



*Know-how for Horticulture™*

**Study tour of carrot  
seed producing  
regions in the Pacific  
North West of the  
United States and  
attendance at the 28<sup>th</sup>  
International Carrot  
Conference in Pascoe,  
Washington**

Cameron Spurr  
University of Tasmania

Project Number: VG00074

## **VG00074**

This report is published by Horticulture Australia Ltd to pass on information concerning horticultural research and development undertaken for the vegetable industry.

The research contained in this report was funded by Horticulture Australia Ltd with the financial support of South Pacific Seeds.

All expressions of opinion are not to be regarded as expressing the opinion of Horticulture Australia Ltd or any authority of the Australian Government.

The Company and the Australian Government accept no responsibility for any of the opinions or the accuracy of the information contained in this report and readers should rely upon their own enquiries in making decisions concerning their own interests.

ISBN 0 7341 0295 X

Published and distributed by:

Horticultural Australia Ltd

Level 1

50 Carrington Street

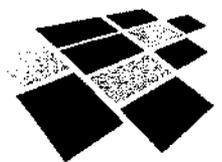
Sydney NSW 2000

Telephone: (02) 8295 2300

Fax: (02) 8295 2399

E-Mail: [horticulture@horticulture.com.au](mailto:horticulture@horticulture.com.au)

© Copyright 2001



**Horticulture Australia**

**VG00074 (9/9/00)**

**“Study Tour of Carrot Seed Producing Regions in the  
Pacific North West of the United States and Attendance at  
the 28<sup>th</sup> International Carrot Conference in Pascoe,  
Washington”**

**Cameron Spurr**

**School of Agricultural Science  
University Of Tasmania**

# HRDC Project VG00074

Cameron Spurr

School of Agricultural Science, University of Tasmania

GPO Box 254 – 54 Hobart, Tasmania 7001, Australia

Telephone (03) 6226 2651

E-mail [cspurr@postoffice.utas.edu.au](mailto:cspurr@postoffice.utas.edu.au)

30/5/01

This project was jointly funded by:



South Pacific Seeds, Australia

and Horticulture Australia Ltd.



## Disclaimer

Any recommendations contained in this publication do not necessarily represent current Horticulture Australia policy. No person should act on the basis of contents of this publication, whether as to matters of fact or opinion or other content, without first obtaining specific, independent professional advice in respect of matters set out in this publication.

## **Purpose of the Tour**

A PhD project at the University of Tasmania in conjunction with South Pacific Seeds is aiming to improve the results of hybrid carrot seed production in South Australia and contribute to the establishment of a hybrid carrot seed industry in Tasmania. The United States is recognised as a world leader in the production of hybrid carrot seed. The specific purpose of this study tour was to make contact with leading vegetable seed researchers and producers through the 28<sup>th</sup> International Carrot Conference and a subsequent tour of carrot seed production regions and research centres in Washington State, Oregon and California. Such contact is considered valuable for future research and to ensure the local industry is familiar with current best practice. The objective of the tour was achieved with a good picture of new developments in the United States with respect to both hybrid carrot seed production and research.

## **Media Summary**

Attempts at hybrid carrot seed production in Southern Australia have met with mixed success, due to unreliable yields and poor seed quality. Similar difficulties have been reported from other production areas outside Australia (Dean *et al*, 1989). A PhD project at the University of Tasmania in conjunction with South Pacific Seeds is currently investigating some of the major factors involved, with the aim of contributing to the development of sustainable hybrid carrot seed industries in South Australia and Tasmania. The development of links to vegetable seed researchers and producers in the Pacific North West of the United States, where a world-leading hybrid carrot seed industry exists, was deemed to be an integral component in the early stages of this project. A 16-day study tour of carrot seed producing regions in the Pacific North West including attendance at the 28<sup>th</sup> International Carrot Conference in Pascoe, Washington, provided an ideal opportunity to develop these links. The outcomes of this include; information on the latest developments in carrot seed production and research; identification of opportunities for improved practice within the Australian industry; local research with an improved focus and awareness of overseas developments; and the development of links to leading vegetable seed researchers with potential for future collaboration. Information from both the study tour and the current PhD program has, and will continue to be, disseminated using several means. These include presentations at conferences including the Australian Carrot Conference (Western Australia, 2000) and the Australian Agronomy Conference (Hobart 2001), presentations to Industry, including South Pacific Seeds's Annual Production Conference (Griffith, 2001) and contributions to grower newsletters and field days.

## **Results of Discussions and Implications For Hybrid Carrot Seed Production In Southern Australia**

Information gathered during the study tour has been grouped into the following categories: 28<sup>th</sup> International Carrot Conference, Climatic Conditions and Cultural Practices for Hybrid Carrot Seed Production and Hybrid Carrot Seed Research Issues. These are reported by title below.

### **28<sup>th</sup> International Carrot Conference**

The 28<sup>th</sup> International Carrot Conference in Pascoe, Washington State, USA brought together industry leaders and scientists in both the fields of vegetable and seed production. A broad range of topics was addressed, with conference sessions on vegetable and seed production, products and marketing, pest management and genetics and breeding. Whilst many of the presentations were directed at vegetable production some of the issues raised, particularly crop establishment, disease management and weed control have relevance to seed production. Abstracts and contact details for most presentations can be found at the 28<sup>th</sup> International Carrot Conference Website <http://www.proed.wsu.edu/spevents/carrot2000/>.

Several presentations were of particular interest to seed producers, notably those on new forms of cytoplasmic male sterility and alternative pollinators for hybrid carrot seed production.

