumigants a grower is allowed to use in a year, caps on the amounts allowed within a township, and new expanded buffer zones meaning large parts of a field may not be treated at all. These new regulations mean that there will be some fields not treated for nematodes because of caps placed on the amount a grower is allowed to use or caps on the amount of fumigants allowed in a township. Alternative methods of nematode control need to be studied in field situations to quickly identify other possible control strategies. Field trials were conducted in 2008 and 2009 to evaluate the effectiveness of commercially available biological and botanical products that claim efficacy for nematode control. Some of these products have shown some potential as a method of nematode control in low to moderate population levels but do not perform as consistently as the standard soil fumigants.

Session: Carrot Production and Marketing

Carrot Production in Southern Africa

Vincent Sequeira

Greenway Farms, Tarlton, South Africa

Residual Phosphorous Influence on Carrot Productivity in African Humid Tropics

Ojo Olubiyi David

HiHort, Ibadan, Nigeria

The Sensory Quality of Carrots: Effects of Some Cultural Factors

François Villeneuve[1], Cathy Echert[1], Valentine Cottet[3], Brigitte Navez[2], Christophe Aubert[2], Michel Jost[2], François Latour[1]

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In France, carrots are one of the main outdoor vegetable as regard to area (14 000 ha) and total marketable production (624 858 tons, fresh market and processing) (Scandella, 2010). The sensory qualities of carrots bring more and more importance for the different operators intervening in the commercialization of carrots and also for French consumers. Different parameters can influence them: the first one is the varieties (Simon *et al.,* 1981; Seljåsen, 2000; Cottet *et al.,* 2007); the second is the importance of the growing soil and storage (Simon *et al.,* 1982; Villeneuve *et al.,* 1994; Villeneuve, 1997); the other one can be the incidence of package type (Seljåsen *et al.* (2004). Thus the aim of the present investigation was to explore the relationship between the sensory quality and biochemical composition of carrots and different growing parameters For the incidence of duration of growing season, in 2008 we compared three duration of growing season for two nantaise type varieties (Maestro -Vilmorin- and Dordogne -Syngenta seeds-: 117 days (sown June 20th, harvest November 12th), 125 days and (July 10th; November 12th) 145 days (July 25th; November 12th). In 2009, the carrots (variety Maestro -Vilmorin-) are sown at the same time (week 27) in five different fields of the carrot area of Aquitaine; they were harvested at two times: 120 days after sowing (week 45) and 150 days (week 49). The sensory analysis was performed by a sensory panel trained specifically for carrot. Prior to each experiment the panel was calibrated according to international standards and the sensory terms (14 descriptors) established for carrot by Cottet *et al.* (2007) are used. Concurrently, the usual physicochemical parameters were measured. In 2008, the results revealed a significant difference between the batches sown at the first and last dates: the shorter duration gives a more rubbery carrot and the longer duration gives a more firm one. We also observe some differences between the two varieties: Dordogne is crunchy and Maestro is more piquant and harsh. Globally, carrots of shorter cycles are less differentiated: fewer firms during cutting, less crunchy, less juicy and more rubbery. For the chemical composition the shorter cycles present less sucrose and more fructose and glucose for the two varieties experimented. But, if we observe an evolution of the composition of terpenoids in the Maestro variety, they are no differences for the Dordogne variety. This variety seems not affected by the duration cycle for terpenoids. In 2009, we observe some difference between the duration of cycle (120 or 150 days) but also between fields. Our results indicate the importance of the cycle duration on the perception of sensory quality by trained panel. We also observe some physicochemical differences.

