ADVANCING CARROT IPM – NEW TOOLS FOR NEMATODE AND LEAFHOPPER CONTROL

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Abstract. Insect and nematode management programs on processing and fresh market carrot crops in Wisconsin rely heavily on the use of frequent foliar applications of insecticides. Many of the pesticides used are broad spectrum chemicals that present considerable, well documented risks to the safety of farm workers and the environment including at-plant treatments of oxamyl and successive foliar applications of synthetic pyrethroids and protectant fungicides. This research attempts to refine and replace current practices, which rely on frequent foliar sprays of broad spectrum insecticides with an

economically viable system that relies on reduced-risk and carbamate-alternative insecticides applied as seed treatments or as in-furrow applications to minimize farm worker exposure to pesticides and mitigate adverse effects on human health, the environment, and non-target organisms. An outcome of this integrated research and extension program in Wisconsin is a management approach which can be tailored to meet the needs of a diversity of stakeholders representative of processing producers and an emerging potential market for a fresh, cut-n-peel segment. Compared to current IPM practices, these reduced-risk systems will increase the sustainability and thus the profitability of carrot production, enhance natural enemy populations and biological control, and reduce adverse effects on farm workers and applicators.

Background and Rationale. Because there is a moderate to low tolerance for insect and disease damage to carrot crops, growers often rely on frequent pre-plant and successive foliar applications of insecticides to manage the complement of nematode and insect pests plus foliar pathogens. The majority of insecticides now used on these crops are older, broad-spectrum insecticides that pose risks to farm worker safety and the environment (USDA-NASS Agricultural Chemical Use Database USDA-NASS 2007), and are subject to FQPA-related regulatory actions. The following problems are a brief summary of the targets of this project.

Figure 1. Adult aster leafhopper, *Macrosteles quadrilineatus*, Forbe

Aster Leafhopper & Aster Yellows Phytoplasma (AYp). The AYp pathogen is vectored primarily by the aster leafhopper (*Macrosteles quadrilineatus* Forbes, formerly *M. fascifrons* Stål) in a persistent and propagative manner (Fig. 1). The leafhopper acquires AYp by feeding on infected plants and may carry and transmit AYp over great distances. A defining feature of the aster leafhopper's biology is the early season migration of the insect from the Gulf-states to Upper Midwest. This early season migratory behavior has been reported to influence the potential for aster yellows epidemics in the upper Midwest regions of the United States (Chiykowski and Chapman 1965). And presumably, the first AYp to enter carrot in Wisconsin is vectored by these adult female leafhoppers reportedly migrating from grain crops in the southern U.S. Long-distance migrants begin to arrive in Wisconsin in late April to mid-May as carrot and small grain cover crops are germinating. Aster yellows disease is caused by the AYp, which is a small prokaryote that is taxonomically placed in the provisional genus, *Candidatus*. As noted previously, this organism is obligately associated with its plant and insect host(s) and has not been successfully cultured in the laboratory to date (which has slowed research progress due to the inability to obtain a "pure" culture). The symptoms caused by AYp are as varying as the number of plant species infected by AYp, but the most common disease phenotypes include vein clearing, chlorosis, stunting, and twisting of the stems and leaves, proliferation of stems and the development of adventitious roots (Fig. 2). These symptoms lead to direct yield and quality losses and processing problems which results from malformed roots challenges associated with cleaning raw product. Currently, the decision to intercede and implement a pest control practice (e.g. insecticide spray) is based upon calculation of the Aster Yellows Index (AYI). Control practices strictly utilize insecticide sprays (primarily Group 3 synthetic pyrethroids, IRAC, Mode-of Action Classification http://www.irac-online.org/) that target not only the aster leafhopper, but will impact all other beneficial insects present in the crop. The synthetic pyrethroids are a class of chemicals that have been introduced over the past three decades for a variety of insecticidal uses including both agricultural and domestic applications. These materials currently comprise the backbone of low-cost registrations which are relied upon for use against the aster leafhopper in support of the AYI. The synthetic pyrethroids were conditionally registered beginning in 1984 for use on selected crops and currently, EPA is assessing risks to non-target organisms. Several of these synthetic pyrethroids remain conditionally registered for use on vegetables grown in muck soils, however, each of these chemicals is highly lipophilic and in aquatic environments tend to strongly adsorb to sediments. Under section 4 of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), US EPA continues to re-evaluate existing pesticides to ensure that they meet current scientific and regulatory standards. These compounds are broadly characterized as having a wide spectrum of activity often with acute oral neurotoxicity to mammals, notable chronic effects as endocrine disruptors, and are classified as both mutagenic and carcinogenic. With the advent of novel, reduced risk, and less broad spectrum seed treatment registrations for many homopterous, sucking insect pests (e.g. thiamethoxam), the continued RED eligibility of this important class of insecticides could be in jeopardy.