Considerable research effort is being directed towards the development of new forms of cytoplasmic male sterility (CMS) for hybrid carrot production. The reasons for this are largely based on removal of a genetic bottleneck limited by the current CMS systems. In particular, reducing the risk of cytoplasmic linked susceptibility to disease is a priority. Two new forms of CMS, one based on complete reduction of the stamens and petals (GUM type) and the other based on reduced white petals and a total reduction of the anthers have been identified (MAR type) (Nothnagel, 2000). Given

the documented importance of similar male and female flower forms and colours for successful hybrid pollination in carrots (Erickson et al, 1979), the importance of petals for successful bee pollination (Hogarth, 1998) and the link between the stamens and nectar production in carrots (Erickson et al, 1982), both are likely to be less suitable for pollination than currently existing CMS forms.

Currently, blue bottle flies (genus *Calliphora*) are being trialed as potential pollinators for hybrid seed crops. These insects have long been used for glasshouse pollination but appear to offer several advantages over honey bees for field based pollination (Ponses, 2000). These included less discrimination in terms of the flower forms that they will forage and the ability to forage at lower temperatures compared to honey bees. Techniques for successfully introducing these insects into field crops and ensuring that they remain within the crop are currently under research by the commercial carrot seed producer, Polonica Seeds. Preliminary results indicate improvements in pollination of field crops when blue bottle flies are used in conjunction with honeybees.

A poster presentation detailing preliminary findings of the current PhD program at the University of Tasmania on the effects of a sap sucking bug, rutherghlen bug (*Nysius vinitor*) on carrot seed quality and yield (Spurr, 2000) was well received. Feedback on the presentation indicated that in both the United States and parts of Europe, another sap sucking bug, lygus bug remains the primary cause of poor seed viability in carrots. In these areas effective control strategies based on monitoring programs and timely applications of chemicals are being refined, enabling the production of high quality carrot seed. These strategies are discussed in greater detail in the research section. The development of similar management strategies for rutherghlen bug has potential to greatly improve the quality of carrot seed produced in Australia.

## **Climatic Conditions and Agronomic Practices for Hybrid Carrot Seed Production**

The Pacific North West of the United States has a long established and successful carrot seed production industry. During the study tour hybrid carrot seed production sites in the Columbia Basin, Washington State, the Madras region of Central Oregon and Modesto, California were visited. These regions are noted for producing good yields of quality hybrid carrot seed. In particular, the Madras area is widely acknowledged as a leading area for production of the European type Nantes hybrid carrots. These currently present the greatest difficulty for Southern Australian producers and are the type on which it is hoped the Tasmanian Industry will be based. In this section some of the key climatic conditions and cultural practices in the Australian and United States Industries are compared and implications for Australian production discussed.

### **Climatic Conditions**

Whilst the effects of temperature on pollination and carrot seed development have not been documented, there is a widespread belief in the United States industry that summertime temperatures influence seed yields and quality through an impact on both pollination and subsequent seed development. This belief is supported by studies in other vegetable seed crops including onion (Chang and Struckmeyer, 1976), where high temperature has been shown to adversely affect pollen viability, fertilisation and embryo development. In the Pacific North West, producers have observed that European type hybrid carrots yield well in Bend (Madras area) but fail to set seed at Modesto. In contrast other types of carrot seed crops, including Chantenay, perform well at Modesto. One notable difference between the two regions is that the Madras area is subject to much milder summertime temperatures compared to Modesto (figures 1 and 2).