Session: Carrot Breeding and Genetics

Carotenoid Gene Nucleotide Diversity Reflects Carrot History and Selection

J. Clotault[1], Emmanuel Geoffriau[1], C. Dubois-Laurent[1], S. Huet[1], V. Soufflet-Freslon[1], M. Briard[1], and D. Peltier[2]

[1]Agrocampus Ouest – INHP, UMR GenHort, 2 rue Le Nôtre F-49045 Angers, France
[2]Université Angers, UMR GenHort, 2 Bd Lavoisier F-49045 Angers, France

Carotenoid content is an important quality attribute for carrot, with a high variation exhibited in this species and along the history of cultivated carrot. The purpose of our work was to study the nucleotide diversity of carotenoid biosynthesis genes. A sample of 48 genotypes, representing a wide carrot diversity, was studied for the sequence polymorphism of seven genes chosen for their position in the carotenoid pathway (*IPI*, *PDS*, *CRTISO*, *LCYB1*, *LCYE*, *CHXE* and *ZEP).* Compared to other species, a quite high single nucleotide (SNP) frequency was found for these genes (1/22 bp on average; 1/11 to 1/38 bp range). The haplotype diversity ranged from 0.523 to 0.851, with 9 to 15 haplotypes per gene. However, this high diversity was mainly due to silent or synonymous sites. The nucleotide diversity was shown to be structured by cultivar geographical origin, reflecting the species history, but also stressing out the consequence of this result when studying carotenoid genetics using association approaches. A second important factor was shown to be the gene position in the carotenoid pathway. When looking for signatures of selection, *CRTISO*, *LCB1* and *LCYE* genes, located in a central position in the pathway, displayed a pattern consistent with a diversifying selection. However, the impact of selection varies depending on the root color group. Upstream genes, such as *PDS*, displayed a negative selection pattern, and may have been subjected to high constraints due to their overall importance for the subsequent pathway. Besides better understanding the functioning of this important pathway, our results provide valuable information for the identification of critical genes for carotenoid genetic studies, and about carrot evolutionary genetics and root color history.

Is Quantitative Resistance Qualitative? An Example with Two Alternaria Leaf Blight Resistant Carrot Genotypes and Four Resistance Assessment Techniques

Cora Boedo, Mickaël LeComte, Stéphanie Bershihand, Sabrina Marques, Pascal Poupard, Mathilde Briard, Valérie le Clerc, Philippe Simoneau, and Romain Berruyer

INHP and University of Angers, UMR GenHort, Angers, France

Alternaria Leaf Blight (ALB), caused by the fungal plant pathogen *Alternaria dauci*, is one of the most important diseases of carrot. Development of cultivars resistant to ALB is needed to limit the financial and environmental costs of fungicide use. The quantitative nature of this resistance and the allogamous character of carrot make all the more precious the precision of resistance assessment from small samples. In this study, our purpose was to find a resistance assessment tool that was either more precise or less material consuming (or both), than the classical visual assessment method. We investigated three techniques by comparison with a visual disease assessment control: *in vivo* conidia germination, a bio-assay based on a drop inoculation method and *in planta* quantification of fungal biomass by quantitative PCR (Q-PCR). These techniques rely on small sample sizes, and give clues on very different stages of the pathogen development, i.e. spore germination, biomass production, and symptom development. Three carrot cultivars showing different degrees of resistance to *A. dauci* were used, i.e. a susceptible cv. (Presto) and two partially resistant genotypes (Texto and Bolero). The drop inoculation results allowed us to distinguish only one partially resistant genotype (Bolero) from the susceptible one. By contrast, *in vivo* conidia germination and Q-PCR clearly differentiated the two partially resistant genotypes from the susceptible cultivar at 1 day post-inoculation and 15 days post-inoculation respectively. Data obtained with the different assessment methods highly suggest that the Texto and Bolero genotypes present qualitatively different ALB resistance traits.

The Search for New *Meloidogyne incognita* Nematode Resistance

Joshua D. Parsons[1], William C. Matthews[2], Philip A. Roberts[2], and Philipp W. Simon[1,3]

[1]Dept. of Horticulture, University of Wisconsin-Madison, Madison, WI, USA
[2]Dept. of Nematology, University of California, Riverside, CA, USA
[3]USDA-ARS Vegetable Crops Unit, Dept. of Horticulture, University of Wisconsin-Madison, Madison, WI, USA

