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Figaro Natoli

Sam Calameri

Albert Grubelich

Allan McKay

Elaine Davison

See next page for additional authors

Authors
Figaro Natoli, Sam Calameri, Albert Grubelich, Allan McKay, Elaine Davison, and David Ellement

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Session 1

AN OVERVIEW OF CURRENT AND FUTURE TRENDS IN THE UK AND EUROPEAN CARROT INDUSTRIES

P.T. Wright
Watton Produce Company, Hargham Road, Shropham
NR17 1DT, UK

SUMMARY

The food industry is being rationalised. This will lead to fewer, larger retailers and fewer, larger suppliers. These suppliers will have production sites in European countries other than that in which they are based.

The environment and worker welfare will be high on the agenda.

Prepared carrots will have a major impact on the industry and increase carrot consumption.

INTRODUCTION

During the last ten years European carrot industries have markedly increased yields of quality carrots. The widespread use of hybrid varieties, air seeders, fungicides and irrigation have been major factors. The application of scientific research has helped in these advances.

The UK industry has been encouraged to consider environmental and welfare issues as well as quality issues. The speculative nature of the industry has held back similar commercial advances. Financial peaks and troughs are quite normal. Destructive retailer price wars have exacerbated the problem.

The trade in carrots is such that the availability in Europe can affect prices in every European country.

BACKGROUND INFORMATION

Retailer Two types are considered:

- National supermarket chains such as Sainsbury's
- National companies such as Mack Southampton, which supplies small wholesalers, retailers and catering groups.

Supplier

- A company that grows and packs it's own carrots. The major suppliers will also have in addition dedicated growers producing crops. The supplier would process at least 300 ha of carrots annually.

General Statistics

- Annual UK carrot area 11-14,000 ha (27-35,000 acres). The area is declining (1)
- Annual UK carrot tonnage 500-700,000 tonnes (1).
- The UK and France are the largest producers of carrots in Europe, supplying 40 per cent of its needs (2).
- UK yields have increased by about 40 per cent over the last ten years, hence the decline in area.
- Value of the UK crop ex-farm is US $65-130 million (1).
- Consumption has declined by about 2 per cent over the last five years.
- Average time spent in the kitchen in the UK is 20 minutes per day in 2000 compared to 60 minutes in 1980.
- Price returned to the supplier has declined by about 30 per cent in real terms during the previous decade.

RESULTING TRENDS AND IMPLICATIONS

1. **Retailer trend**s

   Retailers will become fewer, larger and multinational.

   They will become so either by acquisition or by being acquired. ASDA, the UK's third largest retailer was bought by the US retail giant Wal-Mart in 1999. Other major UK retailers could be taken over. Carrefour (France) and Ahold (Holland) are likely contenders.

   Implications: New owners of the retailers may have other suppliers.

   Retailers are rationalising their supplier base.

   Fierce retailer competition continues to put downward pressure on prices. This reflects on the price paid to suppliers. The result has been fewer and larger suppliers. This trend is likely to continue with large, high volume/low margin suppliers remaining.

   Implications: Some suppliers may disappear or become part of the remaining suppliers.

2. **Supplier trends**

   Suppliers will become multinational.

   Remaining suppliers will be expected to deliver all retailer needs. Such needs will be met in part from other areas of Europe, notably the south. In 1990 no UK supplier had grower or production bases abroad. In 2000 the six biggest suppliers have grower and/or production bases abroad. Further links may be made through trade co-operation, partnerships or merger.

   Key suppliers will act as Category Managers. They will develop new products and put forward ideas and plans to retailers to increase sales and profit for all. All operations will be to high technical and commercial standards.

Implications: Suppliers unable to meet standards will cease to trade with the retailer. Category Management suppliers will be judged against competitor retailer Category Managers.

Suppliers will work to high ethical and environmental standards.
The UK Assured Produce Scheme (crops) considers environmental issues. Schemes based on Assured Produce are being transferred to Europe via EUREP. UK suppliers are furthering its development with its overseas associates. The British Retail Consortium (BRC) accreditation scheme is being transferred to mainland European production sites. Worker welfare is considered by this scheme.

Implications: Adverse media publicity, which, reflects upon the retailer will not be tolerated.

3. **Consumer trends**

Prepared carrots will have a major impact on the consumer and increase overall carrot consumption.
European consumers have increasingly high levels of disposable income. The desire for maximum leisure time reflects on the time now spent in the kitchen. The consumer does however want to eat tasty, healthy and reasonably priced food. Prepared carrots fit these criteria well.

Carrot sticks (batons), shredded carrot and frozen diced and baby carrots have been on the market for some years. The latest addition is peeled mini carrots, originally from the USA. In the US it is estimated that 40 per cent of carrots consumed are now in this form (3). Ready to eat products comprise 26 per cent of all fresh produce sales in the US and Europe is following this trend.

Peeled mini carrot plants now operate in the UK and Holland. Others are being built in Spain and Portugal. A plant also operates in New Zealand!

Peeled mini carrots differ from other prepared carrot products. Imperator carrots are used rather than Nantes or Amsterdam types. The roots are slender, small cored, and crisp textured. New varieties have excellent sweetness and flavour. They are attractive and ideal as a healthy snack.

The commercial development of the peeled mini carrot involves major changes from conventional carrot production practices:

- crops need to be harvested at their peak of flavour, sweetness and size grade
- varieties quality differs through the year
- sequential sowings are required to maintain quality
- there may be no alternative market for unsold crop
- different geographical locations are required, some in southern Europe, to ensure quality supply through the year
- ready-to-eat peeled mini carrots require strict hygiene production standards
- investment costs are high in equipment, development and whilst creating a market
- time scale from concept to production can be up to two years.

Implications: Many existing whole carrot suppliers would be unable to fulfil all of the above requirements. New suppliers, particularly from industries already producing prepared ready-to-eat products are likely to fuel the growth of this new market.

Overall carrot consumption will increase. Some of this however, will be at the expense of the whole carrot market.

ACKNOWLEDGEMENTS
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CARROT TRENDS IN NORTH AMERICA

R. Freeman
Sunseeds Co, 8850 59th Avenue NE, Brooks, Oregon 97381, USA

Fresh vegetables have experienced significant changes in both consumption and production in the United States and Canada over the last 20-30 years. Carrots have participated in these changes as much as any other vegetable. Consumption of fresh raw carrot has been a popular part of the North American vegetable diet for most of this century.

Several trends have impacted carrots throughout the last three decades, but the 1990s produced huge changes in the way carrots are used and produced. When discussing North America, one should realize that the vast majority of production and consumption occurs in the countries of the United States and Canada. Nevertheless, Mexico and Central America have some important domestic production.

Mexico and Central America currently use mostly open-pollinated sub-tropical varieties in the Nantes class. The production area is fairly stable and is mostly composed of very small family farms. Most carrots are grown for domestic use. There is a trend of greater use of hybrids in both the Imperator and Nantes class but it is still a small percentage of the whole.

In the US and Canada, Imperator type varieties have been the mainstay of growers for over 50 years. At this point, over 90 per cent of the US production is grown from Imperator hybrids and this has been solidified with the success of cut & peel carrots. New Imperator hybrids are very high in carotene content, flavor, foliage disease resistance and yield. Many shapes and sizes of Imperators have been developed to accommodate the various niche market uses.

Several carrot trends have taken place over the last 30 years. In the **1970s**, new hybrids started taking market share from established open-pollinated varieties (OP). These first hybrids were not much of an improvement in yield but did provide better uniformity and color. Seed germination and/or field tonnage was often inferior. Significant production began shifting into California from the eastern US areas such as Florida, Texas, Michigan. Consumption was basically flat.

In the **1980s,** production continued to shift to the irrigated desert regions of southern California. Californian production probably tripled during this decade as further declines occurred in the traditional eastern production areas. There was a final shift to almost all hybrid use. Better root quality and foliage resistance showed up in new hybrids that also provided better marketable yields. Per capita consumption began to show slight increases. At the end of the decade, production and market experimentation entered a new phase of vegetable product presentation - fresh cut processing. Carrot cut & peel product started showing up in very small amounts as did cut lettuce mixes.

In the **1990s,** there were some very major changes in the way carrots were produced and sold. The most important was a very rapid growth in production and acceptance of cut & peel carrots. These fresh-cut carrots, as well as cut salad mixes, were huge phenomena in retail produce markets. As demand fueled greater and greater production capacity, many things began to happen. Retail pricing leveled off, consistency in carrot quality and delivery improved, and consolidation of packers began. More production shifted west into California as a greater percentage of the fresh market was taken over by cut & peel carrots.

As packers got bigger and more competitive, a high level of management attention was paid to root quality in the hybrids used (flavor, texture and carotene) as well as to field management of these new hybrids. Closer monitoring of fields for nitrogen usage, irrigation, micro-nutrients and disease was implemented. The larger grower/packers hired agronomists and field specialists to aid in this management. The carrot packers of California funded important relevant research.

Carrot per capita consumption increased by more than 50 per cent in the 1990s, mostly attributable to the quality, convenience and popularity to children of the new cut & peel carrots. The next consumer generation was locked into a new carrot product such as happened 40 years earlier with bunched carrots to cello.

Other 1990s trends were a shift from traditional processed product (frozen and canned slices and cubes) using Chantenay, Nantes and Danvers OPs to more use of Imperator hybrids that provided better color. This also provided an outlet for excess product not used in the fresh end. Organic production took off in the 1990s and became a mainstream product in carrots. Other uses of carrots provided variety to the consumer - juices, sticks, crinkle cuts and shreds all developed a niche. Carrot acreage shifted even more into the desert southwestern US as this climate and soil is ideally suited to high-density plantings of cut & peel Imperator varieties. This also provided close proximity to the main processor/packers that were producing the vast majority of cut carrot product.

Consumer's desire for fresh and convenient vegetables in their diet has caused many new carrot markets to develop in North America. Cut & peel carrot product is one of the most significant expressions of this. Consumption of carrots is rising and the future looks bright for carrot demand in the young generation.

TRENDS IN FRANCE

G. Simon
Vilmorin Seed Co., 30210, Ledenon, France

STATISTICS

France produces around 650,000 tonnes of carrots each year on 16,000 hectares. It is the biggest carrot producer in the European Union, closely followed by the United Kingdom. Together, these countries account for 40 per cent of the 3,300,000 tonnes of carrots produced in the European Union.

FRESH MARKET

Eighty per cent of French carrot production goes to the fresh market (mainly non-processed carrots). The yield has increased in recent years although the cultivated areas has remained constant. Average commercial yield is around 40 to 50 tonnes per hectare.

Sandy soils, water availability, large flat fields, farmers looking for alternatives to corn, and production feasibility almost 11 months per year, have boosted carrot growing in **Aquitaine** (a 40 per cent increase in production since 1995). This region has developed modern equipment (e.g. electronic sorting in packaging units) and now produces half of the French carrots for the fresh market. Part of its early production is exported to the UK.

CANNING and FREEZING

The food processing industry utilizes 130,000 tonnes of carrots each year, mostly for production of canned true baby carrots (using open-pollinated Amsterdam-type varieties sown at high density : 12 to 13 kg of seeds per hectare). Autumn King varieties (open-pollinated or hybrids) are also cultivated for canned or frozen mixed vegetable preparations.

PESTS and DISEASES.

Carrot fly (*Psila rosae*), cavity-spot (*Pythium* sp.), Alternaria blight (*Alternaria dauci),* nematodes (*Heterodera carotae*, *Meloidogyne* sp.), *Rhizoctonia solani* and powdery mildew (*Erysiphe heraclei*) are the main pests and diseases affecting carrots in France .

RESISTANT VARIETIES

Nantes is the predominant variety type for fresh market. The creation of hybrids partially resistant to Alternaria blight, powdery midew and cavity-spot has allowed better control of these diseases .

SEED PRODUCTION

France has become the main European country for carrot seed production. Areas have increased from 1,000 hectares in 1990 to 2,000 hectares in 1999, with the majority devoted to hybrid seed production.

CONSUMPTION TRENDS

The carrot industry is changing to more closely meet consumer needs. Public concerns about food safety have resulted in integrated crop management and organic production. The search for convenience food will probably lead to the development of new ‘Ready to eat’ or ‘Ready to cook’ products in the coming years.

TRENDS IN CARROT PRODUCTION IN AUSTRALIA

A.G. McKay[A] and T.R. Hill[B]
[A]Agriculture Western Australia, Locked Bag 4, Bentley Delivery Centre 6983, Western Australia
[B]Agriculture Western Australia, PO Box 1231, Bunbury 6231, Western Australia

INTRODUCTION

Australian carrot production has increased steadily over the past decade to reach an estimated 258,000 tonnes from 7,000 hectares in 1997 (1). Victoria (38 per cent) and Western Australia (20 per cent) were the major carrot producing states (Table 1). Australian per capita consumption of carrots has increased from about 8 kg/person in 1990 to 11.5 kg/person in 1997 and exports of carrots have also increased.

In recent years, industry rationalisation has accelerated with a smaller number of larger carrot producers dominating the Australian industry. Large-scale expansion has occurred in areas where year-round production has made it possible for specialised operations to enter into supply contracts with supermarket chains. One area where this expansion has been particularly evident is along the Murray River in Victoria.

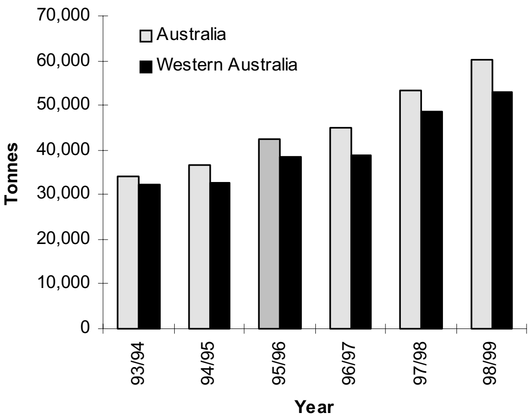
Table 1. Carrot production by Australian state in 1997: source (1)

State	Production (tonnes)
Victoria	99,300
Western Australia	53,000
South Australia	40,300
Queensland	28,400
Tasmania	23,000
New South Wales	14,000
Total	258,000

Nantes carrot varieties, such as Stefano (= Maestro) currently dominate fresh market carrot production in Australia.

EXPORTS

Export of fresh carrots from Australia has grown rapidly over the past decade to 60,000 tonnes in 1998/99 (Fig. 1). More than 85 per cent of Australian carrot exports are Nantes varieties produced in Western Australia and shipped to Asia (Table 2). Some Kuroda carrots are also grown in Tasmania over summer for the Japanese market.



Increasing competition from other countries, most notably New Zealand and China, has put pressure on prices. The direct costs of production of fresh market carrots in New Zealand is estimated to be in the range $A100 to $A120 per tonne while Australian costs are in the range $A160 to $A180 per tonne. Australian exporters predict a loss of market share for Australian

Fig. 1. Australian carrot exports from 1994 to 1999

producers during the main New Zealand carrot harvest season of February to July. Development of new markets for export carrots may help reduce the impact of increasing international competition.