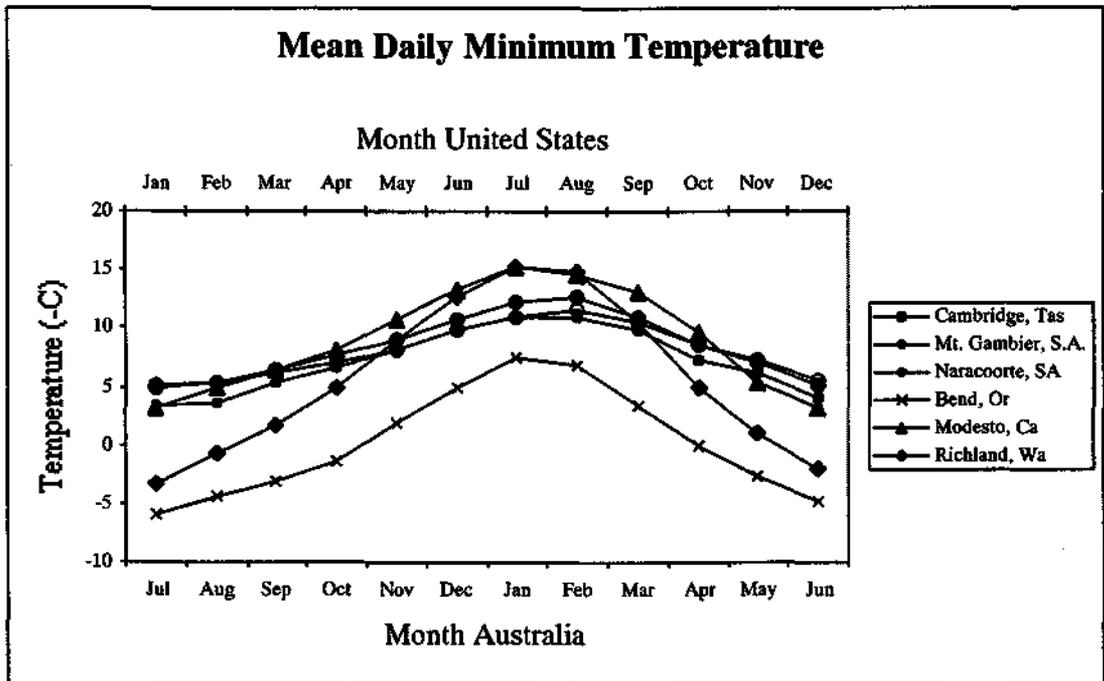
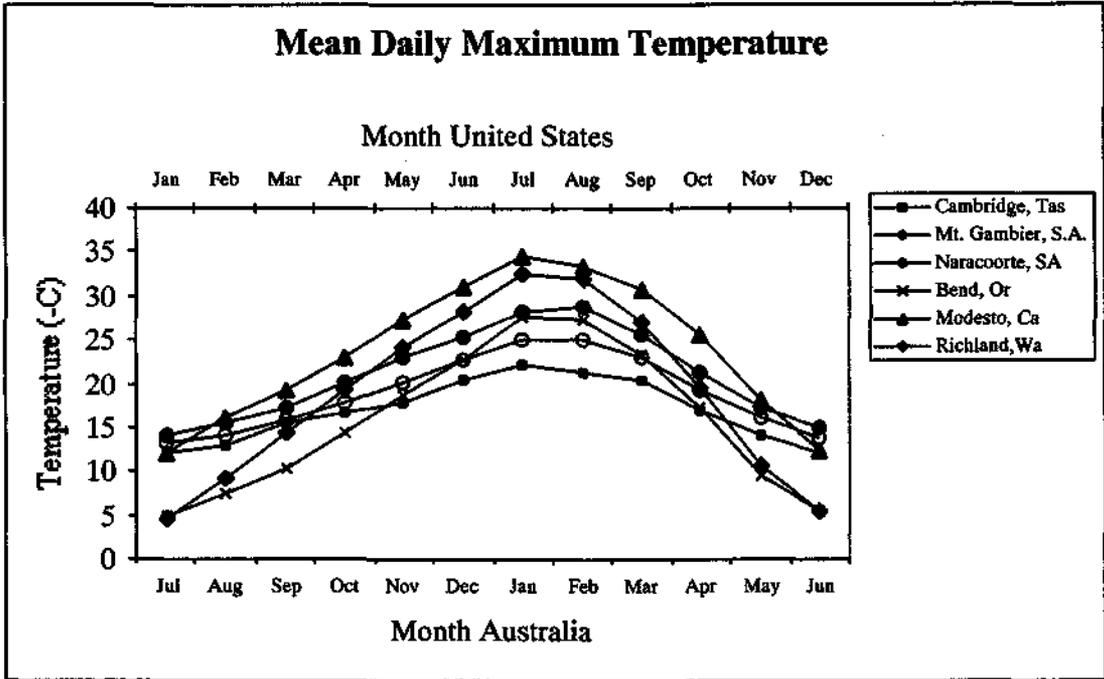


Figure 1 – Long term mean monthly maximum and minimum temperature data for Cambridge, Mt. Gambier and Naracoorte, Australia and Bend, Modesto and Richland, United States. Data sourced from Bureau of Meteorology, Australia and Western Regional Climate Centre, United States.

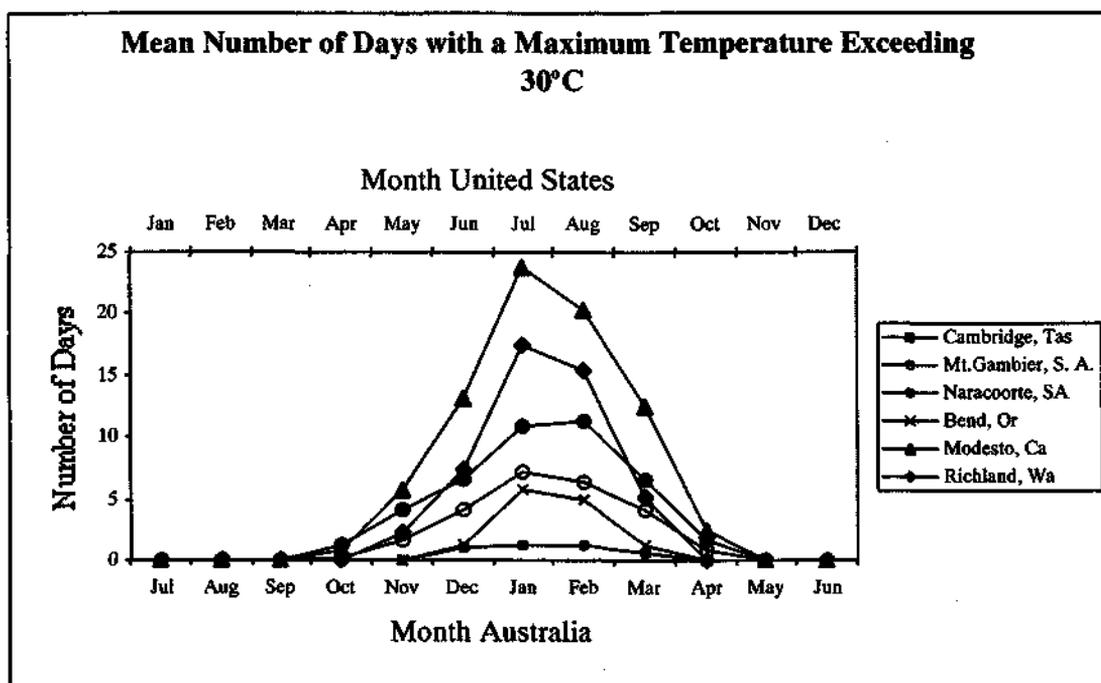


Figure 2 – Long term mean number of days with a maximum temperature exceeding 30°C for Cambridge, Mt. Gambier and Naracoorte, Australia and Bend, Modesto and Richland, United States. Data sourced from Bureau of Meteorology, Australia and Western Regional Climate Centre, United States.