Root knot nematodes (*Meloidogyne* spp.) are a major problem in carrot (*Daucus carota* L.) worldwide. Root knot nematodes cause galling and forking of carrot roots, rendering them unfit for market. While the traditional approach of applying nematicides every year works, they damage the environment and regulations regarding the nematicides commonly used are becoming increasingly stringent. Genetic sources of nematode resistance will play a major role in stepping away from the use, or reducing the use of these nematicides as well as providing resistance to nematodes for areas of the world where nematicides might be too costly or not available. Resistance to nematodes has been identified and mapped for the *Mj-1* locus, with strong resistance to *Meloidogyne javanica*. Other sources of resistance are being identified, especially looking for resistance to *Meloidogyne incognita*. Segregating populations for four new sources of nematode resistance (Brasilia 1091, Brasilia 1252, Homs, and SFF) were pot grown in a greenhouse, inoculated with nematodes, and then evaluated for their resistance to *Meloidogyne incognita*. DNA samples were collected from them and are now being analyzed to determine if their resistance is due to genes other than *Mj-1* and to develop genetic markers to aid in the selection of resistant varieties in the future.

Development and Analysis of SSR and SNP Markers for a Carrot Mapping Population

Pimchanok Satapoomin[1], Massimo Iorizzo[1], and Philipp W. Simon[1,2]

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Carotenoid pigments are important components of the human diet and carrots are the primary source of the vitamin A precursors □- and □-carotene in the U.S. Carotenoids play crucial biological roles in plants, however the role of genes coding for the carotenoid biosynthesis pathway in controlling carotenoid accumulation are not well understood. Previous study has shown that there are two main genes, *Y* and *Y2* control the difference of carotene content between domesticated orange and white wild carrot. Besides these two genes, the function, map location, and inheritance of *y3*, a newly discovered carotene-accumulating gene is being considered. To gain more information about *y3*, development of simple sequence repeat (SSR) and single nucleotide polymorphism (SNP) markers in F_4 populations derived from a cross of domesticated orange B493 crossed with white wild QAL are under investigation. The potential usefulness of these markers will be evaluated for robustness, clarity of band pattern, PCR success rate and polymorphism. All evaluated markers derived from two different approaches will be placed as SRR and SNP markers on the genetic linkage map that includes AFLPs marking carotenoid accumulation QTL to serve as codominant anchor loci across carrot maps.

Genetic Analysis of Prominent Lateral Root Formation in Carrot

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Improvement of the architecture and nutritional value of root crop is an important target for breeders. Prominent lateral root development in carrot is a very important trait, but has received little attention in genetic studies. Consequently, the genetics and inheritance of prominent lateral root in carrot are not well understood. The objectives of this research are: to determine patterns of inheritance of storage root architecture and to utilize molecular markers to map this trait. For this purpose advanced generations, developed from a cross between wild and an inbred line are being evaluated using a lateral rooting evaluation scale of 0 to 4 (0 smooth and 4 profuse lateral roots). These families are being grown over three different locations and SSR and SNP markers are being evaluated.

Analysis of Phytoene Desaturase (PDS) During the Development of Root and Leaf Tissue of the *Rp* Mutant in Carrot (*Daucus carota*)

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The *Rp* (Reduced Pigment) mutation in carrot is characterized as a single recessive gene causing decreased levels of β-carotene and α-carotene, increased levels of phytoene accumulation in the storage root, chlorotic patches on the carrot leaf, and stunted growth. In the carotenoid biosynthetic pathway, phytoene is metabolized to ζ-carotene by the enzyme phytoene desaturase (PDS), making the carotenoid biosynthesis pathway of interest for further research regarding the *Rp* mutation. High performance liquid chromatography was used to measure the accumulation of carotenoid pigments in the leaf and root tissue during several harvest periods during plant development, and a comparison sequence analysis was conducted of the coding region of the carotenoid biosynthesis gene phytoene desaturase (PDS) in *Rp* as well as other pigmented carrot germplasm. Using real time quantitative PCR, the expression of phytoene desaturase was quantified in carrot leaf and root tissue over three periods of development in both *Rp* and W266, the background germplasm from which the *Rp* mutation was isolated. Pigment accumulation, sequence differences, and the analysis of differential expression of genes during the accumulation of carotenoid pigments throughout the entire *Rp* carrot plant will be analyzed.