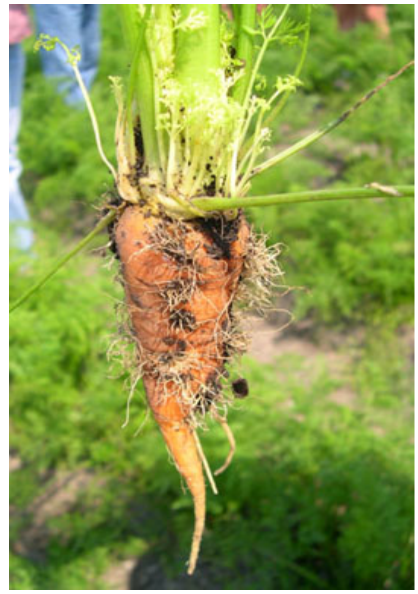

Figure 2. Symptoms of aster yellows phytoplasma in carrot illustrating 'witches-brooming' in foliage and epicormic branching in the roots.

Root-Knot Nematode. Root-knot nematodes *(Meloidogyne* spp.) are major pathogens of vegetables throughout the United States and the world, and particularly in carrot production in the upper Midwest where they impact both the quantity and quality of marketable yields. In addition, root-knot nematodes interact with other plant pathogens, resulting in increased damage caused by other diseases including the foliar pathogens. Only the northern root-knot nematode (NRKN; *Meloidogyne hapla)* has been documented in carrot grown on organic or mineral soil in Wisconsin, as it is able to survive the extreme low temperatures during winter. The NRKN has a wide host range consisting of more than 500 crop and non-

Figure 3. Root knot nematode on carrot (*Meloidogyne* spp.) NCSU, Dept. of Plant Pathology)

crop weed species, including weeds common to both muck and mineral soils. The increasing occurrence and damage of this nematode to carrots grown on muck and mineral soils in Wisconsin has been so severe in certain circumstances to cause marketable yield losses of carrots reduced by as much as 45% in commercial fields and even complete rejection of whole loads. Above-ground symptoms on carrots heavily infected with M. *hapla* include general stunting, delayed maturity, and a patchy and uneven stand. Roots of severely infected carrots exhibit forking, galls, hairiness, and even stubby roots as typical symptoms (Fig. 3). Adversely affected root systems of carrots heavily infected by *M. hapla* are also not efficient in the uptake of water and nutrients that are necessary for normal plant growth leading to susceptibility to other foliar pathogens including Alternaria leaf blight (ALB) caused by *Alternaria dauci* and Cercospora leaf spot (CLS) caused by *Cercospora carotae*, as well as infestation by phytophagous insects including the aster leafhopper.

The NRKN are obligate endoparasites that complete most of their life cycle within their host roots and survive in soil as eggs and also second stage larvae. The infective second stage juveniles' hatch from the eggs and move through the soil in search of roots of suitable host plants. Juveniles usually penetrate host roots just behind the root tip region and establish their special permanent feeding sites (giant cells) in the vascular tissues during early root development, often in the first 2-3 weeks of stand establishment. Control of the nematode can be accomplished through the rotation of cover crops grown between the main crops including rye, barley, oats, and wheat as these have been shown to be non- or poor hosts to this nematode. Rotating carrot with a non-host crop such as sweet corn and other grain crops, if economically possible, can be effective in reducing damage levels of NRKN, however current crop rotations on many commercial farms are of limited value as most crops grown, including potatoes, snap beans, onion, and carrot are susceptible. Effective and economical control is most often achieved with the use of pre-plant nonfumigant-type nematicides including oxamyl (Vydate® L); the primary pesticide tool registered for use in Wisconsin. Oxamyl is a carbamate used to control insects, mites, and nematodes first registered in 1974 by DuPont, Inc. Initial registered application methods included ground, foliar spray, soil spray, soil drench, root dip, preplant incorporated, or transplant water. In recent years, the registrant has undertaken a number of voluntary actions to reduce exposures human and environmental exposures to include the deletion of specific uses (ornamentals, greenhouse, and soil mixing uses), lowered application rates, and established seasonal maximums, restricted entry intervals, and extended pre-harvest intervals. The potential for new, reduced risk, and less broad spectrum seed treatment registrations targeting the NRKN (e.g. abamectin), increasingly provides pest management alternatives for long term control of nematode pests and resulting infection.