Australian producers have concerns over the impact of high summertime temperatures on seed set and development in European type hybrid carrots. A comparison of long term temperature data for Bend, Modesto and Richland with current production sites in Australia, Narracorte, Mt Gambier and Cambridge is presented in figures 1 and 2. Whilst care should be taken in interpreting such data in terms of differences in seed production between locations, several points are worthy of mention. During summer and early autumn, when carrot seed crops flower and mature, temperatures are higher and high daytime temperatures more common at Modesto and Richland than any of the Australian sites. On average though, Naracoorte does have slightly higher daily maximum temperatures, and both Naracoorte and Mt. Gambier have a greater number of days per month exceeding 30°C, than Bend, which may contribute to comparatively poorer seed yield and quality. In contrast, at Cambridge, mean daily maximum temperatures and number of days per month with temperatures exceeding 30°C are lower over the summer and Autumn period than at Bend. The incidence of high

temperature is therefore unlikely to limit yields and quality at Cambridge compared to Bend.

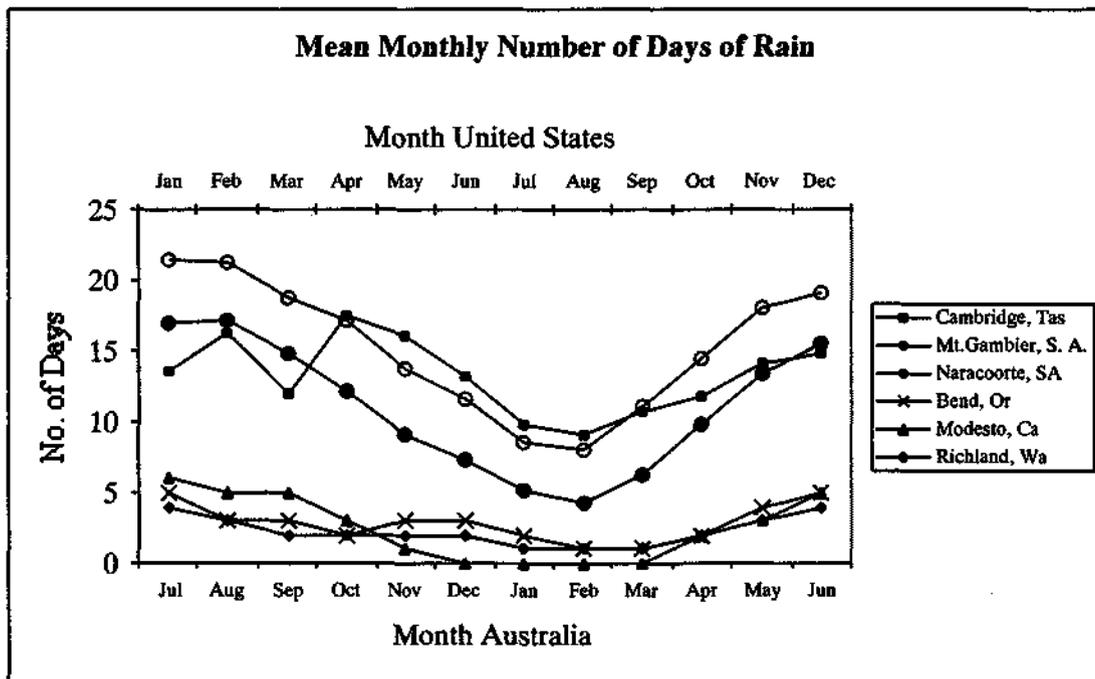
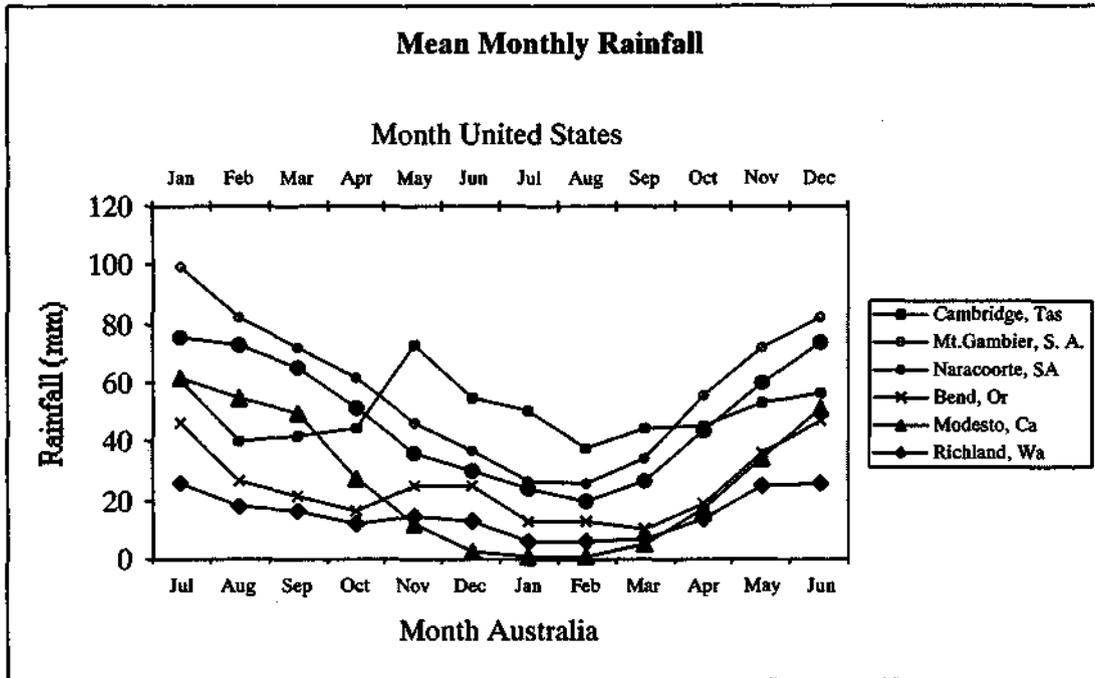