Progress in the Deployment of Nutrient-Rich Nematode Resistant Carrots to Benefit Growers, Consumers, and the Environment

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Carrots are an important source of nutrients for the U.S. diet and have $550 million farm gate value to U.S. growers, but root-knot nematodes (*Meloidogyne* spp.) threaten approximately 3/4 of the U.S. carrot crop. Nematode infection causes forking and galling disfiguration to carrot taproots resulting in 'cosmetic injury' and economic loss. New sources of genetic resistance to the two most important root-knot species affecting carrot production, *M. javanica* and *M. incognita,* have been identified in several unrelated germplasm sources from local carrot populations of diverse geographic origins including Brazil, Europe, Syria, China, and Australia. Inbred lines, single cross hybrids, and diverse populations from several sources of resistance have been developed and evaluated on a small scale in field test sites heavily infested with nematodes. These sources of nematode resistance vary widely in nutritional value attributable to both carotenoid and anthocyanin pigments, and also vary in flavor. The inheritance and genetic map location of resistance genes is being determined, and molecular markers are being developed to facilitate incorporation of resistance genes by indirect selection. Plants with superior levels of resistance have been selected and seed supplies of selected individual plants with elite high resistance are being increased for testing in trials in the upcoming year. A web site is being developed to target large and small-scale carrot growers (http://www.ars.usda.gov/pandp/docs.htm?docid=19858) as a part of this project.

Specialty Crop Research Initiative award 2008-51180-04896 to P.W. Simon and P.A. Roberts.

Isolation of Cold Responsive Genes in Carrot by Suppression Subtractive Hybridization

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Low temperature is one of the major abiotic factors which limit growth, productivity and geographical distribution of plants. Some plants have adapted to survive at very low or even freezing temperatures and, hence, occupy high altitude areas such as mountains and Arctic or Antarctic regions. The mechanisms that a plant uses to survive at such low temperatures have been the subject of intense research for the past few years and modern molecular tools have helped provide understanding of some aspects of low temperature tolerance in plants. Suppression subtraction hybridization (SSH) is a PCR based method used to selectively amplify differentially expressed cDNAs and simultaneously suppress the non-target cDNA. *Daucus carota* is cultivated widely in tropical and temperate regions, but this species does best in cool climates. The aim of this project is to identify potential cold responsive genes which are upregulated during cold stress in carrot. To achieve this, a SSH library was constructed from RNA isolated from the leaves of control plants and cold stressed carrot plants. Out of the hundreds of clones obtained from the forward SSH library, some were sequenced, from which 52 sequences of promising clones were submitted to the EST NCBI database. Sequence analysis revealed that the functions of the identified genes were diverse and have significant roles in signal transduction, osmolyte synthesis and transport, photosynthesis, transcription factors, protein folding, nucleic acid synthesis, transcription and translation. Dot blot analysis revealed the relative expressions of various genes during cold stress. Future studies on this aspect will help increase our understanding of the complex mechanisms of abiotic stress response, in particular cold stress, and may help further the development of cold tolerant transgenic crops.

Evaluation of Vernalization Requirement in Different Carrot Populations

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Carrot is normally classified as a biennial species requiring vernalization to induce flowering. Nevertheless, some cultivars adapted to warmer climates require less vernalization and can be classified as early-flowering or annual. Previous progeny evaluation of crosses between Criolla INTA and two biennial lines, B1 and B2, showed a single dominant gene conditioning the annual habit. The objective of the present work was to evaluate 6 annual carrots from different geographic origins (Pakistan35, India87, Japan63, Turkey60, Turkey88 and Criolla INTA), 2 biennial carrot (USA and B2) and 4 crosses (USAxJapan63, USAxTurkey60, USAxTurkey88 and B2xIndia87). A randomized block design with three repetitions was sown on 29/4/08 at La Consulta, Argentina. Each plot had 35 plants on average. Once per week each plot was evaluated. Individual plants were scored as being vegetative until the first floral internode elongated. Proportion of flowering plants and weeks from sowing to first elongated internode were calculated. Variance analysis and mean differences were carried out. Proportion of flowering plants was between 0–7% for biennial carrots, 96-100 % for annual carrots, and 82-98% for crosses. Carrots from Pakistan and India had the shortest flowering cycle, with 85% of their plants elongated in week 23, followed by Criolla INTA (47%) and B2xIndia87 (30%). Genotypes Turkey60, USAxJapan63 and USAxTurkey60 had their highest proportion of elongated plants around week 26. Dominance of annual habit was confirmed, while the variability in flowering cycle could be due to allelic differences or action of other genes.