Table 2. Major destinations and fob value of Australian carrot exports in 1998/99: source (1)

Country	$ A million
Malaysia	16.0
Singapore	8.6
Hong Kong	6.2
Japan	3.2
Thailand	2.6
Taiwan	2.2
United Arab Emirates	1.9

QUALITY ASSURANCE

Third party audited quality assurance schemes are becoming commonplace in Australian horticulture. Such quality assurance systems, including SQF2000^{CM}, and Freshcare are now being demanded by supermarket chains. Increasingly the focus will be on food safety

Following the trend in European agriculture, environmental accountability is likely to be increasingly demanded of producers by retailers and consumers.

PRODUCTION SYSTEMS

Integrated crop management In mainland Australia the dependence on sprinkler irrigation systems in vegetable production has resulted in high capital costs in developing vegetable production land. This, combined with increasing specialisation and a narrow range of crops in large carrot enterprises, has lead to inadequate rotations. Lack of suitable rotation crops that can be handled mechanically is becoming an increasing issue for carrot producers.

There have been recent reports of rapid breakdown of chemicals (enhanced biodegradation) following repeated application of chemicals such as metalaxyl (2) and metham sodium (3). Strategic use of chemicals will contribute to more sustainable integrated crop management systems that will be widely adopted in future.

Organic production Medium to large-scale production of organically grown vegetables is in its infancy in Australia. There are domestic and export market opportunities for certified organic carrots. Increasing consumer demand will drive some expansion in organic carrot production in the next decade. Organic production will also be supported by quality assurance systems to help ensure food safety.

PROCESSING

Less than 10 per cent of the annual carrot crop is processed. Some carrots are grown for juicing in Victoria and New South Wales. Sliced and diced frozen carrots are produced in Tasmania and 'mini-peel' carrots are produced in Queensland and South Australia.

The market for mini-peel carrots in Australia is currently very small. Retail trends suggest a 'mini-peel boom' such as has occurred in the U.S.A. is at least 5 to 8 years away in Australia and then will only occur if the flavour of mini-peel carrots is improved to match that of fresh carrots. None the less, in future there are likely to be opportunities to increase value-adding for carrots as consumption of pre-prepared food increases.

MARKETING

In future we will see large producers with direct links to exporting companies and supermarket chains in Australia and overseas become more dominant. Smaller-scale producers will struggle to compete unless they develop highly specialised niche markets or else realise the opportunity to cooperate with other producers to reduce production, packaging and marketing costs.

The trend for increasing prepacking of carrots for retail sale will continue and greater choice of carrot products will be available to consumers.

Globalisation While removal of international trade barriers may present producers with new market opportunities in the short to medium-term, the challenge for Australian producers in the longer-term will be to remain competitive with overseas producers who may target the Australian domestic market.

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Session 2

CARROT BREEDING

G. Simon
Vilmorin Seed Co., 30210 Ledenon, France

HISTORY

Use of male sterilities allowed the creation of the first F1 hybrids in the 1960's. Before this period varieties were heterogeneous populations. Uniformity and better root visual qualities were the first improvements brought by hydrids. Breeding for disease resistance has increased in the 1980's. It has led to the release of hybrids with partial resistance to *Alternaria* leaf blight, powdery mildew, aster yellows, cavity-spot. In the past decade, carrot breeding has focused more on consumer needs (eating qualities). Research on resistance to several pests (eg nematodes, carrot fly) is also on the way. At the same time breeding methods have evolved. The most striking changes are due to the development of molecular techniques in the past 10 to 15 years.

BREEDING OBJECTIVES

Along the past decades, new objectives have been added making a long list. In addition to the above mentioned traits (root qualities, pest and disease resistance), the main ones aim at improving yield and adaptation to mechanization. Specific characteristics are often needed, like earliness, premature bolting resistance, growth splitting resistance, climatic adaptation…

BREEDING TOOLS

Carrot breeding uses a lot of different tools :

- crossing and selfing (using cages and pollinator insects)
- a wide range of screening techniques, including pathology and taste tests
- statistics and computer science
- *in vitro* tissue culture
- molecular techniques (molecular markers, genetic modification, genomics…)
- field trials

Genetic modification may bring significant benefits to carrot breeding in the coming years. Transformation systems are applicable to carrots. The success of these techniques, however, will depend on general public perception of "GMO" and, more specifically, on the importance of the new added characteristics compared with the potential risks (e.g. transgene flow to wild carrot populations).

GENETIC RESOURCES

One particular characteristic of *Daucus carota* species is the large genetic variability available to breeders. This ranges from all the different cultivated types to the wide range of wild *Daucus carota* subspecies. This variability is far from being completely exploited. New sources of resistance and perhaps new characteristics will probably be found in the near future, especially in the wild germplasm.

SEED PRODUCTION

Hybrid seed production has considerably improved since the development of the first single-cross hybrids. Three-way hybrids and seed-to-seed techniques are now giving acceptable yields of good quality seeds.

CONCLUSION

Carrot breeding has brought significant progress in the last 40 years through hybrid varieties: better quality, improvement of commercial yield, disease resistance, and earlier varieties. Up to now, it has been a long process as 7 to 10 years have been necessary to make significant improvements. Molecular techniques will certainly allow greater efficiency and will, in some cases, speed up the genetic progress.

The coming decades will probably bring characteristics closely related to consumer demands. New varieties will be improved for pest and disease resistance (food safety), for taste, for nutritional qualities and for adaptation to transformation into convenient food products. Where will these improvements come from? New genes will be introduced from the not-yet exploited *Daucus carota* resources. Transgenes (from foreign species) will also probably be inserted by genetic modification. The relative importance of these two

RESEARCH ON CARROTS IN GERMANY

T. Nothnagel and P. Straka,
Institute of Horticultural Crops, Federal Centre for Breeding Research on Cultivated Plants (BAZ) ,
Neuer Weg 22/23, 06484 Quedlinburg , Germany

INTRODUCTION

Carrots are one of the most important vegetables in Germany. In 1999, 300,000 tonnes of carrots were produced on 8,000 hectares and is slowly rising. The crop has the second highest volume of production after asparagus. Carrot breeding is conducted by the company Julius Wagner (Heidelberg) and the former company Carl Sperling (Lüneburg), today GZG-Marne.

Main carrot types are grown for use in the food industry: 'Pariser Markt', 'Amsterdamer', 'Flakeer', 'Late Berlikumer', and 'Imperator', whereas 'Amsterdamer', 'Nantaise' and 'Berlikumer ' types are produced for the fresh market. Open-pollinated carrot varieties have largely been replaced by F_1 hybrids.

The aims of carrot breeding depend on the production method and the intended use. Breeders select for high carotene and sugar content, low nitrogen content, special root shapes, shape of crown, colour of phloem and xylem, smooth skin, early maturity, yield, tenderness, colour of leaves and storage ability. Disease resistance to *Alternaria dauci* and *Pythium* are very important.

GENETIC RESOURCES

The genebanks of the Institute of Plant Genetics and Crop Plant Research (IPK) in Gatersleben and of the BAZ maintain a total of 470 accessions of seven species of *Daucus*.

Genebank	No. of species	No. of accessions	Availability (%)
IPK	6	301	92
BAZ	1	169	38

Passport data are available on the homepages http://www.dainet.de/genres/ or http://www.ipk-gatersleben.de/ .

An extensive characterisation and evaluation is in progress within the scope of an ECP/GR-project (GenRes105) '*The Future of the European Carrot: a programme to conserve, characterise, evaluate and collect carrot and wild species*'. All results will be transferred into a European Umbellifer Database (EUDB) which will be partially available in 2001 on http://www.cgiar.org/ecpgr/platform/crops/umbellif.htm.

Breeders themselves maintain working collections, especially of open-pollinated varieties. Wild carrots are mainly of interest in research as a source of resistances, new cytoplasms and important traits.

RESEARCH ACTIVITIES IN THE GENUS *Daucus*

At the Institute of Applied Genetics of the University of Hanover (UHG) carrot research had a long tradition. The research includes investigations on the petaloid cytoplasmic male sterility (cms) system (5), investigations on the resistance against *Meloidogyne hapla* (3) as well as the development of molecular marker systems and the development of the first genetic linkage map of carrot (6, 8, 11). The carrot research was completed in 1999.

Nutrient dynamics in the rhizosphere and the mobilisation of phosphorus of carrot are subject of research at the Institute of Plant Nutrition of the University of Hannover (UH) (10).

Activities at the Institute of Plant Nutrition of the University of Giessen (UG) are mainly oriented to the somatic embryogenesis and physiological problems in the in vitro regeneration as well as the development of transformation systems (1, 2, 4).

Most of the German research activities in *Daucus* are concentrated in the BAZ in Quedlinburg so far. The Institute of Horticultural Crops maintains a working collection of 20 species and subspecies of *Daucus* and nearly 40 lines of cultivated carrots. Further, a collection of 12 alloplasmic carrot lines is available (cytoplasm donors are wild species and subspecies of *Daucus*).

In the last five years eight research projects in the BAZ included carrot cultivars or wild species and subspecies. Main topics are genome characterisation and manipulation, hybrid research, resistance and quality (Fig.1).

Four projects are focused, more or less, on the **genome characterisation**. In the course of a project of mapping important economical traits of carrots, two genetic linkage maps have been developed which contain more than 200 markers. The development of further molecular markers and a combined linkage map for both populations is in progress. A project for developing a set of trisomes of cultivated carrots encompasses the selection of trisomes, karyotype characterisation, and the development of chromosome markers (FISH). A protocol for an *Agrobacterium*-transmitted gene transfer was developed. The first transgenic carrots have been grown for investigation.

Three projects are involved in **hybrid research**. An extensive project is directed to the development of new sources of cms for hybrid breeding. Its basis is the search for spontaneously male sterile plants from wild relatives of carrot and induced alloplasmic male sterility. Three new types of cytoplasmic male sterility are now available (7).

An *in vitro* propagation method for special male sterile carrot lines could be developed.

To support the mapping and resistance project, there is an inter- and intra-specific crossing programme, aimed at developing carrot lines with traits of interest, introgressed from alien germplasm. The inheritance of the carrot organelle genomes and cytoplasmic nucleus interaction, were investigated in co-operation with the Institute of Genetics of the Humboldt-University of Berlin (UB) (9).

Topic **resistance**: From 1993 to 1996, 10 carrot varieties and 24 alloplasmic crossing lines were evaluated

for resistance to *Meloidogyne hapla*. Differences in the frequency of attack were significant.

Since 1997, a project has been focused on *Alternaria dauci*. In a first step a laboratory test was developed for the evaluation of resistance. Carrot lines with a stable low and high susceptibility could be selected and have been crossed for genetic studies and the development of molecular markers in future.

Carrot **quality** parameters are the subject of three projects in the BAZ Institute of Quality Analysis. Influences of the cytoplasm on quality determining substances and sensory impression in carrot were analysed and also the occurrence of α- and β-carotene, their precursors, and the sugar content in carrot breeding material. Carrots are being used as the model in a project on the application of near infra-red reflection spectroscopy for the estimation of phytochemicals and quality parameters in fruit and vegetables.

This lecture will give an introduction to the carrot research projects at the BAZ and present interesting results.

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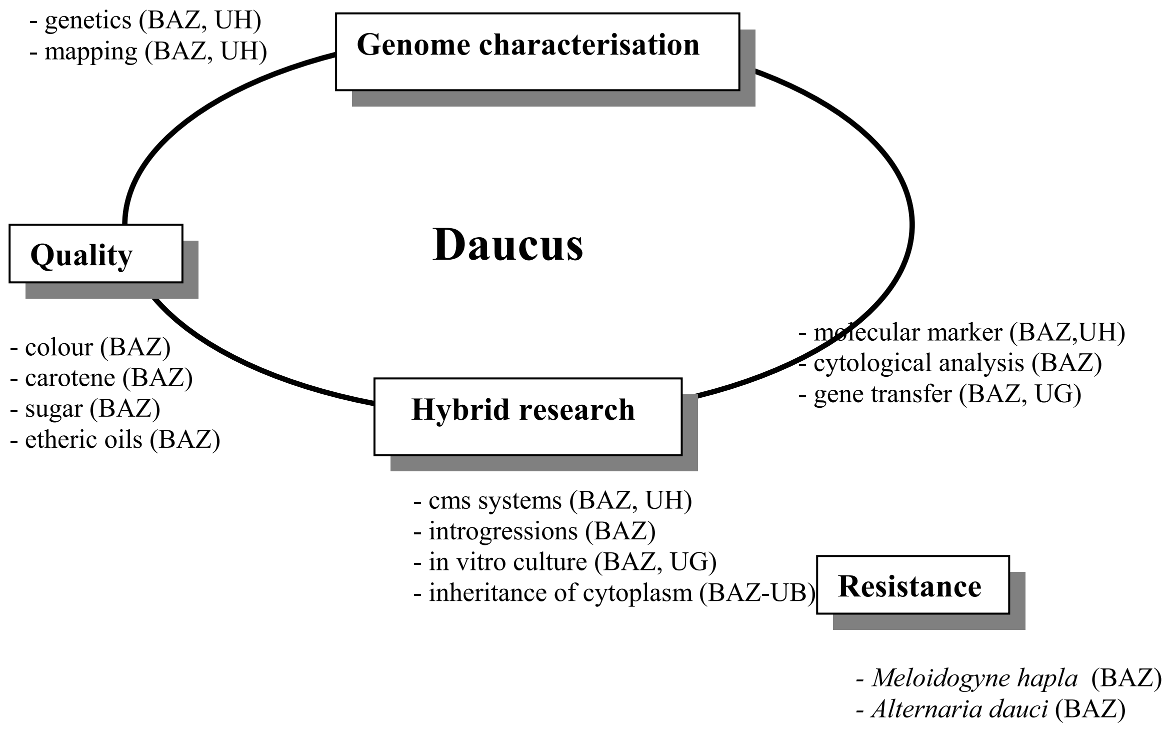

Figure 1: Overview of the research activities in the genus *Daucus* in Germany.

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VARIETAL ASSESSMENT

A.R. Hubbard
Bejo Seeds Pty. Ltd. PO Box 5627, Cranbourne, Victoria 3977, Australia

SUMMARY

In carrots, where hybridisation has lead to an enormous increase in product quality, Bejo plays a leading role. Uniformity, shape, disease resistance and tolerance have been greatly improved in a short time. But Bejo continues to work on improved quality and resistance to diseases and pests, in order to provide for customers needs well into the future.

INTRODUCTION

Varietal assessment is a vital part of the pre introduction and ultimately introduction of new varieties.

Bejo's background in carrots is significant. From it's base in Holland, Bejo is a vertically integrated company focused on breeding, production and sales to the world markets. The involvement in carrot breeding is considerable and encompasses Paris Market (round), Baby Finger, Amsterdam (bunching), Nantes, Berlicum, Flakee, Imperator, Chantenay, Danvers and more recently, Kuroda.

