**Final Report**: Improving carrot quality and yield through strip-tillage and enhanced carrot stand establishment

Daniel Brainard, Department of Horticulture, Michigan State University, A440A PSS Building, East Lansing, MI 48824; telephone: 517-355-5191 ext 1417; email: brainar9@msu.edu

**PROJECT BACKGROUND**

**Key problems addressed:**

Michigan carrot growers face a number of challenges that threaten the viability of the industry including 1) an increasing occurrence of severe weather events which destroy tender seedlings 2) shrinking markets for carrot culls due to the recent ban on deer baiting and 3) insufficient information on optimal carrot population densities for maximizing profit under these new market conditions.

*Loss of deer-bait market.* It is estimated that in 2008 as many as 2,000 acres of carrots in Michigan were planted solely for the baiting market. In addition, growers of carrots for fresh market and processing have lost a major market for culled carrots that do not meet the demands of purchasers due to splits, breaks, decay and malformation. To maintain the economic viability of carrot production in Michigan, growers must seek alternative markets for culls and work towards reducing the percentage of carrots with defects through changes in management practices.

*Poor stand establishment.* Carrots are among the slowest vegetable crops to establish in the field and their tender seedlings are extremely vulnerable to pathogens, heavy rainfall and wind. As a result, problems with stand establishment occur almost every year resulting in losses in carrot quality, yield and profitability. For example, in the spring of 2008, heavy rainfall in many carrot production regions of the state resulted in stands with ½ or less the intended population, and in some cases, complete crop failure. Thin and patchy carrot stands have more variable sizes and a greater percentage of defects like splits than stands with consistent populations. Given the loss of markets for carrot culls, practices which can protect tender seedlings and help growers attain optimal population densities are of increasing importance. Even without the baiting ban, these practices will improve yields of marketable carrots and farm profitability.

Strip tillage has strong potential for protecting vulnerable seedlings while promoting soil health. Several innovative growers have begun planting cover crops before carrot season and maintaining them as wind breaks by tilling only the strips where carrots are to be planted. These pre-established cover crops can reduce erosion due to wind and
heavy rain by serving as wind breaks and holding soil in place. While this system is being adopted for its benefits related to wind protection, growers have encountered problems that must be resolved before this new system is more fully embraced. In particular, side-wall compaction and subsidence in stripped areas has been observed in some fields. Alternative point and shank types are likely to reduce these problems, but need to be evaluated before recommendations can be made.

“Seed priming” (soaking seed in polyethylene glycol and drying before planting) offers another approach to protecting carrot seeds and seedlings and establishing stands with closer to optimal densities. Primed seed is faster to germinate and more capable of withstanding stressful conditions than unprimed seed. However, seed priming imposes additional costs on the grower that may or may not be justified given economic constraints. Given stand losses in recent years, it is likely that the additional cost of primed seed is justified, but little information is currently available to Michigan growers to make this assessment.

Optimal population densities for different varieties and markets are not well understood. Population density has a major impact on total marketable yield. With loss of carrot cull markets, optimal population densities are likely to increase, since higher densities are thought to reduce the number of split carrots—the major category of culls for many growers. However, the effect of planting density on carrot quality and yield is likely to vary with variety and climate. Little work has been conducted to evaluate the effect of planting density on carrot quality and yield. Our proposed work will address this knowledge gap.

GOALS AND OBJECTIVES

The goal of this research was to improve the quality, yield and profitability of Michigan carrot production. Specific objectives to accomplish this goal were:

1) Optimize strip-tillage systems to protect vulnerable seedlings from extreme weather events.

2) Improve carrot germination and stand establishment through variety evaluation and seed priming to reduce stand losses and help growers attain optimal population densities.