Unlocking the Potential of Genebank Carrot Collections: Creating a Carrot Diversity Set as a Research and Pre-Breeding Resource

Charlotte Allender, Ann Baker and Dave Pink

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Plant genetic resource collections such as the carrot collection held at the Warwick HRI Genetic Resources Unit are extremely useful assets for both crop improvement programmes and research. However, it is not practical to screen or assay all accessions within such collections for traits of interest; the Warwick HRI GRU holds over 1600 accessions of carrot and related wild species, which is too great a number for most screening programmes to handle. In order to make the diversity present in the collections more available, we have constructed a Carrot Diversity Set which samples the global carrot genepool in terms of geographical origins and root morphology. We chose 77 accessions from the Warwick HRI GRU collection, and supplemented these with experimental lines such as the parents of genetic mapping populations kindly donated by other researchers. We will also include eight modern elite varieties for comparison in trait screening and genetic studies. The diversity set represents a snapshot of the global carrot genepool held in a manageable format which will be made available to interested parties and allow collation of data from future studies.

Carrot Chromosomes and Linkage Groups

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The genome of carrot (*Daucus carota* L.) consists of ~480 Mb/1C organized in 9 chromosome pairs. The importance of carrots in human nutrition is triggering the development of genomic resources, including carrot linkage maps, a bacterial artificial chromosome (BAC) clone library and BAC end sequences (Cavagnaro et al., 2008). In contrast to these advances, the carrot genome is poorly characterized at chromosome level. While several linkage maps based on different types of molecular markers have been produced, there has been no effort to correlate the linkage groups with specific chromosomes. Carrot somatic metaphase chromosomes are 2–4 mm in length, thus they offer limited resolution for modern cytogenetic tools. On the other hand, preparation of meiotic chromosomes is technically challenging due to the flower bud size. In this work, we present our effort to establish a pachytene karyotype of carrot and to assign carrot linkage groups to pachytene bivalents. Carrot pachytene complements prepared from carrot line 2566B consisted of four metacentric and five subtelocentric chromosomes, and were up to ~8 times longer than their mitotic counterpart. Heterochromatin was mainly confined to the pericentromeric regions of each chromosome. Several BAC clones selected for genetically mapped DNA markers were mapped to specific chromosomes and linked markers were physically linked. Using two-color FISH, a probe cocktail composed by 11 BACs from eight linkage groups was sufficient to identify the 9 pachytene bivalents. Our work will be helpful to integrate the available linkage data with the chromosome morphology.

POSTER ABSTRACTS

POSTER 1

Antioxidant Content of Carrots with Different Pigments Grown in Ontario, Canada

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Carrots provide important nutrients in the human diet. Orange carrots are a major source of beta carotene, a pigment with antioxidant activity that is the precursor to vitamin A. Carrots with different pigments and colours are now commercially available. To determine the relative antioxidant content of carrots with different pigments, cultivars of a purple, red, orange, yellow and white carrot were selected and compared to breeding lines from the USDA carrot breeding program at the University of Wisconsin. All were tested for total antioxidant activity (TAC) and total phenolic content (TPC). The Folin-Ciocalteu method was used to determine total phenolic content (TPC). A standard curve was generated with gallic acid, with a concentration range from 0 to 100 µg/ml (0-100 ppm), from which TPCs in the various fractions were calculated and expressed as milligrams of gallic acid equivalent per gram of dry weight. The antioxidant activity was determined using 2,2-diphenyl-1-picrylhydrazyl radical (DPPH·) induced free radical assay and the Ferric Reducing Antioxidant Power (FRAP) Assay. Significant differences were found for total phenolic content and total antioxidant activity. Cultivar Purple Rain had significantly higher TPC than all other carrots, except breeding line Red-104-3. The FRAP test showed that Purple Rain had a higher antioxidant level than Crème de Lite, a white carrot. When carrots were grouped by color, the purple carrots had significantly higher TPC than the yellow and white carrots and higher TAC than the yellow carrots.