VARIETY TRIALS

Stage One

At Bejo, the testing of new lines are placed in trial situations called "V.O.'s" which stands for varietal observations. Newly bred varieties start life in sizable V.O.'s at a home site in Holland. It is not only the breeders who assess these trials. Sales personnel also spend considerable time viewing and scoring the new lines, as their background knowledge is from the market place, producers, processors, pre-packers, exporters etc.

Stage Two

The 'top prospects' from stage one go forward to V.O. trials at Bejo sites around the world. From this extensive testing, in very different climatic zones and soil types, a clearer picture of performance is scored, recorded and information circulated to all other Bejo company's.

Only a few varieties go forward to the next stage.

The key criteria for new varieties are:
(1) high marketable yield
(2) high quality roots and leaf
(3) greater disease resistance.

Stage Three

When seed is available enough of new varieties which have the potential to offer increased benefits over current used varieties, Bejo offers trial seed to interested producers and national independent trial stations (in some countries) for commercial testing. More often than not, the results are very similar to those from Bejo trial sites.

Indoor Stage

Running in tandem with the field trials, Bejo conducts rigorous checks for the disease tolerance and/or resistance of each new variety. This is done 'in house' within the laboratory complex in Holland. Similarly, flavour tests are conducted. Although flavour is an individual thing, there is a distinct difference between sweet and bland. Flavour has always been an important part of Bejo breeding/testing.

Organic Trials

For some years now, Bejo has been producing organic carrot seed. At first, just a few varieties, and currently becoming extensive. To obtain a true performance result, fully organic trial sites were established. Findings from these trials are also very useful when considering varieties for conventional production.

Recommendation

The investment by Bejo in trials and testing new varieties is considerable, and forms just a part of the total research and development expenditure of introducing new varieties. Whilst Bejo may be confident of the performance and potential of a new line, our recommendation to all producers is to carry out their own trial, on their own site, soil and under their own management regime. This is a most valuable part of variety testing, and could be described as 'the acid test'.

CARROT VARIETY TOLERANCE TO CAVITY SPOT

A.G. McKay and E.M. Davison
Agriculture Western Australia, Locked Bag 4, Bentley Delivery Centre 6983, Western Australia

INTRODUCTION

In 1998/99, 53,000 tonnes of carrots were exported from Western Australia. Nantes carrot varieties are produced for export and increasingly for the domestic market. Cavity spot, a soil-borne disease of carrots caused by *Pythium sulcatum* in Western Australia (1), reduces the marketablility of carrots.

Varietal tolerance to cavity spot is an important component of the integrated disease management strategy (2) for carrots. Attempts to develop laboratory methods to reliably screen for cavity spot tolerance in carrot varieties have been unsuccessful (3). The aim of this work is to screen Nantes carrot varieties for tolerance to cavity spot in the field.

MATERIALS AND METHODS

A cavity spot disease nursery site was established at Medina Research Station (latitude 32.13^o S) to enable screening of carrot varieties under high disease pressure. The soil was yellow Karrakatta sand of pH 6.5 (in $CaCl_2$) containing 0.4 per cent organic carbon in the surface soil (0-150 mm).

In 1994 the site was inoculated with cavity spot infected carrots from a commercial crop which were spread over the site and rotary hoed in. The cavity spot susceptible variety Primo (Vilmorin Seeds, France) was then sown on the site. Following this crop, which developed moderate levels of cavity spot, variety plantings were established on one quarter of the site. The remainder of the site was resown to Primo to maintain a high disease inoculum. Thereafter the site was continuously cropped with Primo while the variety plantings (a quarter of site) were rotated around the site and were preceded by at least two bulk crops of Primo to limit variation in disease history.

This autumn harvested trial was the seventh carrot crop on the cavity spot screening site at Medina Research Station site since 1994. Following broadcast application of 1,200 kg/ha superphosphate, 100 kg/ha potassium sulphate 100 kg/ha ammonium nitrate and 10 kg/ha borax, the site was rotary hoed and beds formed. Raw seed of 15 varieties, including the cavity spot susceptible variety Primo and the cavity spot tolerant variety Bolero, was sown on 20 December 1999 using an Earthway® seeder fitted with a modified lettuce disk. The plots were 4 m long by 4-double rows wide on 1.5 m wide beds. There were four replicates of each variety plot. Plants were thinned at the two to three true leaf stage to a target density of 70 plants/m^2.

Two days after sowing, a tank mix of 1.1 L/ha of Afalon® (linuron) and 2 L/ha of Treflan® (trifluralin) was applied for pre-emergent weed control. Fusilade® (fluazifop-butyl) (1 L/ha) and Afalon® (1.1 L/ha) were applied for post-emergent weed control. Post-planting fertiliser, applied through the overhead irrigation system, was 323 kg N/ha, and 315 kg K/ha and 15 kg Mg/ha. Bravo® (chlorothalonil) and Score® (difenoconazole) were applied to limit leaf blight (*Alternaria dauci)* development.

Carrots were harvested, washed, weighed and assessed for cavity spot from an early and a late harvest. Carrots with three or more lesions were rated as having severe cavity spot. The early harvest was 108 days after sowing (6 April 2000) and the late harvest was 129 days after sowing (27 April 2000). *Pythium* isolates were cultured from cavity spot lesions in randomly sampled carrots and identified according to (1).

RESULTS

Cavity spot *Pythium sulcatum* was isolated from cavity spot lesions. Varieties differed in tolerance to cavity spot. The interaction between variety and harvest time was not significant. Fig. 1 ranks the varieties based on the average incidence of severe cavity spot symptoms for the two harvests.

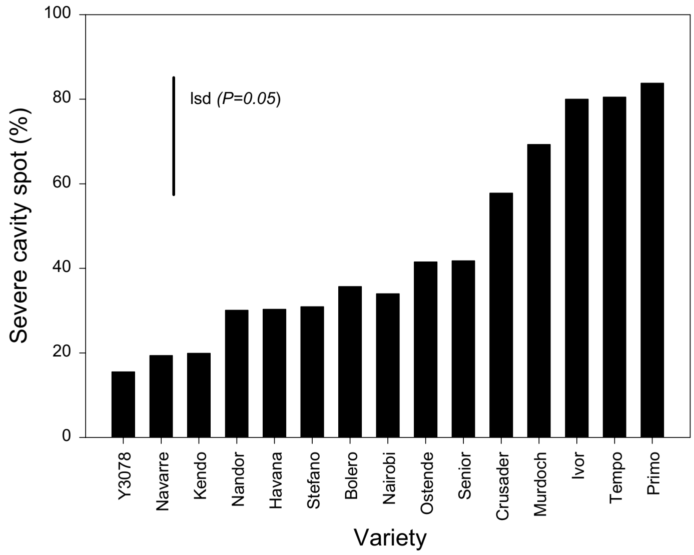

Figure 1. The incidence of severe cavity spot symptoms on carrot varieties grown in the disease nursery at Medina Research Station, Western Australia. Data are means from harvests at 108 and 129 days after sowing.

The most tolerant varieties including Navarre, Havana and Stefano, averaged less than 31 per cent severe symptoms while the most susceptible varieties, including Ivor, Tempo and Primo, averaged greater than 80 per cent severe symptoms. Severe cavity spot increased from an average 35 per cent at the first harvest to 54 per cent at the second harvest, 21 days later.

Yield Average total yield across all varieties increased from 54 t/ha at the first harvest to 68 t/ha at the second harvest. There was an interaction between variety and harvest time for total root yield. Ivor and Nandor had the highest yields at the first harvest, while Ivor, Nairobi and Navarre had the highest yields at the second harvest. Stefano produced the smoothest roots, however, it produced only 74 and 80 per cent of the total yield of Ivor at the first and second harvests respectively.

DISCUSSION

The disease nursery site at Medina Research Station allows the screening of carrot varieties for cavity spot tolerance under high disease pressure. In Western Australia cavity spot is caused by *Pythium sulcatum* (1) which is also the species that causes cavity spot on the Medina site. Large differences in the incidence of disease symptoms are observed among carrot varieties which means that carrot producers can grow tolerant varieties as part of a disease management strategy.

Selection of field tolerant varieties from a single harvest is satisfactory given the absence of a variety by harvest time interaction for cavity spot incidence. Grower trials of varieties identified with disease tolerance are important for assessing the suitability of varieties for commercial production and handling.

The challenge is to identify carrot varieties that:

- are cavity spot tolerant
- are suited to the local environment
- produce high yield
- produce smooth high quality roots
- have good flavour
- are bolting tolerant
- are not prone to breakage
- are free of other disorders and are
- are tolerant of other diseases including leaf blight.

Varieties combining the yield potential of Ivor with the disease tolerance and root quality of Stefano and the root toughness of Nairobi would be of great benefit to carrot growers.

ACKNOWLEDGEMENTS

We wish to thank the staff of Medina Research Station, especially Gavin D'Adhemar, for maintaining the experiment. Rob Deyl and Paul Murphy are thanked for technical assistance. Funding support from the Horticultural Research and Development Corporation is gratefully acknowledged.

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MANAGING CARROT ROOT SIZE

P.H. Brown, A.J. Gracie
Tasmanian Institute of Agricultural Research, GPO Box 252-54, University of Tasmania, Hobart Tasmania 7001

SUMMARY
The size of a carrot root is an important quality attribute for the crop, particularly when carrots are grown for export markets with stringent size specifications. This work has identified the major factors influencing variability in root size within carrot crops and developed recommendations for minimising variability in carrot size.

INTRODUCTION
Though yield of carrots can be large (70 tonnes/Ha or higher), it is not uncommon for packout to be low (e.g. approximately 60%) for fresh market carrots. An increase in the percentage packout of the carrots would substantially increase profit margins to both companies and growers. One of the major causes of low packouts in carrot crops is lack of size uniformity, that is, carrots failing to meet the stringent premium market size range. Project work has been undertaken to firstly identify the factors influencing carrot size uniformity and secondly strategies to minimise variability in size within commercial carrot crops.

MATERIALS AND METHODS
The work presented here has come from several trials run over the past three years. Kuroda and Nantes varieties have been used in the research. Trials have examined the effect of seed grading, plant spacing, arrangement and density on size uniformity in carrots. Seed grading on the basis of size and density was undertaken using a commercial service and the resultant seed lots characterised using standard ISTA seed testing procedures. Embryo size in seeds was assessed microscopically following extraction of the embryo from FAA treated seed. Carrots were harvested in all trials during the establishment phase (approx. 40 days after planting), early bulking (approx 80 days after planting) and harvest (approx. 120 days after planting) and assessed for mean size and shape characteristics as well as variability in carrot weight and length. Size variability was expressed as the coefficient of variability (CV) which is a statistical measure of variability independent of mean size.

RESULTS
Significant reductions in embryo size variability were achieved within seed lots by grading for both seed size and seed density. The results for three graded seed lots, designated high, medium and low variability, are shown in Figure 1. Grading to improved uniformity of embryo size within the seed lot also improved uniformity within the crop during the seedling stage but had little effect on variability at harvest.

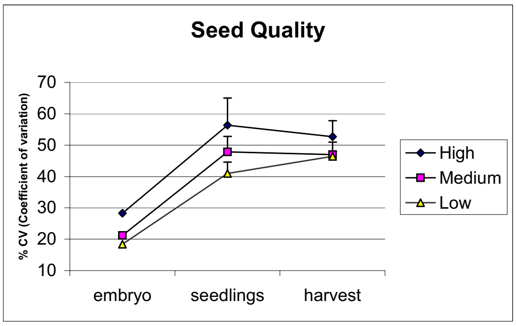

Figure 1. Effect of seed grading (high, medium and low variability seed lots) on size variability.

Salter *et al* (1981) and Benjamin (1984) both found strong relationships between variation of seedling weights soon after emergence and variation of mature root weights. Since CV of embryo length is strongly correlated with CV of seedling weight. (Gray *et al* 1986, Gray and Steckel 1983a, Gray and Steckel 1983a b) it seems reasonable that there should be a relationship CV of embryo size and the CV of mature carrot root. Gray *et al* (1986) tested this and did not find a significant relationship between CV of embryo and root weights at harvest. However, they did obtained a strong relationship between CV of embryo size and CV of seedling weight, but in contrast to Salter *et al* (1981) and Benjamin (1984) they did not find a relationship between CV of seedling and CV of the mature carrot.

The results from the seed grading trials suggested that competition between plants later in development was having a bigger impact on uniformity at harvest than variability during crop establishment. Both the arrangement of plants (Figure 2) and density (Figure 3) were shown to influence uniformity at harvest.

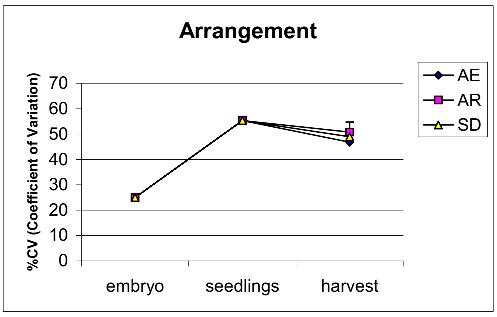

Figure 2. Effect of plant spacing on uniformity. Plants were spaced evenly (AE), randomly (AR) or standard planting (SD) at the same density.

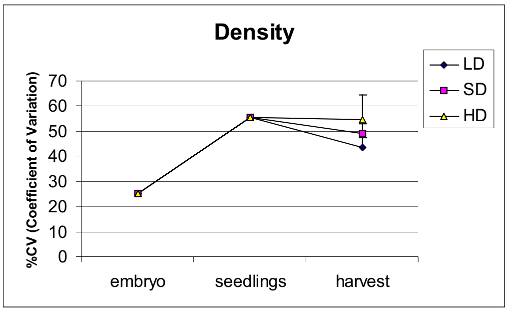

Figure 3. Effect of planting density on uniformity. Treatments were half standard planting density (LD), standard density (SD) and one third higher than SD (HD).

Improvements in root weight uniformity at harvest were obtained using even plant spacing and lower density planting. Yields obtained under lower density were not significantly different to those obtained at higher density, and therefore the yield of larger sized carrots was significantly higher. In addition, the proportion of carrots rejected due to poor shape characteristics was significantly lower under these treatments (Figure 4).

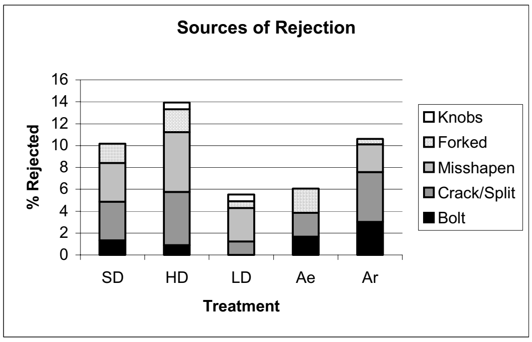

Figure 4. % reject carrots under standard density (SD), high density (SD), low density (LD), even arrangement (AE) and random arrangement (AR) treatments.