3) Determine optimal planting densities for important Michigan carrot varieties to improve quality and profitability given current market conditions.
APPROACHES AND METHODS

Objective 1. Strip-tillage and compost. Field trials were conducted, in 2009 (MSU Horticultural Research Farm in Holt, MI), and in 2010 (Montcalm Potato Research Farm) examining the effects of tillage (conventional vs strip till) fertility management (fertilizer vs fertilizer+compost) and carrot variety (Canada, Finley, and Recoleta or Cupar), on carrot quality and yield. All treatments received approximately 120 lbs N/A (80 lbs/N initial + 40 lbsN/A side-dressed). In compost treatments, dairy manure based compost (Morgan Compost “Dairy Doo”; 1.2-0.63-1.2 NPK on dry weight basis) was applied at a rate of 2.8 T/A with an estimated available N content of 5-10 lbs N/A. In strip-till treatments, a barley cover crop was drilled in mid April. In early May, strips were established 18” apart in 3-row beds using an Unverferth Ripper-Stripper set at 12-14” depth followed by 9” wide roto-tiller set at approximately 2” depth. Conventional tillage was accomplished with a chisel plow followed by two passes with a field cultivator. Carrots were planted the same day at an approximate rate of 200,000 seeds per acre. In early October, carrots were harvested from a 20’ section from each sub-plot and categorized as described above for planting density trial.

Objective 2. Seed treatment effects on establishment. Two field trials were conducted on muck soil at the MSU Muck Farm examining the effects of seed priming on establishment and yield of 2 fresh market carrot varieties. Seeds of two varieties (Apache and Sun 255) with 3 seed treatments (none, fungicide treated and primed) were sown either in early spring or mid-summer. Crops received standard herbicide and pest management treatments. Effects of seed treatments on carrot yield and quality were assessed.

Objective 3. Planting density effects. On-farm trials were conducted on sandy soil in Oceana County in both 2009 and 2010 to evaluate the effects of planting density on quality and yield of four processing carrot varieties (Canada, Finley, Recoleta and Cupar). Plants were sown at approximately 177,000, 207,000 and 248,000 seeds per acre. The plots were arranged in a split-plot design with four replications, with seeding rate as the main plot factor, and variety as the subplot factor. Carrots were managed using strip-tillage with spring-sown barley as the cover crop in 2009 and fall-sown wheat as the cover crop in 2010. In early October, carrots from four 5’ sections from each sub-plot were counted and weighed by category. Carrots were categorized as either marketable, cracked, sprangled (forked) or too small (<1.25” in diameter).

RESULTS AND CONCLUSIONS

Objective 1. Strip-tillage and compost. Heavy nematode populations at the research farm resulted in low yields and a high percentage of forked carrots (Figure 3). Canada was the highest yielding variety at the research farm in both years. Strip-tillage had no
effect on yields or culls for any of the varieties compared to conventional tillage. In 2009, addition of compost increased marketable yields of Canada by approximately 10 T/A (Figure 3A), and 5 T/A for Recoleta (Figure 3B), but had no impact on Finley (Figure 3C). For Canada, approximately half of this increase in yield due to compost was the result of fewer forked carrots. In 2010, compost had no effect on marketable yield, but increased the percentage of forked carrots in some cases.

**Objective 2. Seed treatments.** For the early planting date trial, primed seeds resulted in higher marketable yield than either un-treated or fungicide treated seeds for both varieties (Table 1). Although standard herbicides (Lorox/Dual) were applied, yellow nutsedge pressure was very high. Under these conditions, seed priming resulted in greater survival of carrot seedlings and close to 50% improvement in yields compared to standard fungicide treated seeds. For the late planting date trial, similar improvements in yield were observed for the variety Apache, but not for Sun 255. In contrast to the early planted trial, few weeds escaped herbicide treatments. For the second trial, carrot stand and leaf number counts conducted 17 days after planting revealed more rapid early growth of both varieties (Table 1). We speculate that this more rapid establishment helped protect emerging carrots from early stress, reduce stand losses, and improve carrot yields primarily through increases in carrot density. However, more research is needed to assess the mechanisms for this yield improvement.

**Objective 3. Planting density and variety.** Averaged across all three varieties, carrot yields increased with final population densities up to approximately 150,000 plants/A in both years (Figure 1). Yields in 2010 were lower than those in 2009 due in part to a high incidence of bacterial blight which necessitated early harvest. The percentage of forked carrots decreased at higher densities in both years (Figure 2). As expected, the percentage of split carrots decreased with higher densities in 2009. However, in 2010, higher densities resulted in a higher percentage of split carrots. Overall, the percentage of culls declined from 20 to 2% in 2009 and from 25 to 15% in 2010 as final density increased from 60,000 to 160,000 plants per acre. In contrast to research farm trials, the highest yielding variety was Finley in 2009, followed by Recoleta (see Table 1). In 2010, yields of all three varieties were equivalent; Finley produced the greatest total weight, but had a higher percentage of forked carrots than the other two varieties.