POSTER 2

Efficacy of Scholar (fludioxonil) for Control of Sclerotinia Rot of Carrot in Cold Storage

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Sclerotinia sclerotiorum (Lib.) de Bary is the cause of one of the most important storage disease of carrots, Sclerotinia rot of carrot, also called cottony soft rot. An emergency registration of the fungicide Scholar (fludoixonil) was approved in 2009 for post harvest application to washed carrots to prevent rot in storage. A trial to evaluate the efficacy of Scholar to control Sclerotinia in storage was conducted in 2008 to 2009. Each experimental unit consisted of 30 non-inoculated but treated carrots in a mesh bag with a single Sclerotinia- infected carrot in the middle. Treatments were: Scholar at the rates of 65.6, 131.2 and 250.6 mL product, Mertect (thiamethoxam) at 108.4 mL and Scholar + Mertect at 131.2 mL + 108 mL, respectively, per100 L of water used as dip treatments, and Scholar at the rate of 131.2 mL/100 L of water applied as a drench. Untreated non-inoculated and inoculated checks were also included. Bags were placed in a cold storage (~1^{o}C, 95% rh) and four bags per treatment were assessed each month for 6 months. Incidence and severity was recorded. Disease in the inoculated, untreated check increased from 17% to 74% during the trial. All rates of Scholar applied as a dip effectively reduced disease incidence and severity in the final three months of the trial. Scholar applied as a drench reduced disease in the final two months of the trial. The Mertect treatment was not effective in reducing Sclerotinia rot in storage.

POSTER 3

Regional Ascospore Detection Correlates to Disease Incidence Providing Accurate Timing for Disease Management of Sclerotinia Rot of Carrot

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Sclerotinia rot of carrot (SRC), caused by *Sclerotinia sclerotiorum* (Lib.) de Bary, is an important disease of carrot (*Daucus carota* L., subsp. *sativus*); epidemics are sporadic but infection can be severe, particularly in postharvest storage. The objective of this study was to determine the relationship between ascospore counts and disease incidence to improve the timing of disease management practices against SRC. In 2008, ascospore counts remained below the SRC forecast model threshold of 5 ascospores (0-4.4, with single peaks of 11.8 and 28.5 at two test sites) and there was low incidence of SRC at all three test sites (0-3%, with a single peak at one test site of 14%). Considering a 1 week delay between ascospore detection and infection, the mean daily number of ascospores were correlated with disease incidence at all sites (r=0.78–0.87, p=0.0026-0.0118). In 2009, at two of four test sites, low numbers of ascospores were detected (0-4.3 with a single peak of 9) and showed similar trends with low disease incidence (0-4%). At the remaining two test sites, ascospore counts surpassed the SRC forecasting model threshold (0-31.7) and were correlated with disease incidence (r=0.74 and 0.88, p=0.0097 and 0.0095, respectively). Trimming the carrot canopy in combination with boscalid or 0.2% chitosan timed according to ascospore detection reduced SRC compared to the untrimmed/untreated control (AUDPC: trim + boscalid or chitosan 22 and 70, respectively; boscalid or chitosan alone 215 and 252, respectively; control 564; p<0.0001). These results indicate that disease prediction is accurate and demonstrate that control is effective when accurately timed according to inoculum detection.

POSTER 4

Diversity of Volatile and Non-Volatile Compounds in a Gene Bank Collection of Cultivated *Daucus carota* L.