DISCUSSION

Current investigation has shown that seed quality in terms of uniformity of embryo sizes can have a large influence on uniformity of seedling establishment, and is directly correlated with uniformity of carrot size until approximately 80 days after sowing. After this period competition appears to be the main factor influencing uniformity of root size. Density and evenness of spacing of the carrot seedlings at establishment also influence the distribution of taproot sizes at harvest and other important shape characteristics for marketing.

ACKNOWLEDGEMENTS

This work is part of the HRDC funded project VG9719 Factors Influencing Carrot Size and Shape. The support of Field Fresh Tasmania, Harvest Moon and Serve-Ag is acknowledged.

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Session 3

USING SOIL MOISTURE MONITORING TO IMPROVE IRRIGATION

J.M. Hulme, M. J. Hickey, and R Hoogers
NSW Agriculture, Yanco Agricultural Institute, Yanco 2703, New South Wales, Australia

INTRODUCTION

Carrot production in the Murrumbidgee Irrigation Area (MIA), New South Wales Approximately 10,000 tonnes of carrots from 250 hectares are produced by a handful of farming enterprises in the MIA. Half of the crop is grown for the fresh market, with the remaining supplying a local juicing factory. Carrots are planted throughout the year, except during the colder months of May and June, to avoid harvesting during the extreme heat in January. Traditional Imperator varieties and Western Red are popular, as they are well suited to local conditions.

Generally, carrots are grown on clay soils using furrow irrigation. Furrow irrigation is an inexpensive option on these heavy soils with gentle slopes (e.g 1:500). Furrow irrigation provides flexibility and suits other crops in the rotation such as rice and onions. Problems associated with furrow irrigation are uneven water distribution and inability to irrigate daily.

Salinity and a high watertable threaten the area. Seventy percent of the MIA, has a watertable within 2 m of the surface (1). Carrots are moderately affected by salinity. When soil salinity is greater than 4 dS m^{-1} carrot emergence is severely affected (2).

Irrigation Management The aim of irrigation is to maintain an ideal level of soil moisture.

Carrots are intolerant of waterlogging. Excessive moisture depletes available oxygen, limits nutrient absorption and increases the chance of attack by soil-borne pathogens. During early tap root development, exposure to waterlogging for periods as short as 12 hours can severely retard growth (3).

MATERIALS AND METHODS

An EnviroSCAN® unit was placed in a commercial carrot crop to monitor changes in soil moisture. The EnviroSCAN is a continuous moisture monitoring device based on capacitance sensors. Measurements from the sensors were relayed at 30 minutes intervals via a cable to a data logger. The information was down loaded weekly and the results discussed with the grower.

Probes were placed at the top, middle and bottom of the row, to determine if water was applied evenly to the field.

On each probe, sensors were placed at 10 cm, 20 cm, 30 cm, 50 cm and 80 cm below the surface. An extra sensor at 100 cm was placed on the probes at the top of the row to measure changes in soil moisture down the profile.

A watertable flag was used to monitor changes in the height of the watertable.

OBSERVATIONS

Examination of the data from the EnviroSCAN, observations of the site and discussions with the grower indicated:

- All sites were waterlogged at some point during the season.
- Waterlogging was more prominent early in the season.
- The top of the furrow was waterlogged for longer than the bottom.
- Later in the season when the profile dried out roots were actively extracting water at 100 cm.
- The watertable flag fluctuated between 1.5 and 2 m.
- The practice of quick, alternate furrow irrigations after establishment reduced waterlogging and maintained oxygen levels in the root zone.

These results are shown in Figure 1.

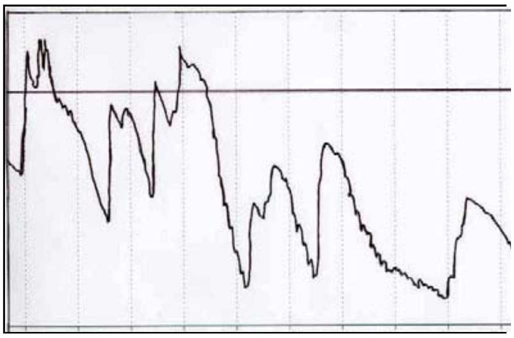

Figure 1. EnviroSCAN graph from the top of the field shows the soil was saturated for over 10 days.

DISCUSSION

Waterlogging is greatest at the start of the season, when growers tend to saturate the soil to encourage germination and establishment. However, yield potential can be reduced, as the soil remains waterlogged for more than 12 hours.

By using shorter, quicker irrigations the grower could potentially reduce the duration of waterlogging. Alternatively, lateral move irrigators could be used to grow the crop.

The grower has developed a number of strategies to minimise the risk of waterlogging from late root development, through to harvest.

Soil moisture monitoring is an efficient tool to diagnose problems and schedule irrigations. By maintaining the soil moisture in the ideal range, carrot quality and yield are maximised

ACKNOWLEDGEMENTS
Thanks to the carrot grower for making his field and time available for our research, and the Murray-Darling Basin Commission for funding the project. The project is conducted in conjunction with the Victorian Department of Natural Resources and the Environment.

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WATER RELATIONS OF CARROTS

M. R. Gibberd[A,B], N. C. Turner[B] and B. R. Loveys[C]
[A]CSIRO Plant Industry, PMB Merbein 3505, Victoria
[B]CSIRO Plant Industry, Centre for Mediterranean Agricultural Research, Wembley 6014, Western Australia
[C]CSIRO Plant Industry, Adelaide 5064, South Australia

INTRODUCTION

Free-draining, deep sandy soils, with a low waterholding capacity (c.f. 10 per cent) are widely used for the production of carrots in the south-west of Australia. The industry standard for irrigation on these soils is 1.5-fold replacement of class A pan evaporation. Even with such high rates of irrigation there is an industry perception that carrot productivity is limited by drought stress. There is no published information on the physiological responses to water deficit of carrots grown for fresh root production. The aim of this experiment was to investigate the incidence of drought stress in irrigated carrot production.

MATERIALS AND METHODS

The data presented are for Nantes carrots grown under centre pivot irrigation where frequent irrigation maintained the bulk soil water content (0 to 50 cm depth) at or above field capacity. Further data for Nantes and Imperator carrots and a comparison between cool and warm season crops can be found in Gibberd *et al*. (1).

RESULTS

Leaf water potential is a measure of the degree of 'drought stress' of a plant, the more negative the value the greater the 'stress'. There is a rapid decline in leaf water potential of well-watered carrots during the morning. Photosynthesis peaks in the early morning and then declines (Fig. 1). Leaf water potential and photosynthesis were negatively correlated with vapour pressure deficit (VPD - a measure of evaporative demand based on temperature and humidity) (Fig 2.).

DISCUSSION

A large decline in leaf water potential during the day and a mid-morning decline in photosynthesis is typical of plants receiving insufficient irrigation. However in this experiment the trends were observed even though a high soil water content was maintained by frequent irrigation. We conclude that shoot water potential and photosynthesis respond to the vapour pressure deficit and productivity is often limited under hot and dry conditions. This may be because carrots are unable to maintain the high transpiration rates required to meet the evaporative demand of high vapour pressure deficits. In turn, this is due to either a high resistance to the flow of water through the carrot tap root or a high resistance to the localised flow of water through the sandy soil.

ACKNOWLEDGEMENTS

We thank the Sumich Goup Pty Ltd for access to their field sites and their assistance with the development and/or maintenance of the experiments.

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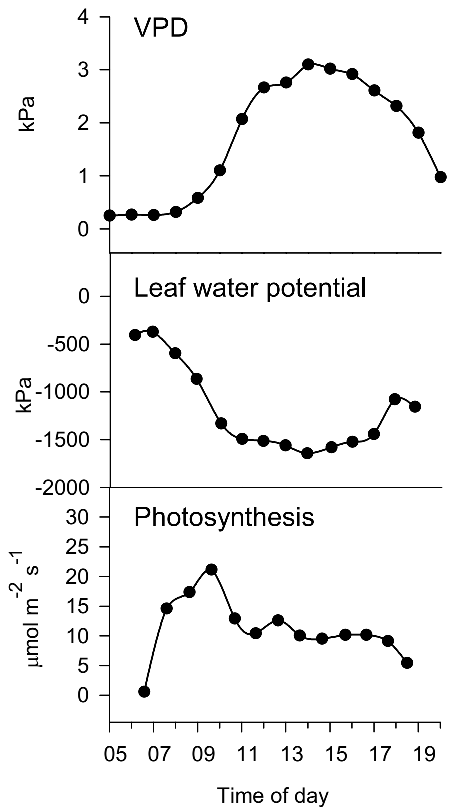

Figure 1. Diurnal (daily) trend of vapour pressure deficit (VPD), leaf water potential and photosynthesis for well-irrigated, summer-grown Nantes carrots.

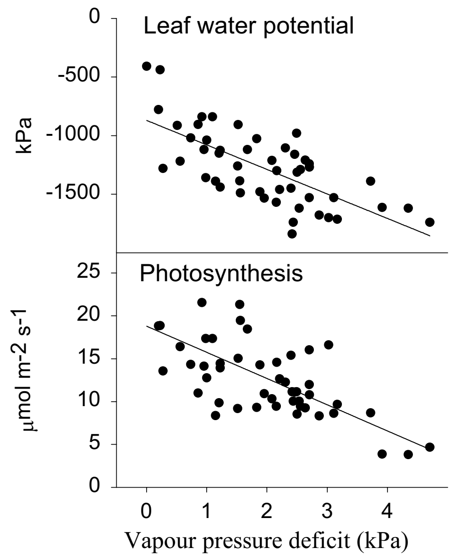

Figure 2. Relationship between vapour pressure deficit and leaf water potential (upper figure) and photosynthesis (lower figure) for Nantes carrots irrigated within the previous 12 hours.

PERFORMANCE OF KURODA AND NANTES CARROTS IN THE MURRUMBIDGEE IRRIGATION AREA

M. A. Quadir, M. J. Hickey, M. Snudden and A. Boulton
Vegetable Industry Centre, NSW Agriculture, Yanco Agricultural Institute, Yanco 2703, New South Wales

SUMMARY

Evaluation of Kuroda and Nantes carrot varieties in the Murrumbidgee Irrigation Area (MIA), New South Wales, indicated good performance of these varieties in sandhill cultivation. A number of Kuroda and Nantes varieties produced good yield and root quality in respect to shape, size, colour and brix which showed potential for export and domestic market.

INTRODUCTION

Among different vegetables, carrots are considered to have the most potential for export to southeast and northeast Asian countries either as fresh and/or processed. During last few years Australia had been successful in capturing a share of the export market for carrot juice. But recent problem of juice quality including poor colour and bitterness has shrunken this export market. But demand for fresh carrot export to Japan and other Asian countries is still there which Australian producers can target as the potential market.

In 1996/97 Australia exported 44,901 tonnes of carrots worth A$30 million. The major importers were south eastern and north eastern Asian countries such as Malaysia, Singapore, Hong Kong, Korea, Thailand and Japan. Although Victoria was the largest producer the bulk share of carrot export was from Western Australia. Due to close proximity of Perth to the exporting Asian countries, Western Australia had the advantage over the other states.

Different countries have their preferred specification in terms of size and variety (2). The blunt ended hybrid Nantes is the variety desired by most Asian countries. However Japanese prefers Kuroda types with wide top and tapering ended short carrots. Japan is importing more than 30,000 tonnes of carrots and Australian share of export was found to be decreased from 4,490 tonnes in 1995 to 1,096 tonnes in 1996/97. Taiwan, New Zealand, China and US are supplying the most of their demand. It is believed that the outlook for carrots on the Japanese market is strong (1). During the months between May and August when the prices are at their peak there exists a shortage of carrots that Australia can fill in. However exporters need to have differential quality in their product against continuous competition from the Northern Hemisphere countries. The preferred Japanese varieties with the best possible quality should be ensured. Being at the lower end of the national carrot production the existing carrot growing areas in New South Wales are mainly concentrated in the Murrumbidgee Irrigation Area and the varieties grown here are of Imperator type and the processing ones for juice. In revitalizing the NSW carrot industry, Vegetable Industry Centre at Yanco has attempted trialing Asian preferred Nantes and Kuroda varieties. Previously trials in Griffith and Gosford in 1995 and 1996 have previously indicated that the Japanese preferred variety Kuroda variety, Koyo No. 2, performed very well with good yield, uniform root size, shape, colour and high brix content (3).

MATERIALS AND METHODS

Varietal trials consisting of several Nantes and Kuroda varieties were performed at the sandhill of Yanco Agricultural Institute during autumn, 1997 season. The trial included evaluation of 14 varieties (Kuroda and Nantes type sourced from different seed companies) in a replicated trial (completely randomized block design with four replications) and a non-replicated observational trial of several other varieties. Seeds were sown by a hand driven seed driller in a raised bed of 45 cm width in two rows at 20 cm apart. Seeds of replicated trial and observational trial were planted on March 6 and 14, 1997 respectively. Seedlings were thinned at about 6-8 cm apart. Standard cultural practices were followed including nematicide and herbicide application and top dressing of fertiliser. Overhead sprinkler irrigation was used and the soil moisture was monitored by tensiometer and enviroscan. Harvesting commenced from early June, and continued till early July 1997. Root yield, size and brix were recorded. For the replicated trial mean separation were done by least significant difference test at 5 per cent probability.

Four Kuroda varieties that performed well in the autumn trial were grown for a replicated trial in summer 1997-98. Additionally three Kuroda and three Nantes varieties were also grown for a non-replicated trial. Planting was done on November 28, 1997. Similar cultural practices were followed. Due to dry summer, the trial was irrigated more frequently than the autumn trial.

RESULTS AND DISCUSSION

The results on the performance of the root yield characteristics and quality for the autumn trial are presented in Tables 1 and 2 for the replicated and the observational trial respectively.

Kuroda varieties from the replicated trial were harvested at 91 days after planting which were 10-15 days earlier as compared to the Nantes types taking more than 100 days. The root yield and quality varied significantly among the varieties (Table 1). Among the Kuroda varieties NW 653 and CR 386 produced reasonably good yield with fairly good quality roots. For the Nantes types Top Pak, CR 287 and Red Brave resulted good yield.

From the non-replicated observational trial Nantes varieties showed very high yield potential and good quality roots (Table 2). The hybrid lines 3063, 3042, wan produced more than 35 tonnes/ha with good potential for some Asian countries. All the four Kuroda varieties produced good yield. However as these varieties were planted one week later they took little longer duration requiring 115 -117 days to harvest. The roots of the variety Koyo No 2 were very smooth and uniform in size, shape and colour with wide top in the range desired by the Japanese market. Sarooshi (3) also reported good performance of this variety at Gosford.

