Identification and Management of Factors Limiting Hybrid Carrot Seed Production in Australia

by

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Summary

Worldwide, carrot seed production is a highly dynamic industry, with vegetable breeders contracting the production of proprietary varieties to areas where technology and climate combine to give the most reliable yields of high quality seed. Australia has had a significant share of the world market for carrot seed production since 1984, servicing customers in Asia, Europe and the United States. Since the mid 1990s, requirements for increased quality and reliability of production, coupled with improvements in the production standards of other carrot seed exporters, have threatened Australia’s market share. The failure of a significant number of Australian crops to meet the current minimum production standard of 85% seed germination required by export markets has been the major issue faced by the industry during this period. In addition, producers have experienced difficulty in consistently achieving satisfactory yields of seed of some hybrid varieties.

The present study was undertaken to address both of the issues facing Australian producers, with an emphasis on achieving improvements in the production of seed of European hybrid carrot varieties. Preliminary work established that the problems of low germination and unreliable yields were largely unrelated, leading to two research themes based on cause and management of low germination and unreliable seed yield.

Low germination of Australian seed lots was closely correlated to the occurrence of seeds without embryos or with embryos exhibiting extensive physical damage. Surveys of carrot fields and caging trials in South Australia and Tasmania established that both conditions resulted from feeding of the endemic insect, Nysius vinitor Bergroth (Hemiptera: Lygaeidae) on developing carrot seeds. Adult N. vinitor were found to infest carrot seed crops in a series of migratory flights from shortly before flowering until harvest. In Tasmania evidence was collected that suggested that a significant proportion of migrants originate from nearby areas of weedy host species. During peak periods of migration populations of up to 17 insects per carrot plant were observed. Field based
caging trials showed that loss of germination due to *N. vinitor* feeding could occur from flowering through to harvest. For individual male sterile plants, daily reductions in seed germination of 0.04 to 0.11% per insect were observed during this period.

Because of the need to respond quickly to *N. vinitor* infestation to minimise germination loss, work was undertaken to develop protocols for monitoring the insect in carrot seed crops. In trial plots, sticky traps detected migrations of *N. vinitor* into carrot fields, with the number of insects caught closely correlated to average population densities on the plants. In commercial crops *N. vinitor* population densities were non-randomly distributed across the fields, with gradients associated with the prevailing wind directions during the periods of migration. Thus, the positioning of the sticky traps was shown to be important for reliable detection of *N. vinitor* as well as accurate estimation of population size.

The issue of unreliable seed yield was examined in two hybrid crosses, No. 22, a 3-way (F1 male sterile line) Nantes hybrid with brown anther cytoplasmic male sterility (CMS) and W0030, an F1 Nantes hybrid with petaloid CMS. Two alternative hypotheses; source limitation (assimilate) and pollination limitation, were tested to explain the occurrence of low seed yields. Shading, umbel removal and leaf trimming treatments applied to both hybrids over two seasons did not significantly affect seed yield, seed size or seed quality. Supplemental hand pollination treatments increased seed yield by up to 284%, providing evidence that seed yield was strongly limited by inadequate pollination in No. 22, and to a lesser extent in W0030. In both hybrids, pollination was restricted by variable pollen viability at anthesis, low pollen longevity under field conditions and low rates of pollen transfer to the male sterile line.

Commercial hybrid carrot seed production is based on the strip method of hybrid seed production in which rows of the pollinator line are alternated with the male sterile line. Within the strip method, varying the ratio of pollinator and male sterile lines between 1:4 and 4:4 and distance between adjacent male beds between 2.4 to 7.2m had no effect on pollination or seed yields of No. 22. Surveys of insect pollinator visitation, pollen loads
and foraging patterns explained these results. Honeybees, *Apis mellifera ligustica* Linnaeus (Hymenoptera: Apidae) and two Dipteran species *Calliphora ruficornis* Macquart (Diptera: Calliphoridae) and *Eristalis tenax* Linnaeus (Diptera: Syrphidae) effected most pollination in carrot seed plots. All three species showed a strong tendency for directional foraging within a single row of plants, thereby restricting the opportunities for pollination of the male sterile line. These findings suggest that the strip method of production may be incompatible with the foraging behaviour of some important pollinators of hybrid carrots and hence the attainment of optimum seed yields in some varieties.

This thesis identifies significant opportunities for improvement of the quality and reliability of hybrid carrot seed production in Australia. Management protocols for *N. vinitor* derived from the research have contributed to an increase in the percentage of commercial carrot seed crops achieving the germination standard required for export from below 70% prior to 2000 to 100% in 2003. Studies of yield variability identify inadequate pollination as a contributing factor. Efforts to improve pollen viability and pollen transfer in commercial production may contribute to greater reliability of hybrid seed yields.
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General Introduction

This chapter is written in three sections. The first provides a brief historical background to the Australian carrot seed industry within the context of the worldwide industry. The status of the Australian industry during the late 1990s, at the time of commencement of this project, and the development of the problems that were its genesis are described. The second section explains the concepts of reproductive development and seed production that are fundamental to the research that was undertaken. The final section of the chapter describes the focus and broad objectives of the research and outlines the structuring of this thesis.

1.1 - The Carrot Seed Industry

Worldwide Carrot Seed Production

Worldwide, in excess of 3000 ha of carrot seed crops are produced annually (Schreiber and Ritchie, 1995; Simon, 2000). A large proportion of this is contracted or ‘in house’ production of proprietary varieties for vegetable breeding companies. The United States (Washington, Oregon, Northern California and Idaho) and southern France currently dominate the seed production industry. Other significant producers include Australia, New Zealand, Italy, Israel, Japan and Chile. Based on the figures provided by Schreiber and Ritchie (1995) and Simon (2000) hybrid seed accounts for approximately 60% of carrot seed production.