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Carrot roots and leaves contain various volatile and non-volatile metabolites such as carotenoids, sugars and terpenoids. While carotenoids especially beta-carotene has high beneficial effects on the human health (1,2,3), sugars and terpenoids contribute substantially to the pleasant taste and typical odour of carrot roots and leaves (4). To characterise the diversity of volatile compounds in carrot leaves and the occurrence of non-volatile compounds in carrot roots an association study was performed. Therefore, 104 different carrot genotypes were cultivated in the greenhouse for 100 days at controlled conditions. This material comprises a selection of *Daucus* genotypes from different gene banks representing all climates of *Daucus* cultivation. The material is composed of 18 modern varieties, 74 older varieties and 12 land races. For rapid analysis of non-volatile compounds, a fast sample preparation using accelerated solvent extraction (ASE) combined with a fast HPLC-DAD method was established according to earlier studies (5). For semi-quantitative analysis of the volatile compounds a rapid headspace-SPME-GC method was applied and a so-called “non-targeted data processing” based on pattern recognition was performed. On one hand this kind of analytical approach provides the possibility to cover the huge metabolic diversity in the plant material used and on the other hand high numbers of samples can be efficiently analysed. The statistical evaluation of volatile substances occurring in carrot leaves principally allows predicting various carrot quality parameters (e.g. presence and level of non-volatiles) of the related root. This opportunity is of great advantage for early single plant selection in breeding research and applied breading as well.

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POSTER 5

Heterosis for Quality Traits in ems Based Hybrids of Tropical Carrot (*Daucus carota* L.).

Nouri Kushlaf

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FULL PROCEEDINGS ARTICLE

Session: Carrot Breeding and Genetics

Unlocking the Potential of Genebank Carrot Collections: Creating a Carrot Diversity Set as a Research and Pre-Breeding Resource

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Abstract
Plant genetic resource collections such as the carrot collection held at the Warwick HRI Genetic Resources Unit are extremely useful assets for both crop improvement programmes and research. However, it is not practical to screen or assay all accessions within such collections for traits of interest; the Warwick HRI GRU holds over 1600 accessions of carrot and related wild species, which is too great a number for most screening programmes to handle. In order to make the diversity present in the collections more available, we have constructed a Carrot Diversity Set which samples the global carrot genepool in terms of geographical origins and root morphology. We chose 77 accessions from the Warwick HRI GRU collection, and supplemented these with experimental lines such as the parents of genetic mapping populations kindly donated by other researchers. We will also include eight modern elite varieties for comparison in trait screening and genetic studies. The diversity set represents a snapshot of the global carrot genepool held in a manageable format which will be made available to interested parties and allow collation of data from future studies.

Introduction
In recognition of the fact that the production of many important crops depended on the performance of a relatively small number of elite varieties derived from a small part of the crop genepool, much effort in recent decades has been put into the collection, conservation and management of plant genetic resources. Material representing older varieties, traditional landraces and populations of related wild species has been collected, catalogued and placed into long-term storage. For carrot, these resources are seed collections held at various institutions across the world including a globally significant collection at the Warwick HRI Genetic Resources Unit. However, the sheer number of accessions in these seed collections may make easy access for plant breeders or researchers difficult, and with so many accessions to choose from it is easy to see how data from different studies cannot be compared if different accessions were used as starting material. The number of carrot accessions available in two major combined collections can be seen in Table 1.

These and similar collections of carrot genetic resources may contain traits and alleles which would be of use in crop improvement programmes, such as novel pest and disease resistances and tolerance of water and nutrient stresses. In order to locate such novel traits, it is necessary to adopt a structured screening approach, as it is not

feasible to look at >5000 accessions in trials and experiments. 'Core collections' have been designed for other crops such as *Brassica oleracea* (cabbage, cauliflower, broccoli etc) where the range of diversity of cultivated and wild types has been maintained in a structured subset of all the available accessions (Leckie et al, 1996).

Our aim was to develop a 'diversity set' for carrot which represents the diversity of the carrot genepool but has a more tractable number of accessions to allow for easier use in trials and experiments. We wanted to include accessions which have already been used by other researchers as we hope the diversity set will enable data to be pooled from different studies, adding to its value.