Table 1. Root yield and quality of Kuroda and Nantes carrots in MIA (autumn 1997, replicated trial)

Varieties	Diameter (mm)	Length (mm)	Yield (T/ha)	Brix
Kuroda				
Kurodado	40	154	18.2	9.3
CR 386	47	166	20.3	8.9
SPS 911	40	157	16.1	9.6
SPS 912	45	144	17.0	9.7
NW653	42	151	27.5	9.1
Nantes				
Red Czar	35	178	18.5	9.8
Red Chief	36	179	19.8	9.2
Red Brave	36	182	20.0	9.6
CR 287	33	164	24.8	9.2
CR 402	32	168	14.8	10.0
Archer	35	181	14.8	9.2
Top Pak	37	170	26.8	8.9
Hi Pak	37	176	19.8	9.9
Barwon	33	171	18.8	9.7
LSD(P=0.05)	2.66	11.99	4.9	0.4

Table 2. Root yield and quality of selected Kuroda and Nantes carrots in MIA (autumn 1997, non-replicated trial)

Varieties	Diameter (mm)	Length (mm)	Yield (T/ha)	Brix
Kuroda				
Koyo No. 2	47	158	26.2	8.4
NW 6113	42	150	28.6	9.2
NW 6114	34	153	23.5	9.0
NW 6115	40	140	24.2	9.4
Nantes				
CR 345	41	188	29.4	10.0
Swan	42	187	38.3	9.0
Yates 3042	51	175	36.3	8.6
Yates 3063	43	156	37.2	9.0

The root yield characteristics for the replicated and the non-replicated trials during summer '97/98 are presented in Table 3 and 4 respectively. In general the summer crop were earlier in harvesting but had low yield as compared to the autumn trial. However all the Kuroda varieties in replicated trial showed moderate yield with CR 386 having the highest yield. In respect to root quality Koyo No. 2 showed the best performance. From the non-replicated trial Kuroda variety NW 6115 also showed promising root yield. All of the Nantes varieties produced poor yield except Hybrid 2785.

Table 3. Root yield and quality of selected Kuroda carrots in MIA (summer 1997/98, replicated trial)

Varieties	Diameter (mm)	Length (mm)	Yield (T/ha)	Brix
CR 386	48	179	23.4	8.4
NW 653	48	179	17.2	9.4
NW 6113	47	198	15.1	9.4
Koyo No. 2	45	178	14.0	10.1

Table 4. Root yield and quality of selected Kuroda and Nantes carrots in MIA (summer 1997/98, non-replicated trial)

Varieties	Diameter (mm)	Length (mm)	Yield (T/ha)	Brix
Kuroda				
Kurudado	44	150	7.9	9.1
NW 6114	59	185	12.1	9.3
NW 6115	45	173	21.4	8.9
Nantes				
Yates 3042	45	174	11.7	10.4
Yates 3063	37	162	9.6	10.2
Red Chief	33	218	9.6	8.9

These trial results indicated very good potential of some of the Kuroda and Nantes varieties for the sandhill cultivation in MIA during autumn as regards to root shape, colour, uniformity and brix content. The Japanese preferred variety Koyo No. 2 performed very well with all desirable characteristics for export potential to Japan. Some preliminary trial in Canowindra, NSW also showed promising results indicating the potentiality of growing Nantes carrot in Lachlan Valley. However more trials are needed in respect to planting time, spacing, nutrition, best irrigation practice and product development. Some aspects of handling and processing in regard to cleaning and packaging also needs to be determined for quality assurance with support from the industry.

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THE POTENTIAL FOR RECYCLING CARROT WASH WATER—WATER QUALITY CONSIDERATIONS

A.J.Hamilton and M.I. Mebalds
DNRE, Institute for Horticultural Development, Private Bag 15, Scoresby Business Centre 3176, Victoria.

SUMMARY

The quality of source-waters and waste-waters associated with the carrot washing process was analysed with respect to the potential to reuse the water. Agrochemical concentrations were generally low. Post-harvest and field pathogens were isolated, and faecal indicator organisms were frequently detected. Therefore, in many instances, some form of disinfection would be required before water is reused for irrigation or washing.

INTRODUCTION

Re-using water from the carrot washing process is likely to be advantageous from both economic and environmental perspectives, particularly in regions where water is limiting. If water is to be recycled, it needs to be done in a manner that protects the health of both crops and consumers. The aim of this research is to determine the quality of carrot waste-water with respect to the potential to recycle it.

MATERIALS AND METHODS

Source and waste-water samples were taken from a total of 17 different properties — 10 Victorian, four Tasmanian, two South Australian and one Queensland. Some properties were sampled more than once; 25 source-water and 25 waste-water samples were collected in total.

The total number of coliform bacteria and *Eschericia coli* was determined for all source and waste-water samples using Petri Film® (1) and a membrane filtration method (2). The membrane filtration method was used for enumeration of very low numbers of coliforms or *E. coli*, beyond the limit of detection for Petri Film® (i.e. < 100/100ml). Eighty to 100 ml of sample was filtered through a 0.45 µm filter. The filter was placed on a moist endonutrient pad (Sartorius) and incubated at 37 °C. For both methods, coliform and *E.coli* counts were made at 24 and 48 hours respectively.

The presence of fungi in source and waste-water was assessed by plating out two 0.5mL aliquots of sample water from a dilution series from 0 to 10^{-3} onto potato dextrose agar, malt extract agar and water agar. All fungi growing on plates were identified at least to genus level. Fungi that were considered to be potentially pathogenic were identified to species level. Pathogenicity of selected isolates was assessed by placing a small portion of mycelium into a carrot wound made by piercing the carrot with flamed forceps. A pear baiting test for *Pythium* and *Phytophthora* spp. was also undertaken for every water sample. In addition to isolating specific fungi, the total concentration of yeasts and moulds was determined for each sample using Petri Film® (1).

The concentrations of fifteen agrochemicals were determined, via gas chromatography and/or HPLC, for each source and waste-water sample. The chemicals tested for were: fenamiphos, chlorpyrifos, diazinon, dimethoate, malathion, phorate, trifluralin, chlorothalonil, dithiocarbamates, metalaxyl, prometryn, linuron, alpha-endosulphan, beta-endosulphan and endosulphan sulphate.

Nutrient concentrations (nitrate-N, nitrite-N and soluble reactive phosphorus) were determined using standard colourmetric techniques—adapted APHA techniques (2) using HACH DR/2000 spectrophotometer methods. Other physiochemical parameters were anlysed according to APHA methods (2).

Comparisons between source and waste-water were not analysed statistically, for any parameter, because of the pseudoreplication associated with the distribution of samples over farms.

RESULTS

Coliform levels in excess of 1,000 bacteria/100 ml were encountered more frequently in waste-water than source water. The highest levels reported for source and waste-waters were 114,000/100 ml and 109,000/100 ml respectively. The source water in this case was obtained from a channel. The next most polluted source—10,000 coliforms/100 ml—was a small farm dam.

In general, levels of faecal indicator bacteria, and frequency of occurrence, were higher in the waste-water than the source water (Table 1).

Table 1. The number of samples where potentially hazardous levels of faecal indicator bacteria were observed (n=25 for source and waste-water).

	Source	Waste
E. coli (>0/100 ml)	12	14
Coliforms (>1,000/100 ml)	12	18

Of the fifteen agrochemicals tested for, five were not detected in any of the samples—phorate, trifluralin, chlorothalonil, dithiocarbamates and metalaxyl. In general, agrochemicals were more commonly detected in the waste-water than the source-water (Table 2). This would suggest that they are derived from the soil which is removed in the washing process. Linuron and chlorpyrifos were the most commonly encountered chemicals in the waste water—detected in nine and seven samples respectively (Table 2). The highest concentrations reported for linuron, chlorpyrifos, prometryn and endosulphan-sulphate were 34, 2.6, 45 and 0.39 µg/L respectively. With the exception of endo-sulphan sulphate, all of these were from the waste-water. In general, most of the agrochemicals detected were at low concentrations (<0.5 µg/L).

Table 2. The number of samples where the four common agrochemicals were reported (n=25 for source and waste).

	Source	Waste
Linuron	2	9
Chlorpyrifos	1	7
Prometryn	4	6
Endosulphan sulphate	3	5

As would be expected, the waste-water was substantially more turbid than the source water (Table 3.); values in excess of 1,000 NTU were recorded. Biochemical oxygen demand was also substantially higher in the waste-water (Table 3.). There was little difference in the concentrations of nitrate and nitrite

between the waters, but soluble reactive phosphorus was generally higher in the waste-water (Table 3).

Table 3. The mean levels of physiochemical parameters reported in source and waste-water samples (n=25 for source and waste).

Parameter	Source	Waste
Turbidity (NTU)	62.5	195.2
BOD_5 (mg/L)	7.7	29.6
Nitrate-N (mg/L)	2.0	1.15
Nitrite-N (mg/L)	0.05	0.15
SRP-P (mg/L)	1.79	32.7

The fungal population was greater in the waste water compared with source water, and soil-borne fungi predominated on agar plates. A sample of fungi, which may cause either field of post -harvest diseases, is shown in Table 4. A further 25 fungal taxa were isolated from the water samples.

Table 4. Incidence of potentially pathogenic fungi in source and effluent waters used in washing carrots (n=25 for source and waste).

Fungus isolated	Source	Waste
Alternaria alternata	5	13
Aspergillus niger	5	9
Fusarium moniliforme	2	2
Fusarium oxysporum	3	16
Fusarium solani	4	9
Fusarium sporotrichiodes	0	1
Geotrichum candidum	3	5
Mucor sp.	4	12
Penicillium spp.	17	20
Pythium sp.	0	2
Rhizoctonia solani	2	0
Rhizopus oryzae	1	10
Verticillium sp.	3	9
Trichoderma sp.*	10	19
Total yeasts & molds (no./100 ml)	41,591	418,409

*Potential biocontrol fungus

Pathogenicity tests showed that *A. alternata* and *F. sporotrichiodes, Pythium* sp. were pathogenic to carrot while the *F. oxysporum, F. solani, R. solani, G. candidum, Mucor* sp. did not cause lesions in the carrot.

Penicillium spp. were commonly isolated from both source and waste-waters. *Trichoderma* spp. were frequently isolated from source and waste-waters and may represent a population of naturally occurring fungi which may have a biocontrol effect on plant pathogens.

Pythium spp. were not isolated from any pear bait tests.

DISCUSSION

Whilst no distinction was made between total coliforms and faecal coliforms, for the purposes of this study we have made the assumption that most coliforms are of faecal origins. Whilst there are no specific guidelines relating to acceptable levels of coliforms when reusing waste-water, we can gain an idea of reasonable levels from sewage reuse guidelines (4). Such guidelines allow for faecal coliform levels of up to 1,000/100 ml for water to be used for irrigation of crops. However, these guidelines are currently under review and it is possible that the WHO guidelines of <10/100 ml will be adopted.

In situations where water was sourced form a dam, it may be possible that contamination was derived from waterfowl defecation. The mallard (*Anas platyrhynchos*) has been found to be responsible for increases in faecal coliform bacteria in a lake (3). This bird is very closely related to the Pacific black duck (*Anas superciliosa*), which can often be found on farm dams.

It also appears that the soil removal process adds substantially to the coliform loading of the water. Determining the precise origin of faecal contamination was beyond the scope of this project. However, it is possible that crop fertilisation with chicken manure, a common practice in the industry, may be the source of the contamination.

It was shown that fungal pathogens were frequently present in carrot waste-water and that they are capable of causing field and postharvest disease. Water samples taken from settling ponds have shown that many of the pathogenic fungi found in the waste-water were still present and could potentially initiate disease if recycled for washing or irrigation. Chemical disinfestation of effluent water is required to reduce the risk of spreading human and crop pathogens through recycled water. However, the high very high turbidity levels of the waste-water would prevent effective disinfection using most chemicals. Effective disinfection usually demands a turbidity of less than two NTU (4).

The generally low levels of agrochemicals in the water are unlikely to lead to produce levels in excess of the Food Standards Code (5).

Nitrate and nitrite levels are unlikely to be of concern with respect to discharging waste-water into the environment. However, phosphorous levels, turbidity and organic loading may be issues, particularly for point source discharges.

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Session 4

COMPOST AS AN IMPORTANT TOOL IN SUSTAINABLE FARMING SYSTEMS

A. Gulliver
Custom Composts, PO Box 2040, Mandurah 6210, Western Australia, 6210

Agriculture and horticulture in Western Australia (WA) are multi-billion dollar industries providing much-needed food, fibre and forestry products as well as amenity, employment and export income. Agriculture recognises the need to manage its most valuable asset, the land, in a sustainable way. Compost is an important tool in sustainable soil fertility programmes.

Agriculture WA forecasts that WA's agricultural sector has the potential to grow from an estimated $4.5 billion (97/98) to more than $8 billion within ten years. Natural growth will account for half of this increase. The difference will require innovative and market focused development. Whilst all sectors are likely to grow, greater relative increases will come from horticulture, cereals, pulses and oilseeds and new industries. ("Focus on the Future", AgWA, 1998).

Important trends that will affect agriculture include:

- Population growth and economic growth
- Discerning consumers, quality demands
- Globalisation of trade, tougher competition
- Customer demand for ecologically sustainable production systems (manufacturing & farming)
- Growth of biological sciences
- Advances in communications and IT
- Fewer government services
- Community expectations regarding management of natural resources

Despite the apparently difficult and demanding market conditions of the new millennium, Australian farmers are well placed to turn potential threats into opportunities. They are highly skilled, experienced and have demonstrated an ability to adopt technological advances to cost effectively produce high quality products. Australia has a range of soil types and climates, seasons that are counter-cyclical to many other major production areas and a geographic proximity to the growth markets of south east Asia.

Some of the reasons for adoption of compost in soil fertility programmes may now be apparent: 'clean & green' produce, marketing advantage, sustainable practices, management responsibility, resource security, liability for damage to resources, environmental pressure, public perception and industry image all play a role. In WA the two social amenity issues of stable fly breeding in, and odour from, raw manures are also important.

An analysis of some of the challenges confronting horticulture will serve to demonstrate the role of compost as a management tool in sustainable farming systems.

Establishment of new horticultural enterprises is increasingly difficult. Existing enterprises are coming under closer scrutiny. Land resource allocation and security are increasingly doubtful. Whilst every citizen with a garden, or council with amenity areas, has a similar potential for pollution it is the professional horticulturists who will experience regulatory and community pressure first.

Urban encroachment has made agricultural practices more visible and more likely to affect the social amenity and lifestyle of neighbours. The importance of groundwater for public drinking supplies in WA and media attention on algal blooms in river systems has resulted in greater scrutiny of farming methods. The process of water reform in WA has highlighted the importance of water as a critical resource. Water could well be the limiting factor for the future development of agriculture and horticulture. Public health scares and food product recalls have resulted in greater sensitivity to consumer protection and food safety issues. Quality assurance, SQF 2000 and HACCP programmes are becoming the norm rather than the exception.

Sustainable management practices and safe, quality food are not a fashion – they have become an expectation.

In WA nearly 60 per cent of the State's vegetable production occurs on the Swan Coastal Plain. This area is made up of sandy soils, with very low nutrient retention capability, over significant groundwater bodies. Crops are irrigated with large amounts of water, particularly in summer. Winter rainfall is high. These factors contribute to:

- Extra financial cost of leached fertilisers (75-90 per cent of some nutrients).
- Ground water contamination.
- Pollution of drainage and river systems, evidenced by seasonal algal blooms.