Figure 3 – Long Term mean monthly rainfall and mean number of rain days per month for Cambridge, Mt. Gambier and Naracoorte, Australia and Bend, Modesto and Richland, United States. Data sourced from Bureau of Meteorology, Australia and Western Regional Climate Centre, United States.

It should also be noted that mean daily minimum temperatures are much lower at Bend than at any other location. The impacts of these low minimum temperatures on seed set and development are unknown.

The very low winter temperatures of the United States sites compared to Australia offer an advantage in term of reduced over wintering of disease pathogens but can cause the loss of crops through 'freeze outs' when the ground freezes and expands, forcing the carrot roots out of the ground.

The incidence of rainfall between the Australian and United States sites is compared in figure 3. Australian sites receive a higher summer and autumn rainfall in terms of both amount of precipitation and number of rain days. Rainfall during the flowering period can negatively impact on pollination and seed yields. During seed maturation, rainfall can increase the incidence of seed borne disease and reduce seed germination and vigour. Whilst producers can do little about the effects on pollination and seed quality, timely applications of fungicide can reduce rainfall induced seed borne disease.

### **Agronomic Practices For Hybrid Carrot Seed Production**

Hybrid carrot seed producers in the United States are amongst the world's leaders in best practice. Most Nantes type hybrid carrot seed crops produced in the Madras region of Oregon yield 250 – 400+ Kg of seed per hectare and consistently meet the industry requirement of 85% or higher germination. In contrast Nantes hybrid seed crops produced in Southern Australia vary widely in yield from 100 to 500 Kg per hectare, with most closer to 100 Kg/ Ha. Furthermore, most crops fail to achieve 85% germination. Whilst many of the agronomic and cultural practices in the United States and Australian Industries are similar, opportunities exist for Australian producers to adopt beneficial practices from the United States. Some of the key

agronomic and cultural factors in both industries are compared in Table 1 and differences between the industries are discussed below.

FACTOR	UNITED STATES	AUSTRALIA
Crop Establishment	Sown mid July onwards. Precision sowers or mechanical thinners used to establish very uniform stands. Early establishment is critical for successful flowering	Sown late February onwards. Most stands not precision sown or mechanically thinned. Early establishment critical
Irrigation	Predominantly furrow irrigation to minimise risk of disease	Overhead irrigation resulting in increased disease pressure
Disease Problems	Disease problems minimal due to combination of cold winters, warm, low humidity conditions during the growing season and furrow irrigation. Relatively low chemical input	Alternaria and Cercospora infections common from bolting onwards due to overhead irrigation and higher summer rainfall. These also contribute to the incidence of seed borne disease. Heavy reliance on chemical control.
Pollination / seed set	Flowering period no more than 4 weeks. Pollination principally by honey bees. Hybrid pollination is variable due to differing attractiveness of lines. Suspected difficulties with seed abortion in high temperature low humidity environments in certain lines.	Flower period generally greater than 4 weeks. Honey bees used for pollination but native insects make a significant contribution. Hybrid pollination is variable due to differing attractiveness of lines. Some problems (Tasmania) with competition for pollinators from native vegetation and other crops. Aborted seed appears to be a problem in certain lines.
Pest Management	Lygus bug is the major pest during seed maturation. Most production companies have monitoring programs with empirically established thresholds for control. A range of chemicals are available for control. Control strategies are successful.	Rutherglen bug is a major pest during seed maturation and is the principal cause of poor seed germination in carrot seed crops grown in Australia. Monitoring strategies and thresholds need to be developed for effective control. A range of chemicals need to be assessed as suitable control agents.

Table 1 – A comparison of some key agronomic and cultural factors in the United States and Australian hybrid carrot seed industries for crops using the seed to seed method of production.

### Crop Establishment

A critical factor for production of seed to seed hybrid carrot seed, particularly Nantes lines, is early establishment. In contrast to most Australian crops United States crops are established using either precision sowing equipment or are mechanically thinned to accurate spacings to give very uniform stands. Although the benefits of this have not been quantified, there are a number of perceived advantages. These include:

- A lower percentage of plants failing to flower, resulting in improved yields.

- A more uniform flowering and reduced flowering period, which contributes to more even seed maturity. This in turn contributes to better timing of harvest and improved yields and quality. A reduced flowering period also facilitates chemical control of lygus bug as a greater number of chemicals are available for use once pollinators are not a factor.

There is potential for Australian producers to benefit from adopting technology or practices that will result in more evenly spaced stands.