Table 1. Summary of carrot accessions (*Daucus carota* including both wild and cultivated subspecies) available in two major collections in Europe and the USA. These collections include weedy, hybrid and breeding material in addition to the wild, landrace and cultivars listed in the table.

Source	EURISCO[1]	ARS-GRIN[2]
Total *Daucus carota* accessions	4379	882
Wild material	379	154
Landraces	845	207
Cultivars	1552	116

[1] Data downloaded from the EURISCO database at http://eurisco.ecpgr.org. EURISCO is a web-based catalogue that provides information about *ex situ* plant collections maintained in Europe, including that of the Warwick HRI GRU
[2] Data downloaded from the Genetic Resources Information Network (http://www.ars-grin.gov), a program within the United States Department of Agriculture's Agricultural Research Service

Methods

We have selected a total of 77 accessions from the carrot collection held at the Warwick HRI Genetic Resources Unit, one of the most comprehensive collections of carrot germplasm in the world. Although some molecular marker studies have found the carrot genepool to be unstructured (Bradeen et al, 2002) we selected our accessions on the basis of root type and colour and geographical origin to make sure we had a good representation of all types. We obtained input and advice on the composition of the set from the wider carrot research community, and attempted to overlap with sets of accessions used by other researchers where possible. Emphasis has been put on landrace accessions as these may be pools of useful diversity as they have been locally selected over many generations to perform well in particular ecogeographical environments. We have concentrated on *Daucus carota* accessions which include some related subspecies to sample the wild genepool at the same time as facilitating crossing into cultivated types. We have also included some representatives of more distant relatives of carrot such as *D. capilifolius*. This wider genepool has already been the source of useful traits such as enhanced resistance to carrot fly (Ellis et al, 1993). A list of the accessions selected for the diversity set can downloaded from the website for the Vegetable Genetic Improvement Network (VEGIN) at www.warwick.ac.uk/go/vegin.

In order to facilitate research into the genetic control of traits of interest, we also wanted to include parental lines from as many genetic mapping populations as possible. This

will allow the best mapping population for further investigation to be identified at the time of the initial diversity set screen/trial rather than having to carry out follow-up investigations. Parental lines were very kindly donated by P. Simon (University of Wisconsin, Madison) and T. Nothnagel (Julius-Kühn-Institut). We have also included space for several modern elite cultivars so that direct comparisons of performance can be made.

Our diversity set is based on open-pollinated accessions with varying levels of intra-accession diversity. This is useful as it reflects the pattern of diversity in the carrot genepool but has drawbacks when it comes to comparing the results of genetic studies on different individual plants. We are structuring each accession in the diversity set to attempt to address this problem, whilst delaying the onset of inbreeding depression that can be observed in highly selfed lines. Each accession in the diversity set will be represented by seed collected individually from ten intercrossed plants. This will result in 10 'half sib' families, each derived from an individual maternal plant. We will also self pollinate an additional individual so that a more homozygous line is available for each accession if required.

We are currently producing seed according to the design described above through the use of isolation cages and blowfly pollinators in polytunnels. We have prepared a DNA extract of each parental plant for future use. We are also quantifying the genetic diversity of the whole set through sampling a subset of each accession using DArT markers (Jaccoud et al, 2001) which can detect genomic wide variation. This will allow comparisons of inter-and intra-accession diversity and indicate where the greatest amounts of genetic variation lie within the set.

Summary

Our Carrot Diversity Set is based on the carrot collection held in the Warwick HRI GRU, together with parental lines of genetic mapping populations and modern elite varieties for comparison. We have tried to make the best use of available data by selecting accessions that have already been screened in other projects.

We anticipate that the carrot diversity set will be a useful tool for bringing new traits as rapidly as possible into crop improvement programmes and to that end we plan to make the Carrot Diversity Set available to all interested users. Small quantities of seed will be made available on either a collaborative basis or for a small charge to cover costs. Samples of the DNA extracts for each of the eleven plants per accession will also be made available.

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