This can lead to:

- Poor public image of horticulture
- Adverse planning and regulatory decisions for the industry.
- Reduced resource security.
- Significant risk of damage to markets (particularly export) due to loss of 'clean & green' image, as customers perceive that our cropping systems damage the environment and are not sustainable.

The direct application of manure and the incorporation of crop residue are common practice in horticulture. The difference between these products and compost are not well understood in the industry. The composting process stabilises organic material by converting the soluble components (e.g. nitrogen) into forms that are not readily leached (compared to direct application of manure where the

nitrogen leaches within 4-6 weeks). It is commonly stated that only 20 per cent of the nitrogen in chicken manure applied to irrigated sandy soils is actually used by the plant. Most of the balance is leached with obvious consequences. By comparison, plants use over 80 per cent of the nitrogen in compost. Compost is also non-odorous and will not breed stable fly – two important social amenity issues where horticulture exists close to expanding urban areas. The humus from the organic matter provides an increase in water holding and cation exchange capacity of the soil.

The net effect of addition of composts to the soil can best be described as providing a nutrient and moisture 'sponge' under the plants. Nutrients are released slowly to the plants as the compost organisms break down and are themselves recycled in a living soil. Inorganic fertilisers applied to the soil are absorbed within this 'sponge' rather than being leached by rainfall or irrigation water. This means that less fertiliser can be applied, resulting in cost savings and environmental benefits. After a period of repeated use compost can supply a significant proportion of the plant nutrients.

Other benefits arise from the better structure of soil and reduced water stress on plants. Compost is suitable for all soil types and all crops – it will both improve the aeration of a clay soil and improve the water holding capacity of a sandy soil. This can result in significant quality improvements in crops.

Compost also helps to create a 'living soil' where microbial, fungal and pest problems are reduced resulting in savings in pesticide costs and other risks associated with pesticide applications. A most important part of the composting process is the pasteurisation that occurs through self-heating caused by microbiological action. This results in the killing of weed seeds, pests and plant pathogens. This is of vital importance to commercial horticulture. Compost can also be modified to address particular applications such as soil stabilisation or *Phytophthora* control. Metham sodium or methyl bromide applications can be omitted with huge cost savings to production horticulture.

Compost can have a positive influence on the physical, chemical and biological factors that affect the soil ecology. Farming is all about managing ecosystems and compost provides a valuable tool in the farmer's tool kit.

In summary, composts in soil management programmes (for horticulture):

- Reduce nutrient leaching and consequent effects on water bodies.
- Reduce water stress on plants (very important in irrigated horticulture).
- Aid in protection and more effective use of ground water resources
- Aid reduced and more efficient use of expensive inorganic fertilisers
- Help suppress plant diseases leading to reduced reliance on pesticides
- Help build healthy soils
- **Cost no more** than programmes based solely on synthetic fertilisers.

Once the grower starts on a programme he soon realises the benefits in cost and the huge improvement to the quality of the soil.

The need to improve the management of soil has coincided with community and government desire to manage society's waste streams in a more environmentally responsible manner. Federal and state governments have set ambitious targets for the reduction of organic wastes in landfill. The composting of these waste streams and recycling on land is an obvious solution that will receive an enormous amount of attention in the next few years. This is both a risk and a benefit for farmers. The demand for better management of our waste streams will mean that a large number of resources will be directed to solve the problem and we can expect quick results. The risks are that our most valuable asset, the land, is effectively used as an aboveground landfill for the rest of society to dump its wastes on. The risks are obvious. There is also a risk that well meaning but ill informed waste recyclers would promote so-called 'compost' that is not suitable for land application.

Farmers need to be aware that waste recycling to agriculture should be driven by the needs of farmers and not by the needs of waste producers. There are Australian standards for compost production and these provide a starting point for assessing the quality of compost products and the competency of compost producers.

The horticultural industries are predicting nearly a five-fold growth of export income from A$180 million in 96/97 to A$880 million in 2008/09. It would be foolish to compromise the social and economic benefits that such growth can deliver to WA simply to serve the needs of waste producers. The factors driving this growth will be 'clean & green' food from unpolluted soils farmed using ecologically sustainable practices. The emerging composting industry must take note of the opportunities and needs of the farming industry it serves.

In summary, the benefits of compost in production systems on WA soils are indisputable. The economics of compost use in a wide range of horticultural crops has been demonstrated. The adoption in large-scale crops awaits the development of cost effective solutions for a geographically dispersed market. The move towards recycling community organic wastes may provide the required breakthrough. Compost quality will be a key determinant of the success of these developments. A customer focussed, market oriented approach is necessary if we are to fulfil the promise of effective organic resource recovery at the same time as helping agriculture achieve its vision for a sustainable future.

PRACTICALITIES OF ORGANIC CARROT PRODUCTION

A. Scherer and S. David
Organic Farming Systems
PO Box 419, Cottesloe 6911, Western Australia

In the last 50 years agriculture has become increasingly dependent on chemical control of weeds, pests and diseases. There is now a significant international demand from consumers for carrots grown using environmentally sensitive methods. Conventional agriculture, however, is feeling an increased need for productivity, profitability and competitiveness but at the same time consumer pressures are asking for a decrease in pesticides used in food production.

Organic agriculture answers the immediate needs of the more conscious consumer by providing a practical means of producing, marketing and certification of produce for the grower and consumer alike.

This session provides an overview of the practical issues that growers face when converting to organic farming systems. These include the agronomic issues of soil health, plant nutrition, weed, pest and disease control, cover crops and crop rotations.

The basic premise of organic agriculture is to treat each farm as an ecosystem and the key to converting to organic agriculture is to change our thinking from a problem solving (see a pest then control it) to a systems approach. This systems approach has an integrated plan that develops a balance in the farm ecosystem that keeps pest and disease incidence below the levels that cause economic damage.

For those growers starting the conversion process for organic carrot production the starting point is soil health where the focus is on optimising the environment for soil microbial activity. Practically this is achieved by bringing the soil pH towards neutral, resolving soil structural issues and providing organic matter to feed the soil microbes. Organic matter is usually supplied as compost which supplies a form of predigested organic matter to soil microbes that they then breakdown to provide the nutrients required for the crop. Soil organic matter is also boosted with the incorporation of cover crops in to the soil.

A positive outcome from using these softer, organic forms of nutrients and resulting increased soil microbial activity is that we find carrots are more resistant to pest and disease attack. However, rather than relying solely on the increased strength of carrot plants, the natural control of pest and disease can be supplemented with soil biological stimulants such as compost tea, release of beneficial insects (including habitats for their survival) and crop rotations to reduce disease pressure.

Finally, let's look at weed control. This is obviously extremely important in carrot production whether it be organic or conventional. Organic weed control is successfully managed with a combination of cover cropping, cultivation, flame weeding and hand weeding. Timing becomes particularly important for maximum weed control and limiting the yield robbing effects of weeds.

In summary, organic agriculture can provide yields similar to conventional agriculture using natural farm inputs in place of chemical fertilisers and sprays. It can be particularly rewarding, both personally and financially, and as more and more consumers insist on supplies of "clean" food the pressure will be on all of us to find ways to provide food that will be acceptable to them.

MARKETING ORGANIC PRODUCE

S. McCoy
Agriculture Western Australia, Locked Bag 4, Bentley Delivery Centre 6983, Western Australia

WHAT DOES THE TERM "ORGANIC" PRODUCE MEAN?

The label "organic" or "organically grown" is generally used to describe a production system or method of growing produce without the use of chemicals and artificial fertilizers. However, organic farming is far more than simply substituting synthetic chemical and fertilizer inputs for naturally derived, less toxic or less persistent alternatives.

Modern organic farming can be defined as *"a whole farm management system where biology and balanced soils give sustainable yields without chemicals or forced growth."*

WHAT IS DRIVING CONSUMER INTEREST IN ORGANIC PRODUCTS?

Consumer demand, in the highly differentiated affluent food markets of Europe, Asia and North America, is growing for food and agricultural products that are perceived to be healthy and have low impact on the environment. A willingness to pay a premium for such products is apparent where products carry a verifiable assurance they are safe, nutritious and produced using systems that care for the environment. Products certified as Organic or Biodynamic are increasingly perceived as providing such assurances.

Essentially the main drivers of sales in organic produce can be divided in two types, namely:

- Pull drivers – these are typically consumers demanding more of a product. This has the effect of "pulling" supply volumes up as retail shops put more products on shelves to cope with demand.
- Push drivers – these can typically be promotion effort by retailers, advertising or "pushing" consumers to buy a product, or by governments providing support and incentives as a means of "pushing" the community to accept and adopt a new idea or product.

In Australia, consumer "pull" has been the main driver behind growth in sales of organic products, with relatively little "push" effort from supermarkets or government. In contrast, for example in the UK, supermarkets put great emphasis on promoting organic products. In addition, the government provides direct financial assistance for conversion to organic production systems.

NEED FOR VERIFIABLE ASSURANCE THAT CLAIMS MADE ARE TRUE.

Australia has a well-regulated system for organic and biodynamic production and processing that has gained a good international reputation. The "National Standards for Organic and Biodynamic Produce" administered by AQIS, form the minimum mandatory requirements for export of products labelled as "organic" or "biodynamic". These standards are implemented by seven independent AQIS accredited certification organisations, who conduct whole farming system inspections and ensure a comprehensive record keeping system is in place to allow trace back and verification of inputs used, management practices, yield and sales.

EXPANDING WORLD MARKETS FOR ORGANIC PRODUCTS

Multi-billion dollar organic markets are reported to be the fastest growing sector of the food industry in the USA, Japan and a number of European countries. Worldwide markets for organic foods are estimated to be worth US$13.5 billion (1998) and display growth rates of 20 – 30 per cent per year for the past 5 years. The main markets are USA (US$5.4 billion 1999), Western Europe (US$5.3 billion 1999) and Japan (US$2.5 billion 1999). Europe and Japan are the fastest expanding markets with USA and New Zealand producers the fastest to respond to these market demands.

AUSTRALIAN MARKETS FOR ORGANIC PRODUCTS

The Australian organic industry is relatively small and undeveloped, worth about $200 -250 million, however good opportunities exist to capture a share of rapidly expanding markets. Major supermarkets across Australia have renewed interest in selling organic products and are actively looking for reliable suppliers of a full range of consistent quality organic fresh and processed products.

In Western Australia, speciality "growers market" retail stores, and major supermarkets have indicated a desire to offer organic produce to consumers, however inconsistent, poor quality supply continues to frustrate attempts to develop this market sector.

ORGANIC CARROT MARKET OVERVIEW

Opportunities appear to exist in a number of different markets for carrots certified as organically grown. A number of Australian markets indicate strong demand with inadequate and unreliable supply. Most sales are through specialty health food stores and home delivery services. However, renewed interest by mainstream retailers and major supermarkets to stock a range of organic products, including carrots, provides an opportunity for large scale organic production. In addition, export demand for organic carrots and processed carrot products also suggests considerable potential.

MARKETING ORGANIC PRODUCE

Organic carrot production provides market opportunities as either fresh product, semi-processed, frozen, fully processed ingredient and juice products.

For growers new to organic carrot production, one strategy could be to target the market for organic juicing carrots as the main focus, with a small proportion of top grade carrots dedicated to increasing the volume of sales in the fresh market.

By way of example, the following section looks at developing the domestic market for fresh organic carrots.

THE "MARKETING MIX" FOR FRESH ORGANIC CARROTS.

Retail stores are likely to offer both organic carrots and conventional carrots, possibly side-by-side, as part of their product range. Establishing reliable volume sales of fresh organic carrots will require careful attention to the 4 P's of marketing as follows.

Place – where to market your product can influence other components of the marketing mix. Aim to select target markets with commitment to develop the sales volumes, product specifications, pricing structure and sales support necessary for market establishment and longer-term profitable business relationships. Good wholesale agents may assist in this development, but insist on maintaining direct communication throughout the supply chain especially with target retailers.

Speciality "healthfood" stores can attract high prices but only move small volumes. Major supermarket chains may offer volume opportunities but may have tight specifications and require pre-packing. Smaller independent supermarkets may see organic carrots as an opportunity to distinguish themselves from competitors and may be willing to provide more advertising and other promotion. Greengrocers or growers-markets may have more personalised customer service enabling better marketing of the "story" behind organic products.

Product –Taste, taste, taste. Delicious flavour is essential to ensure repeat purchasing, and to reinforce values associated with organically grown produce.

Product appearance remains very important i.e. clean, straight, good colour and well graded. Reputable organic certification is essential. A reliable supply of appropriate quantity of product is essential for developing new markets and maintaining established markets. Quality assurance system can be important to ensure each consignment meets expectations.

The end product must ultimately satisfy consumer preferences, and this can vary for different markets. Regular communication with retailers is vital. Adjustments to product details such as variety, size, shape, colour, packaging and presentation may require fine-tuning to match consumer preferences. Supermarkets typically require pre-packaging to avoid mixing with other product and allow identification at checkouts.

Price – a sensitive issue that must be profitable for the grower, others in the supply chain and ultimately be acceptable to the target market customer. Know your own cost structure.

Price can vary to reflect product qualities, target market, supply and demand, and can be manipulated for promotional activities to development markets.

Huge premiums are unrealistic for volume sales. Retail pricing in the range $1.49 - $1.99 /kg, for suitable quality product, is suggested as realistic for volume sales. A stable pricing structure can help development markets. Ensure all partners in the supply chain contribute some profit margin in support of reduced price promotional campaigns.

Promotion – a crucial component for market development and maintaining sales volumes. Commitment from retail stores to develop and support promotion strategies may determine which stores are best to target for marketing organic carrots. Ensure sufficient resources are allocated for promotional effort.

Promotion can take many forms including; branding and labelling on pre-pack bags, point of sale signage, prominent in-store positioning, feature displays or tastings, reduced price and other specials, specific advertising or cross promotions (e.g. organic beef & carrots) and general media advertising.

Some greengrocers or growers-markets have indicated they would stock only organic carrots, given a reliable supply of good quality product at a workable price.

Key points:

- Food safety, food health and the method of production are becoming increasingly important to consumers. Organically grown foods appeal to many of these concerns.
- Organic certification provides a verifiable assurance of the production method used.
- Markets for organic vegetables are expanding rapidly both in Australia and overseas.
- The "marketing mix" for organic carrots must reflect the target market where:

  place (retail store) is chosen based on commitment to market development,

  product taste and appearance encourages repeat purchasing,

  price is profitable for the grower and acceptable to the consumer, and

  promotion strategies are well developed and supported.

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ENHANCED BIODEGRADATION OF METHAM SODIUM

B. Warton and J.N. Matthiessen
CSIRO Entomology, Private Bag 5, Wembley WA 6913, Western Australia
Email: benw@ccmar.csiro.au

SUMMARY

Soil samples were taken from a carrot-growing property near Perth and treated with metham sodium soil fumigant. The concentration of the active toxin, methyl isothiocyanate (MITC), was measured at various intervals. In soil with a prior history of metham sodium use, the MITC reached a much lower concentration and was present in the soil for a dramatically reduced time compared to previously untreated soil.