### **Irrigation**

In the Pacific North West the majority of carrot seed is produced with furrow irrigation of levelled fields or dripper tape irrigation. In contrast, in Southern Australia almost all irrigated carrot seed production relies on the use of over head irrigation. This is a large disadvantage for the Australian industry in terms of incidence of disease and has led to a much greater reliance on chemical control and higher chemical inputs compared to the United States Industry. Of particular concern are infections of *Alternaria sp* and *Cercospora sp.* during flowering, which severely limit seed yield and quality, and an increased incidence of seed borne pathogens such as *Alternaria sp.* and *Xanthomonas sp.* As the quality standards for vegetable seed rise, customers and industry regulators are increasingly demanding seed free of pathogens. Such requirements are difficult to achieve in crops produced with overhead irrigation. Australian producers will therefore need to adopt cost effective alternatives to overhead irrigation in order to gain the economic benefits associated with disease free crops and to reliably meet industry requirements for disease free seed. Whilst furrow irrigation may not be an option for many producers due to the constraints of their land and infrastructure, dripper tape irrigation may provide a viable option, particularly for higher value seed crops.

## **Pollination**

In the United States and mainland Australia, honeybees are the principal pollinators of hybrid carrot seed crops. In Tasmania, honeybees are used but tend to be diverted onto other crop and native nectar sources, with native pollinators playing a much more important role in pollination. One producer in Oregon, Round Butte Seed Growers, has developed stringent selection criteria for pollinator hives, with factors such as bee strain, hive age, pollination history and foraging behaviour being taken into account when selecting hives for carrot pollination. They report that this selection process has, over a number of years, improved pollinator efficiency. The problem of competing nectar sources is also addressed to some extent by staggering the introduction of hives into the crop during the flowering period.

Several producers in the United States including Polonica and Seminis Seeds, are developing techniques for the introduction of a range of pollinator species into hybrid seed crops. Early data from Seminis Seeds indicates that this strategy may result in improved seed yields in brassica crops, but it has not been tested on carrots.

In both industries there are difficulties with seed set in some hybrid lines. This has been attributed to a range of factors including pollen viability, inadequate pollen transfer and abortion of developing seed. There has been little research to properly identify the basis of the problem.

## **Pest Management**

Lygus bug (*Lygus oblineatus*) has long been recognised as the primary cause of embryoless carrot seed in both the United States and Europe (Flemion, 1949). Early infestations during flower bud development also contribute to yield loss. Both the nymphs and adults of lygus bug feed on reproductive carrot plants by sucking the sap from developing ovaries and seeds. Although there is little published research on the subject, most carrot seed production companies have conducted their own research to

develop monitoring strategies and thresholds for control and have a good understanding of the biology of the insect.

Monitoring strategies are based on weekly sweeping of carrot seed crops with a butterfly net. Sweeping is conducted from the onset of flowering until seed harvest as caging trials have demonstrated that lygus bug can cause crop damage throughout this period. Comprehensive guidelines for sampling have been developed by Krivohlavek (1999) in conjunction with Seminis Seeds. On the basis of this sampling technique and caging trials, thresholds for pesticide application of an average of 0.1 – 0.2 adults per sweep and 0.05 nymphs per sweep have been developed. In properly managed fields this results in less than 10% embryoless seed. Thresholds for nymph control are lower than for adults because they are more voracious feeders. Furthermore, adult thresholds have been set to prevent the risk of significant egg deposition and subsequent nymph hatches on the carrot plants. An additional aspect of the control program for lygus bug has been the identification of alternative host plants. Mustard, wild radish and vetch and crops of onion, garlic, safflower, sunflower and alfalfa have been identified as alternative hosts. Consequently weed control in crop borders and choice of adjacent crops are important factors in the control of lygus bug in carrot seed crops.

A range of pesticides have been registered for use on lygus bug in carrot seed crops. Amongst those in current use are: Endosulfan ® (a.i. alpha and beta endosulfan) Capture® (a.i. bifenthrin), Orthene ® (a.i. acephate) and Monitor ® (a.i. methamidophos). Several companies have also developed techniques for controlling lygus bug organically, but the information is closely guarded.

Rutherglen bug (*Nysius vinitor*) has recently been confirmed as the primary cause of embryoless seed from Australian carrot seed crops (Spurr, 2000). Both lygus bug and rutherglen bug belong to the same suborder of the order Hemiptera (true sap sucking bugs), Heteroptera, but are quite different in terms of both taxonomy and biology. Whilst they are similar in terms of mode and site of feeding on reproductive carrot plants, damage inflicted on the developing seed and alternative hosts, rutherglen bug infests carrot seed crops in far greater numbers. Furthermore, whilst lygus bugs are

predominantly found on the umbels, rutherghlen bugs often shelter in leaf axils beneath the reproductive canopy and may therefore require different monitoring strategies. Clearly, the control program used by the United States is not directly transferable to the Australian industry, but can serve as a useful model for the development of an appropriate control strategy. Research requirements for this are discussed in the following section.

## **Hybrid Carrot Seed Research Issues**

Currently, there are two major issues within the Australian hybrid carrot seed industry in need of research; the development of effective control strategies for rutherghlen bug to minimise the incidence of embryoless seed, and poor seed yields. Within the United States Industry the problem of embryoless seed has largely been overcome through the development of control strategies for lygus bug, but poor seed yields remain an issue in some lines. This section expands on the current research requirements and reviews developments within the United States. Recommendations are made as to the future direction of local research.

## **Control Strategies for Rutherghlen Bug**

Control of lygus bug in carrot seed crops in the United States is based on a monitoring system with established threshold for control and a range of suitable chemical controls.

In order to effectively control rutherghlen bug, the Australian carrot seed industry requires information on the damage relationship between rutherghlen bug and carrot seed crops similar to that available to the United States Industry for lygus bug. Specifically, information on the following is required:

- The population dynamics and biology of rutherghlen Bug.