**SUMMARY OF LESSONS LEARNED AND POTENTIAL IMPACT**

In 2009-10 field trials we found: 1) higher population densities were associated with higher yields and fewer carrot culls; 2) strip-tillage had no effect on carrot quality and yield relative to conventional tillage; 3) compost applications resulted in higher yields and lower percentages of forked carrots in a field heavily infested with root-knot and
lesion nematodes; 4) primed seed improved carrot stand establishment and yield relative to standard fungicide treated seed.

Our findings suggest that growers of carrots should consider 1) increasing their seeding rates and 2) investing in high quality primed seed. These practices are likely to improve carrot yields substantially particularly under conditions of high stress, including heavy rainfall, high winds and high weed pressure, all of which are quite common in carrot producing areas of MI. We estimate that adoption of these practices could result in a 5-10% improvement in marketable yield and a direct increase in cash receipts of over $1 million for MI carrot producers. Continued studies and demonstration trials will improve our understanding of the consistency of these results and provide growers with increased confidence that the extra seed costs are justifiable.

Although we saw no improvements in yield under strip tillage in our trials, the fact that strip-tillage did not reduce yields is an important result that should increase grower confidence that this approach is useful. Indeed, three major growers of carrots for processing have adopted strip-tillage, primarily as a means of reducing risk of stand losses due to heavy wind. Heavy winds were not an issue in our two years of trials, but under the strip tillage system, cover crop windbreaks are maintained through the early season, to help insure that stand losses do not occur.

Finally, our results provide evidence that under conditions of high nematode pressure, addition of compost may be a worthwhile investment. We saw reductions in carrot culls under compost treatments in 1 year, although no benefits were seen in the second year. Growers have expressed interest in this result, and it is spurring additional research to further understand the potential benefits of this practice.

**PROGRESS TOWARDS LONG TERM OUTCOMES**

Improvements in carrot stand establishment, resilience to extreme weather events and soil health will help improve the profitability of carrot producers in both the short and longer term. We anticipate that our proposed work with carrot seed treatments, strip-tillage, compost applications and higher seeding rates will improve carrot stand establishment, thereby allowing growers to save costs of re-planting and/or costs of yield or quality reductions due to sub-optimal planting densities.

**PUBLICATIONS AND PRESENTATIONS**

Brainard, D. C. and D.C. Noyes, "Tillage and Plant Population Effects on Carrot Culls and Yield", (December 2010). Great Lakes Fruit, Vegetable, and Farm Market Expo, Grand Rapids, MI. (Published in proceedings.)


Popular Press Articles featuring carrot research:


Figure 1. Relationship between final population density and marketable yield. Data is combined for all three varieties.

Figure 2. Relationship between final population density and percentage of cull carrots by weight, 2009 and 2010. Data is combined for all three varieties.
Photo 1: Carrots emerging in strips between barley windbreaks

Photo 2: Carrot density trial, Oceana county, 2010
Figure 3. Effects of tillage and compost on yield of three processing carrot varieties: Canada, Recoleta and Finley.
Photo 3: Seed treatment trial at Muck Farm, 2010

Table 1: Seed treatment effects on stand establishment and crop yield, 2010

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Early Planting</th>
<th>Late Planting</th>
<th>17 DAP*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number (#/m)</td>
<td>Yield (kg/m)</td>
<td>Culls (%)</td>
</tr>
<tr>
<td>Apache</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>57 a</td>
<td>2.5 a</td>
<td>5.5 ab</td>
</tr>
<tr>
<td>Fungicide</td>
<td>92 b</td>
<td>3.6 a</td>
<td>3.9 a</td>
</tr>
<tr>
<td>Primed**</td>
<td>109 c</td>
<td>5.3 b</td>
<td>7.4 b</td>
</tr>
<tr>
<td>Sun 255</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>101 c</td>
<td>3.6 a</td>
<td>8.6 c</td>
</tr>
<tr>
<td>Fungicide</td>
<td>105 c</td>
<td>4.0 a</td>
<td>6.5 bc</td>
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<tr>
<td>Primed***</td>
<td>124 d</td>
<td>5.4 b</td>
<td>4.3 a</td>
</tr>
</tbody>
</table>

*Days after planting
**Primed but no fungicide treatment
***Primed and fungicide treated