This effect was the result of a build-up of microbes adapted to feeding on the pesticide, causing the phenomenon known as enhanced biodegradation, which has resulted in soil-borne pest and disease control failures in Europe and the US. With the current dramatic increase in use of metham sodium in Australia, there are implications for its efficient and sustainable use in this country. Our research will determine the risk of enhanced biodegradation occurring in different soils and horticultural production systems so that growers can adopt prevention strategies.

INTRODUCTION

Metham sodium is a soil fumigant widely used in horticulture in Australia and around the world. It is a broad-spectrum pesticide, acting on a wide range of soil-borne pests and diseases: insects, nematodes, fungi and weeds. It is not very effective against bacteria. When applied to moist soil, metham sodium reacts with the moisture to form methyl isothiocyanate (MITC), which is the compound responsible for the pesticidal action.

The use of metham sodium in Australia is increasing rapidly - as a result of the phaseout of methyl bromide under the Montreal protocol ban on ozone-depleting substances, as well as increasing market demands for high quality, blemish-free produce.

One of the problems growers can face with newer, less persistent pesticides applied to soil is the phenomenon of *enhanced biodegradation*. Enhanced biodegradation is an extreme case of the natural process of biodegradation, where compounds decay in soil through biological action.

Enhanced biodegradation occurs when microbes that are by chance adapted to break down a pesticide build up high numbers in response to an abundance of the compound (1). As the microbial population increases, the pesticide is consumed more rapidly. If this process becomes too rapid it potentially leads to control failures as the pesticide may not be present long enough to have its desired effect. Commonly, control failures have led to users applying larger or more frequent doses of the pesticide, which literally feeds the problem and makes it worse. In Europe and the US, instances of enhanced biodegradation of metham sodium have been reported, with the first case occurring in the Netherlands (2).

This paper reports a severe example of enhanced biodegradation of metham sodium in a carrot-growing enterprise in Western Australia. It is a message to all users of metham sodium to be aware of the phenomenon and the importance of prevention to ensure sustainable, effective use of this product.

MATERIALS AND METHODS

Soil sampling Soil samples were collected from two locations on a carrot-growing property north of Perth, WA. At each location, soils were collected at a depth of 0 – 20 cm from four points within an area of approximately 10 m^2. Each set of four samples was mixed thoroughly and stored in loosely sealed polythene bags at 15° C prior to use. Soil A had never been treated with metham sodium, while Soil B has been treated with metham sodium approximately annually for the past several years.

Treatment of soil samples with metham sodium For each experiment, three replicate 150 g samples of soil were placed in 250 ml Erlenmeyer flasks. A sufficient quantity (18 μl) of metham sodium soil fumigant was added to each sample. This amount imitates standard field usage, based on the manufacturer's recommended application rate of 500 L/ha and assumes penetration in the soil profile to a depth of 30 cm. The flasks were sealed with a double layer of parafilm to prevent losses of volatile compounds and manually shaken for two minutes to disperse the metham sodium through the soil.

Sterilisation of soils In order to determine the effect of biological activity on the behaviour of metham sodium in soil, a subsample of Soil B (Soil Bs) was sterilised prior to treatment. Sterilisation was conducted by subjecting the soil to a temperature of 121 °C and a pressure of 100 kPa for one hour in an autoclave.

Extraction and analysis of soil samples Periodically, 10 g subsamples were removed from each flask and extracted with ethyl acetate (3 × 8 ml), with 10 minutes shaking time for each extraction. The extracts were combined and 1 ml of 11.25 ppm benzyl isothiocyanate added as a normalisation standard. Samples were dried and filtered through a plug of anhydrous magnesium sulfate (approx 4 cm) in a pasteur pipette prior to analysis using gas chromatography (GC).

Samples were analysed for MITC using a Hewlett Packard 6890 GC equipped with a flame photometric detector in sulfur mode (394 nm). A 30 m × 0.32 mm i.d. WCOT fused silica capillary column coated with a 0.25 μm methylsilicone stationary phase (HP-1, Hewlett Packard) was used. The GC oven was programmed from 50-220 °C at 20 °C /min. Samples were injected splitless using a HP 7683 auto sampler at an oven temperature of 50 °C. Helium was used as the carrier gas at a linear velocity of 19 cm/sec.

The concentration of MITC in the soils was expressed as the percentage of the amount of MITC that could theoretically be produced from the metham sodium applied to the soil, assuming its complete conversion to MITC.

RESULTS

In the previously untreated soil A, the maximum measured concentration of MITC was 93 per cent of potential, reached one hour after application of metham sodium (Figure 1). The concentration of MITC in the soil decreased to zero over 17 days. The same dose applied to soil B gave a maximum concentration of MITC of only 42 per cent of potential, and no MITC was detectable after only seven *hours* (Figure 1). The sterilised sample of soil B (soil Bs) treated with the same dose of metham sodium yielded a maximum MITC concentration of 88 per cent of potential, which decreased to zero over 18 days (Figure 1).

A measure of the toxic potential of MITC in the three soils was approximated by calculating the areas under each of the three curves shown in Figure 1. When normalised to soil Bs which gave an area of 100 per cent, soil A gave an area of 94 per cent and soil B gave 0.98 per cent.

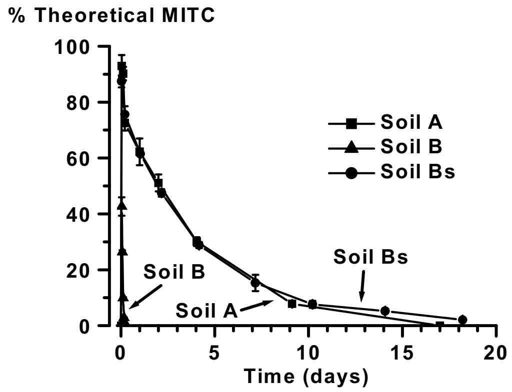

Figure 1. Change with time in the percentage of the theoretical amount of MITC produced in the three soils after treatment with metham sodium. Soil A was cultivated, but without previous exposure to metham sodium, soil B had a previous history of metham sodium use and soil Bs was a duplicate portion of soil B that was sterilised by autoclaving.

DISCUSSION

The dramatic difference in both the maximum MITC concentration (93 per cent v 42 per cent) and its persistence (17 days v seven hours) in the previously untreated soil A when compared with the previously treated soil B suggests that the MITC was being transformed very rapidly in the latter soil. The previous history of metham use on this soil raised the possibility that enhanced biodegradation may be causing this rapid removal.

This was confirmed when a sample of soil B was sterilised to kill any microorganisms present. The MITC concentration reached a maximum of 88 per cent and was present for 18 days - very similar figures to those for the soil never previously treated with metham sodium (soil A). These results confirm that the previously treated soil (soil B) is suffering from enhanced biodegradation, with microbes present in the soil consuming the MITC rapidly.

Enhanced biodegradation of soil-applied pesticides such as metham sodium in Europe and the US has resulted in many cases of inadequate pest control, leading to reduced crop yields. Research has shown that there is no cure to the problem – the only management strategy once the problem has occurred is to discontinue treatment of the affected land with the pesticide for several years. This usually needs to be longer than the time it took to induce the problem. The best practice therefore is to prevent enhanced biodegradation from occurring in the first place. This is done by limiting the frequency with which the soil is treated with the pesticide.

The risk of development of enhanced biodegradation is influenced by soil characteristics, with pH being an important factor. Generally, higher soil pH increases the risk of enhanced biodegradation developing.

Our research is aimed at developing an index of the risk of development of enhanced biodegradation of metham sodium for different soil types and horticultural production systems. This will allow growers to determine how frequently they could use metham sodium on their land before being in danger of inducing enhanced biodegradation. In this way, we will enable growers to avoid the onset of enhanced biodegradation, a phenomenon which could potentially reduce the effectiveness of one of their valuable weapons against soil-borne pests and diseases.

ACKNOWLEDGEMENTS

Research on the environmental fate of metham sodium and ways to help growers use it efficiently is being supported by the vegetable and potato levies through the Horticultural Research and Development Corporation.

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BIOFUMIGATION FOR SOIL-BORNE PEST AND DISEASE SUPPRESSION

J. N. Matthiessen[A] and J. A Kirkegaard[B]
[A]CSIRO Entomology, Private Bag 5, Wembley 6913, Western Australia. johnm@ccmar.csiro.au
[B]CSIRO Plant Industry, PO Box 1700, Canberra 2601, ACT. j.kirkegaard@pi.csiro.au

SUMMARY

Biofumigation refers to the use of brassicas that produce toxic isothiocyanate compounds, similar to the methyl isothiocyanate toxin from metham sodium soil fumigant, for suppressing pests and diseases in soil. It seeks to offer a biological alternative for producing fumigant-like chemicals, providing an option for suppressing soil-borne pests and diseases, and helping promote other desirable soil characteristics. Our research, in collaboration with others, is aimed at understanding how biofumigant effects occur, how we can best harness them and how we can enhance them through breeding and management to offer producers more choices to meet production needs.

INTRODUCTION

Soil-borne pests and diseases are a major issue for growers of crops such as carrots and potatoes. They are difficult to detect because of microscopic size, (eg. fungal pathogens, nematodes) and because of resting stages that differ from the active stage (eg. fungal pathogens). Treatment during crop growth is almost impossible.

Any scouting system for detection and diagnosis requires major effort, specialist services and needs to be carried out pre-planting. Growers generally counter the threat of soil-borne pests and diseases with prophylactic applications of pesticides. A pesticide often used in carrot production is the broad-spectrum soil fumigant metham sodium.

Metham sodium produces the toxic compound methyl isothiocyanate (MITC) upon contact with moist soil. While referred to as a soil fumigant, which implies that the pesticide moves through the soil as a gas, metham sodium is probably more accurately described as a soil pesticide as the MITC is highly water soluble and primarily disperses in the soil moisture.

Despite its widespread and increasing use in horticulture generally, and intensive use in some carrot-producing regions, growers are often concerned about using such a powerful broad-spectrum pesticide for safety or environmental reasons. Based on adverse past experiences, there are also concerns about becoming reliant on a single pesticide. In the case of soil fumigants, there is an extremely limited and shrinking choice and no new products are on the horizon.

Biofumigation, the idea of using plants that produce toxic compounds, seeks to offer a biological alternative to the pesticides for exerting control over pests and diseases in soil. It aims to provide a further option for growers, based on their circumstances of pest and disease pressure, economics and their ideals for a cropping system.

Our particular focus is on the *Brassica* group, because many of them produce compounds similar to the MITC toxin from metham sodium. The biocidal activity of various isothiocyanates (ITCs) released by *Brassica* tissues is well-known (1), and the potential of brassicas to suppress a range of soil-borne pests and diseases is supported by considerable empirical field evidence (2).

Our research, in collaboration with others, is aimed at understanding how biofumigant effects occur, how they can best be harnessed and how they can be enhanced through breeding and management.

CURRENT STATUS

Both scientific studies and general observations have shown that various brassicas can produce suppressive effects on soil pests and diseases. The effects are related to the ITCs that form from precursor glucosinolates (GSLs) when the plant is disrupted, such as when it is incorporated into soil. There are many different GSLs in brassicas, with about six types being most common.

'Any old *Brassica*' will not necessarily produce a biofumigant effect! Many species and varieties have been chemically analysed to assess their capacity to produce ITCs. A wide variation in GSL types, mixtures and concentrations has been found. The ITCs produced from the GSLs in various plants and different tissues (roots, shoots) have been assayed against common pathogens and soil pests to measure their toxicity. The assays and chemical analyses have shown that certain ITCs are more toxic than others, that their volatility varies, and that various combinations of ITCs may exert greater effects than the components alone.

The toxicity of an ITC sometimes differs among organisms, suggesting that specific plants could be utilised more successfully than others for biofumigant effects by matching them to particular pests or diseases. Aromatic ITCs produced from GSLs often found in roots are very toxic (50 or more times greater than metham sodium's MITC) but as they are of low volatility, contact with organisms may be reduced. Aliphatic ITCs are more common in shoots and, while less toxic, their greater volatility may improve contact with organisms.

The concentration of GSLs is highest in growing tissues, declining as the plant ages. For optimal effects, it is necessary to grow types high in the best GSL, or mix of GSLs, in the most appropriate part of the plant. There is a good association between root GSLs and effects on pests and diseases, and roots may release ITCs during growth as well as at decomposition. Consequently the biofumigation potential of roots may be disproportionately higher than shoots, which recent evidence suggests may be lessened by too high a biomass of tissue.

Maximum GSL content occurs near budding, after which it declines quite quickly. Since genetic diversity exists for both GSL production and biomass, it is possible to select for both attributes to optimise potential.

About 150 brassicas already commercially available for other purposes, such as oilseed production or as animal fodder, have been analysed and tested for biofumigation potential (3). Those that produce the greatest amount of toxic ITCs have been selected for commercial release. These are by no means the 'best possible' varieties, but are currently the 'best available'.

The chemical analysis and toxicity testing techniques developed to assess the potential of existing lines are being used to breed superior lines.

FUTURE DIRECTIONS

Biofumigation should be seen as an option for suppression of soil-borne pests and diseases. Alone, it is unlikely to provide the on-demand high-impact control offered by synthetic chemical fumigants applied in large doses. However, the suppression of a range of pests and diseases achieved to date with little or no knowledge of the types or concentrations of the active chemicals produced in the plants strongly suggests that improvements should occur with purposeful selection for biofumigant types.

There are many reasons why producers may not have the desire to use chemical fumigants. In order to better utilise biofumigation, how the beneficial effects occur needs to be better understood and developed for greater impact. Continued research and trials is occurring to provide information on biofumigant effects and growth characteristics in various cropping systems and regions. This will offer producers a more soundly-based option to gain the best possible benefits in soil-borne pest and disease suppression.

Many fine-tuning aspects of effects in soil need further research. Information on the fate and activity of the biocidal compounds in soil, and the effects of soil characteristics (eg. pH, texture, organic matter content) on the release and efficacy of the toxins, through a systematic research approach, will maximise the chances of obtaining optimal biofumigant brassicas. Such aspects are complex and not easily measured, but only with an understanding of these factors will we be able to offer guidance to plant breeders on the most appropriate directions for developing improved varieties. Such knowledge will also help advise on how best to utilise biofumigant green manure plants in practice.

Conducting field trials on pests and diseases in 'heavy' horticultural crops such as carrots is notoriously difficult. High cost and high value make it problematic for establishing and assessing research plots in pest and disease-infested areas. Most field research can only be readily carried out in commercial crops in which pests and diseases may be very patchy. Links with research on biofumigation effects in cereal production systems where field experimentation is more readily carried out is providing transfer of knowledge and benefits to the more complex horticultural production systems.

The agronomic aspects of growing brassicas in different areas and production systems is being tested to determine the appropriateness of the biofumigation approach and to maximise its potential in relation to the major pests and diseases. For example, in northerly areas or for spring sowing it is better not to use mustards as they flower too quickly to provide good biomass. In colder areas growth of many brassicas may be too slow during winter to produce adequate biomass to precede a spring-sown crop. While varieties with desirable agronomic characteristics may exist or be developed, research results will ensure that selection accounts for the type and efficacy of the ITCs that will be produced.