- The stage of seed development at which rutherghlen bug damage can occur.
- The importance of different stages during the rutherghlen bug life cycle to seed damage (ie. nymph vs adult).
- Appropriate monitoring strategies.
- Threshold levels of infestation for control.
- The importance of alternative host crops and weeds to infestation of carrot seed crops.

In response to these requirements, research into the seasonal population dynamics of rutherghlen bug, the stage of seed and insect development at which damage occurs and thresholds for control are being investigated as part of the current PhD program at the University of Tasmania.

The insecticide Endosulfan® has been used to provide knock down and residual control of rutherghlen bug in rotation with various pyrethroid insecticides in carrot seed crops within Australia. With the increasing restrictions on the usage of Endosulfan® and development of new insecticides, there is a need to evaluate the potential of a range of alternative insecticides. Impact on pollinator insects may be an important issue given that rutherghlen bug damage has recently been observed during flowering and early seed development (Spurr, unpublished data). In response to this, a range of insecticides is being evaluated for control of rutherghlen bug in carrot seed crops by South Pacific Seeds.

## **Low Seed Yields**

The issue of poor seed yields in hybrid carrot seed crops has been widely reported and the impact of many agronomic treatments have been trialed with limited success. Pollination is often considered to be the cause of poor seed yields in hybrid carrot seed crops in the United States, but other than investigations into the attractiveness of different forms of cytoplasmic male sterility to pollinators and the use of alternative pollinators, has been poorly researched. The current PhD program at the University of Tasmania has demonstrated that Tasmanian hybrid carrot seed yields can be significantly increased when insect pollination is supplemented with hand pollination in both brown anther and petaloid CMS types (Spurr, unpublished data). A current objective of this research is to identify factors contributing to the inadequacy of pollination, for example pollen viability, pollen transfer or events during pollen tube growth, fertilisation and subsequent seed development. With this in mind, an aim of the study tour was to examine the research and techniques being used to investigate pollination of carrot seed crops in the United States.

Discussions were held with several seed researchers from France and the United States during the 28<sup>th</sup> International Carrot Conference, and also with Research and Development groups from Polonica Seeds and Seminis Seeds. Companies breeding carrots primarily conduct pollination research and the results are closely guarded. It appears that research is currently limited to the screening of hybrid males for ability to cross with females prior to commercial release. Few breeders screen for pollen viability and those that do use the aceto-carmin staining test. As this tests only for the presence of cytoplasm it provides a limited estimate of pollen viability. Other more precise pollen viability tests are available but have not been validated for use with carrot pollen. Techniques for other aspects of pollination biology studies do not appear to have been validated for use with carrot pollen.

In several hybrid vegetable seed crops including members of the umbelliferae, inadequate pollen transfer, arising from low levels of insect visitation to one or both lines has been identified as the major factor limiting seed yields. Techniques for the assessment of factors affecting insect visitation levels have been developed for hybrid

onion seed crops (Silva and Dean, 2000; Dean and Silva, in press). These include quantification of nectar production, analysis of nectar content and analysis of floral volatiles. Insect visitation and seed set have been correlated with both nectar production and floral volatile profile. These techniques are likely to be of value in carrot pollination studies if insect visitation is shown to be the major factor limiting seed yields.

Although it is widely believed in the industry that temperature during flowering and seed development plays an important role in determining seed yields, particularly in European type hybrids, the impact of temperature on factors such as carrot pollen viability, fertilisation and seed development have not been studied.

On the basis of these findings several recommendations can be made with respect to the direction of local research into low carrot seed yields.

- Whilst pollination is implicated as a limiting factor in carrot seed yields, little research has focussed on which aspect of pollination, for example pollen viability, pollen transfer, pollen growth in the pistil, fertilisation or subsequent seed development, is most limiting seed yields and the factors that affect this. Clearly such an understanding is important in order to be able to develop practical strategies to improve yields.
- In order to conduct such research there is clearly a need for development of techniques for use in carrot pollen biology studies. Techniques for assessing pollen viability, levels of pollen transfer and for examining events during fertilisation and seed development would be of value immediately. Such techniques are readily available to pollen biologists for a wide range of species but have not been validated for use on carrots.

## **Summary**

The Australian hybrid carrot seed industry can benefit from the adoption of some of the cultural practices employed by producers in the Pacific North West of the United States. These include, the use precision sowing or thinning equipment to achieve more uniform stands and the use of alternatives to overhead irrigation. The development of control strategies for rutherghlen Bug similar to those used for lygus bug in the Pacific North West is also of great importance to the Australian industry. In light of this, development of control strategies is a key area requiring research. There is evidence that seed yields in Australia and the United states are limited by pollination and seed abortion. The underlying cause of these limitations remains poorly understood and is in need of research. In order to do this there is a need for validation of techniques for the study of carrot pollen biology. Links developed with leading vegetable seed researchers during this study tour will be of benefit for furthering Australian hybrid carrot seed research.

## **Dissemination of Information**

A key objective of this study tour was to learn of developments in research in the United States with respect to hybrid carrot seed production and build links to vegetable seed research groups within the United States. Information and links arising from this are, and will continue to, be of benefit to vegetable seed research being conducted at the University of Tasmania.

The current research program involves a close working relationship with South Pacific Seeds and has links to other major seed production companies. These relationships provide an opportunity for regular contact with stakeholders at all levels in the Australian carrot seed industry. A formal presentation to South Pacific Seeds in August 2001 will highlight the latest developments in hybrid carrot seed production in the United States, the results of research initiated on the basis of this study tour, and future research directions.