Project Purpose. Protection of young seedlings against plant parasitic nematodes and vectors of plant disease is a major concern in carrot production. In Wisconsin, protection against the northern root-knot nematode (NRKN) is of great significance often because of their wide-spread distribution in carrot production fields and their low threshold for causing economic damage. Injury to the growing carrot root tip by the nematode's parasitic activity causes forking and stubbing, in particular during the first few weeks after seed germination. While soil fumigants typically provide excellent efficacy against soil-borne pathogens, the use of soil pesticides in Wisconsin, and other locales, is likely to decline because of regulatory pressure to limit potential air quality and non-target exposure problems. These issues will further foster efforts to develop nematode resistant carrot cultivars as well as new seed treatments that deliver small amounts of nematicides to the target root zone. The low application rates associated with seed treatments are likely to result in reduced risk for the user and environment as well as increased production efficacy.

Currently several agrochemical companies are developing combinations of their plant protection products to provide seed treatments with a wide spectrum of activity against pests and diseases. Recent greenhouse trials with a development product of Syngenta Crop Protection has indicated that carrot seed treatments containing the nematicide, 'abamectin' will provide very useful protection against the early attack of NRKN. The treatments increased carrot stand in heavily root-knot nematode-infested sandy loam and typically reduced root galling by two rating classes. Abamectin, a natural fermentation product of the bacterium *Streptomyces avermectinius,* has been known since the mid-1970s for its insecticidal and antihelmintic activity, but it has never been registered as a soil-applied nematicide. However, branded as Avicta®, it has been registered in the U.S. since 2006 as a cotton seed treatment with activity against plant parasitic nematodes. More recently it received U.S. EPA registration in several vegetables as well as corn. While nematicidal seed treatments do not provide comparable efficacy to fumigants, they might be useful in combination with other nematode management tactics and as a replacement for the carbamate oxamyl (Vydate).

Potential Impact. The goal of the National IPM Program outlined in the National Road Map for IPM (www.ipmcenters.org/Docs/IPMRoadMap.pdf) is to improve the economic benefits of adopting IPM and to reduce potential risks to human health and the environment. Current IPM practices for carrots and many other vegetable crops rely extensively on frequent foliar sprays of older, broad spectrum insecticides including oxamyl (Vydate®)and synthetic pyrethroids (Asana®, Permethrin®, etc.). Although successful from the perspective of managing insect pests in a cost-effective manner, this approach presents considerable, well documented risks to the safety of farm workers and the environment. We propose to refine and implement a pest management program based on reduced risk insecticides and an application technology that: 1) minimizes farm worker exposure to high-risk pesticides and newer RR insecticides, 2) reduces environmental risks by utilizing insecticides with a more friendly environmental profile on an as needed basis to reduce or eliminate drift and run-off into water resources; and 3) creates incentives for adoption by the grower community by documenting enhanced profitability. The project encompasses the leading vegetable producing region in the state where issues concerning water quantity and now water quality are emerging as real and important issues. The multidisciplinary cooperation of research and extension specialists in applied vegetable pest management and program evaluation will enable these reduced risk IPM programs to be evaluated and refined to meet the needs of carrot producers in Wisconsin and potentially throughout much of the carrot producing regions of the upper Midwest and California. Specifically, this project addresses 3 of the 8 research needs

identified in the Road Map for IPM: (1) development of advanced management tactics for specific settings, (2) improved efficiency of suppression and demonstration of cost effectiveness, and (3) development and implementation of new delivery methods to expand options for IPM implementation. This project will train graduate students in pest management and evaluation that will contribute to future advances in IPM. The extension component includes diverse strategies to maximize grower adoption of reduced-risk programs and enhance public awareness of advances in mitigating adverse effects of pest management on human health and the environment. Given the uncertainty of the Group 1 (carbamate) and Group 3 (synthetic pyrethroid) insecticides and future re-registration eligibility decisions from EPA, the outcomes of this research are critical for documenting alternative strategies to control key insect pests in carrot crops.
crop destruction associated with experimental treatments.