Presentations, including a report of findings from this study tour, have been made at the Australian Carrot Conference (Western Australia, 2000) and the Australian Agronomy Conference (Tasmania, 2001). Written contributions to South Pacific Seed's production newsletters have informed growers of developments in hybrid carrot seed production and research. Publication and presentation of research findings from the PhD program is an ongoing priority.

## **Recommendations for Future Travel**

The International Carrot Conference is a biennial conference held in various areas of the United States. It attracts leading carrot breeders, producers and researchers from both the United States and Europe. Much of the research presented is of an applied nature and is aimed at vegetable production and would be of benefit to researchers and producers alike. People with an interest in carrot seed production also benefit from sessions dealing specifically with breeding and seed production. Furthermore, the conference provides an excellent opportunity to develop links with leading vegetable seed researchers given that most carrot breeding companies within the United States and Europe, and vegetable seed research groups within the United States, are represented. The 29<sup>th</sup> International Carrot Conference will be held at in Bakersfield, California in February 2002. Details can be obtained from the International Carrot Conference Website <http://vric.ucdavis.edu/carrot/>.

The Pacific North West offers considerable benefits as a destination for study tours by Australian vegetable seed producers and researchers. It is a major, long established region for vegetable seed production and leads the world in many aspects of vegetable seed production best practice and vegetable seed research. In this region, several research facilities such as the Washington State University Irrigated Agriculture Research and Extension Centre and Seminis Woodland Research Centre have well recognised vegetable seed research groups. Combined, these groups are at the leading edge of both theoretical and applied research into vegetable seed production.

## **Itinerary**

- Aug 25<sup>th</sup>, 2000**      **Depart Hobart, Tasmania.**
- Aug 27<sup>th</sup> – 30<sup>th</sup>**      **Attend XXVIII<sup>th</sup> Carrot Conference in Pasco, Washington State.**
- August 29<sup>th</sup>**      **Meet with Bill Dean, Washington State University Irrigated Agriculture Research and Extension Centre.**
- Aug 30**      **Meet with Krystina Markevich-Ladd of Polonica Seeds**
- Aug 31<sup>st</sup>**      **Meet with Kurt Farris of Round Butte Seed Growers, Culver, Oregon.**
- Sept 1<sup>st</sup>**      **Meet with Steve Ferschweiler of North Pacific Seeds, Willamette Valley, Oregon.**
- Sept 5<sup>th</sup>**      **Meet with researchers at the Seminis Vegetable seeds Woodland Research Centre, California.**
- Sept 6<sup>th</sup>**      **Meet with Peg Coffin of Haris Moran Seed Company, Modesto, California.**
- Sept 7<sup>th</sup>**      **Meet with Chad Garewal of North Pacific Seeds, San Joaquin, California.**
- Sept 9<sup>th</sup>**      **Return to Hobart, Tasmania.**

## **Acknowledgments / Contacts**

The financial support of South Pacific Seeds and the Horticulture Australia towards this study tour is gratefully acknowledged.

The time and effort of the following people in meeting with or hosting the author on the tour of seed production regions is also gratefully acknowledged:

Peg Coffin, Harris Moran Seed Company, California

Bill Dean, Washington State University Irrigated Agriculture Research and Extension Centre.

Kurt Farris, Round Butte Seed Growers, Culver, Oregon

Steve Ferschweiler, North Pacific Seeds, Willamette Valley, Oregon

Chad Garewal, North Pacific Seeds, Modesto, California

Krystina Marchevich-Ladd, Polonica Seeds

Eric Sorenson , Washington State University Co-Operative Extension Unit.

Juan De Vries, Matt May and Julian Barrera, Research and Development, Seminis Woodland Research Centre.

## References

Chang, W. N. and Struckmeyer, B. E. (1976) Influence of Temperature, Time of Day, and Flower Age on Pollen Germination, Stigma Receptivity, Pollen Tube Growth, and Fruit Set of *Allium cepa* L. *Journal of the American Society for Horticultural Science*. 101; 1, 81 – 83.

Dean, B.B., Noland, T. and Maguire, J. D. (1989) Correlation of low seed quality with growing environment of carrot. *Hortscience* 2; 247 – 9.

Dean, B. B. and Silva, E.M. (In Press) The effect of hybrid onion floral volatiles on honey bee activity.

Erickson, E. H., Peterson, C. E. and Werner, P. (1979) Honey Bee Foraging and Resultant Seed Set among Male Fertile and Cytoplasmically Male Sterile Carrot Inbreds and Hybrid Seed Parents. *Journal of the American Society of Horticultural Science*. 104; 5, 635 – 38.

Erickson, E. H., Garment, M. B. and Peterson, C. E. (1982) Structure of the Cytoplasmic Male-Sterile and Fertile Carrot Flowers. *Journal of the American Society for Horticultural Science*. 104; 6, 698 - 706

Hogarth, C. R. (1998) Apetalous Canola (*Brassica napus*) Hybrid Seed Production. PhD Thesis, University of Tasmania.

Krivohlavek, R. V. (1999) A study of the activities and control of the lygus bug. Report prepared for Seminis Seeds.

Nothnagel (2000) Results of a Project to the Development of New Sources of Male Sterility of Carrot. 28<sup>th</sup> International Carrot Conference presentation.

Ponses, P. (2000) Pollinating Carrots Using Blue Bottle Flies. 28<sup>th</sup> International Carrot Conference presentation.

Silva, E. M. and Dean, B. B. (2000) Effect of nectar composition and nectar concentration on honeybee visitations to hybrid onion flowers. *Journal of Economic Entomology* **93**; 1216 – 1221.

Spurr, C. (2000) Improving Hybrid Carrot Seed Production in Southern Australia. 28<sup>th</sup> International Carrot Conference presentation