Brassicas are subject to their own pests and pest control in different areas and seasons also needs to be taken into account, as does the potential for weediness. While most brassicas are not hardseeded, it is prudent that they are ploughed in before any seed can set. This also ensures advantage is taken of the highest levels of ITC production. Thorough incorporation into the soil will also provide the greatest chance of ITCs coming into contact with pests and diseases as the plant tissue breaks down, and give the best green manuring benefits.

Obtaining best advantage from the biofumigation approach to soil-borne pest and disease management across a diversity of crops, production systems, geographic locations and seasonal differences will need a range of research and trial work. While some quite spectacular effects have been observed, it is a biological approach, and therefore not an 'off the shelf' or 'silver bullet' solution, but rather an option that has to fit or be built into the production system.

Researchers need to advance knowledge of the processes that produce the biofumigant effects and use these to make selections and help breeders achieve improved lines. Seed companies need to determine appropriate agronomic practices to guide usage in various areas. Importantly, producers need to carry out their own trials to assess potential advantages and disadvantages of the approach in their own situation, as one method will not fit all systems.

OUTCOMES FOR INDUSTRY

Biofumigation may offer industry an alternative biologically-based means of suppressing soil-borne pests and diseases. Currently, it is based on the availability of brassicas selected from current commercially-available fodder and oil-crop lines on the basis of their relatively high production of ITCs. However, these lines have not been specifically selected for superior ITC production and it is clear that there is potential for improvements in the quantity and type of ITC profile by plant breeders in the longer term. The systematic collaborative approach to this research in assessing the chemistry and toxicity of the various ITCs and linking that to breeding development, and commercial seed suppliers and agronomic evaluators across Australia will ensure that lines optimised for biofumigant effects are developed and become available to industry.

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Session 5

ALTERNARIA RADICINA AND ITS IMPACT ON CARROT SEEDLING ESTABLISHMENT IN SOUTH AUSTRALIA

R.B. Coles and T.J.Wicks
South Australian Research and Development Institute, GPO Box 397, Adelaid 5001, South Australia
Phone 08 8389817 Fax: 08 8389 8800 Email: coles.robin@saugov.sa.gov.au

SUMMARY

Carrot seedlings sampled from eight carrot growing regions in South Australia (SA) from December 1998 to March 2000 showed that *Alternaria radicina* Meier, Drechsler & Eddy was the main cause of seedling losses. The disease is wide spread throughout the state with the highest incidence recorded during February to April. On some properties 47 per cent of seedlings were infected with *A. radicina*. The fungus is seed borne and was found in 18 of 19 non fungicide treated seed batches at levels of 2 to 35 per cent and in 11 of 16 fungicide treated batches at levels 0.2 to 14 per cent.

The fungus survives in the soil for an extended time and has been isolated in carrot growing areas using selective media with levels as high as 260 colony forming units (CFUs)/g of soil.

INTRODUCTION

Losses due to poor seedling establishment and damping-off have been reported by carrot growers in SA since the 1970s. This disorder occurs unpredictably, usually during periods of warm humid weather and has not been successfully controlled by fungicide applications on seed such as thiram and iprodione.

A limited survey in the Virginia area 12 km north of Adelaide in 1994 implicated *Alternaria* and *Fusarium* as possible causes of carrot seedling damping-off (T. Wicks, unpublished data). This paper reports on a more extensive survey undertaken to determine the extent of the problem in SA. Studies were also made to determine the cause of seedling losses and to ascertain if infected carrot seed was associated with the problem.

MATERIALS AND METHODS

Survey of carrot plantings. Carrot plantings of 4 to 6 week old seedlings with obvious damping-off symptoms, stunting, stem rot, wilting or leaf discolouration were collected at 1 to 2 monthly intervals from the eight growing regions in SA, with up to six sampling times for each area. At each sampling time 50 to 100 plants/site from affected areas were collected, with a similar number of healthy plants collected from adjacent plantings.

Isolations were made from at least six seedlings from each affected sample that showed obvious disease symptoms. Sections of plant material, 1 mm thick, were surface sterilised in 70 per cent ethanol, rinsed in sterile water and surface dried on sterile filter papers. Three sections from the stem, hypocotyl region and the storage root were then plated onto (i) corn meal agar (CMA), (1); (ii) potato dextrose agar (PDA with 200 ppm chlotetracycline); (iii) V8 juice agar (200 ml juice/L with 2 g calcium carbonate and 250 ppm streptomycin and (iv) water agar (WA, Difco bacto-agar with 200 ppm chlotetracycline).

Foliage pieces showing lesions and marginal necrosis were surface sterilised and incubated in moist chambers at room temperature. Pieces were examined after 1, 2 and 10 days, fungi were identified from spore morphology using a standard mycological key (2).

Isolation of fungi from commercial carrot seed. Seed samples were donated by seed companies and carrot growers or purchased from retailers. Ten to 20 replicate batches each of 50 seeds were tested for the presence of pathogens with a total of 500 to 1000 seeds screened for each cultivar. A standard freezer-blotter method for assaying carrot seed quality was used (3). Commercial seed batches, 19 not treated and 16 treated with fungicides thiram and or iprodione, were tested for levels of *Alternaria* spp.

Isolation of *A. radicina* from soil. At least twenty 2.5 cm diameter soil cores were taken randomly to a depth of 25 cm in a zigzag pattern over a 200 m square in five different carrot fields. The soil was air dried for 2 weeks at room temperature, crushed in a grinder and passed through a standard sieve then stored at 4 ^{o}C. A standard assay method using *A. radicina* selective agar (ARSA) was used to determine the number of colony forming units (CFU/g) in the soil (3).

RESULTS

Survey of carrot plantings. Seedlings with damping-off were found in six of the eight regions surveyed. *A. radicina* was the main fungus isolated from damped-off seedlings, stems and petioles of stunted plants. Often a black to purple discolouration developed on the stem and microscopic sections showed the fungus had invaded the periderm and phloem tissue and formed a constricted area near the upper seedling root. Infected plants failed to grow as rapidly as healthy seedlings.

The pooled monthly data from the eight properties surveyed shows that the incidence of *A. radicina* was highest between February and April, with the maximum of 25 per cent occurring in March, 15 per cent in February to April and 10 per cent in January. At other times, the incidence of *A. radicina* on seedlings was no higher than 5 per cent (Table 1).

Isolation of fungi from commercial carrot seed. Three species of *Alternaria* were found in seed batches with levels ranging from 0.1 to 59 per cent. *A. radicina* was found in 18 of the 19 non fungicide treated batches at levels of 2 to 35 per cent and in 11 of the 16 fungicide treated batches at levels of 0.2 to 14 per cent. *A. dauci* (Kühn) Groves & Skolko was found in four batches of both fungicide and non-fungicide treated seed levels at levels of 0.1 to 0.3 per cent. *A. alternata* (Fr.) Keissler was present on all 19 untreated seed batches at levels of 2 to 37 per cent and on treated seed at <1 to 14 per cent.

Table 1 Incidence of *Alternaria radicina* on carrot seedlings in South Australia, 1998-1999.

Month 1998-1999	Percentage incidence of *Alternaria radicina*[A]
Nov.	0
Dec.	5
Jan.	10
Feb.	15
Mar.	25
Apr.	15
May	5
June	5
July	5
Aug.	0
Sep.	5
Oct.	5

[A] Percent values based on 800 samples/month from a total of eight carrot growing regions

Isolation of *A. radicina* from soil *A. radicina* selective agar (ARSA) inhibited the growth of soil bacteria and many common soil borne fungi. The vegetative growth of *A. radicina* was distinctive and different from other soil and saprophytic fungi such as *A. alternata*, *Stemphylium* spp., *Ulocadium* spp. and other dark coloured hyphal species. *A. radicina* produced brown to black hyphae, occasionally branched, that grew downward into the media in a concave shape with little or no aerial growth. The mean and ranges of CFUs/g of soil in five carrot growing areas are shown in Table 2. Parilla (255 CFUs/g) had a history of carrot production, cereal rotation and high soil nematode numbers with no soil fumigation practices. Blanchetown (210 CFUs/g) had a 3 year history of continuous carrot plantings, Paringa (26 CFUs/g) had high levels of seed stock infestations and Virginia 1 (10 CFUs/g) had a past history of carrot and potato rotations. Ashbourne (6 CFUs/g) had no history of carrot production and Virginia 2 had (3 CFUs/g) and used carrot and broccoli rotation with soil fumigation.

Table 2. Levels of *Alternaria radicina* in soil collected from SA carrot production regions, 2000

Region	Soil population density(CFU/g of soil)	
	Average	**Range**
Parilla	255	250-260
Blanchetown	210	200-220
Paringa	26	0-40
Virginia 1	10	0-30
Ashbourne	6	0-20
Virginia 2	3	0-10

DISCUSSION

The survey shows that *A. radicina* was associated with damping-off of carrot seedlings and was wide spread in carrot plantings in SA. Damping-off was most frequent in summer and autumn. High temperatures (up to 46 ^{o}C) and heavy rainfalls of 94 mm were regularly associated with the development of disease in the field. During December to May 2000 dust storms and high winds at this time damaged seedling stems near ground level and may have provided points of entry for *A. radicina.*

During seed assays for *A. radicina*, healthy seeds adjacent to diseased seeds often became infected during the 21 days incubation at room temperature. Infected seed developed sporulating mycelial strands that grew over the sterile filter papers and infected adjacent healthy seed. This suggests that there where seeds are densely planted in soil, healthy seedlings may be come infected as a result of mycelial spread from infected seed. Seeding rates in SA are approximately 2 million seeds/hectare. In some of the samples that we tested, 35 per cent of the seed was infested with *A. radicina*. Planting this seed would introduce approximately 0.7 million infested seeds/hectare.

Although fungicides had been applied to carrot seed, our tests showed that the seed dressings did not inhibit the development of *A. radicina.* Fungicide application on the seed surface are unlikely to control internal infections of *A. radicina*.

Higher levels of *A. radicina* were recovered from soils where carrots had been planted previously, or where seed with high levels of infection were planted. The lowest levels where found where clean soil was planted, either by fumigation or new ground. However levels of up to 10 CFUs/g infection found in these soils, indicates that controlling seed borne infection is most important when planting clean ground.

A. radicina has been shown to survive in the soil for up to 8 years in the absence of cultivation and its hosts (4). It can be quantified as a soil borne pathogen using a semi-selective media (ARSA) which may be a valuable tool in determining soil population densities of *A. radicina* at the time of planting and the incidence of seedling damping-off.

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CAVITY SPOT IN AUSTRALIA

E.M. Davison and A.G. McKay
Agriculture Western Australia, Locked Bag 4, Bentley Delivery Centre 6983, Western Australia

INTRODUCTION

Carrot exports from Western Australia (WA) to Asia increased rapidly during the 1990s. This developing industry has been supported by local research on carrot quality and agronomy. A survey of carrot crops in 1990/91 showed that cavity spot disease reduced marketable yield by more than 10 per cent in 16 per cent of crops. (1). Management of cavity spot has been a major part of carrot research, covering varietal tolerance, chemical control, rotation, harvest time and manipulation of soil pH.

In WA, cavity spot is caused by the soil-borne fungus *Pythium sulcatum* (2), but this is not the only species that can cause this disease. *P. violae* is the most important cause in some other parts of the world. Knowing the identity of the causal organism is important because these two fungi differ in their host range.

Cavity spot disease is also important in other parts of Australia where carrots are grown for the fresh market. If the control measures for cavity spot that have been developed in WA are to be confidently applied in other regions, it is important to know whether *P. sulcatum* or *P. violae* are causing this disease elsewhere.

AUSTRALIAN SURVEY

Identity of *Pythium* spp. from carrots Of the isolates from carrots, 61 per cent were *P. sulcatum* and 5 per cent were *P. violae*. *P. sulcatum* occurred in all states, *P. violae* occurred in the Murray River basin (Fig. 1).

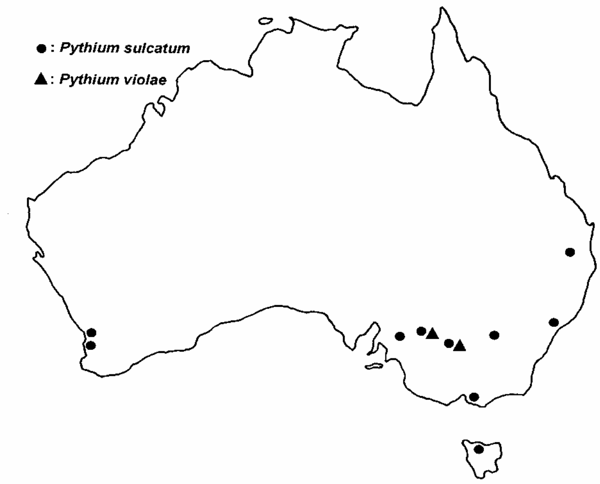

Figure 1. Distribution of *P. sulcatum* and *P. violae* in the main carrot growing regions of Australia.

INTEGRATED DISEASE MANAGEMENT

Tolerant varieties Assessment for disease tolerance has been conducted in WA in a disease nursery (3) with the most promising cultivars being trialed on growers' properties.

Chemical control Metalaxyl reduces the incidence and severity of cavity spot disease in WA when applied at or shortly after seeding. However, if it is used too frequently it can loose its effectiveness because of an increase in its rate of breakdown in soil (4). Metham sodium has failed to control cavity spot.

Rotation In WA members of the carrot family (Apiaceae) can be hosts of *P. sulcatum,* so it is important to rotate carrots with unrelated plants. A trial where broccoli (non-host) is grown in rotation with carrots is underway, and the results are promising.

P. violae has a wider host range than *P. sulcatum*. As it can attack broccoli (5) using this as a rotational crop may exacerbate cavity spot in the Murray River basin.

Harvest time Experience in WA is that cavity spot develops rapidly on overmature carrots, so harvest them as soon as they reach marketable size.

Soil pH In WA, liming soil to increase pH reduces the incidence and severity of cavity spot (1). The target pH is 7.2 or higher (measured in calcium chloride) (6).

CONCLUSIONS

Cavity spot disease can be managed by using tolerant varieties, metalaxyl (if not used too frequently), rotation, raising soil pH and harvesting on time. These control measures should be applicable in Queensland, New South Wales, southern Victoria and Tasmania. In the Murray River basin the presence of *P. violae* will affect the choice of an appropriate rotation. Recent research findings can be accessed on the internet at http://www.agric.wa.gov.au/programs/hort/carrots/

ACKNOWLEDGMENTS

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CAVITY SPOT - POTENTIAL CONTROL MEASURES

L.H. Hiltunen, S.R. Kenny and J.G. White
Horticulture Research International, Wellesbourne, Warwick, CV35 9EF, U.K.

SUMMARY

This paper reports the concepts developed, and current experimental approach in ongoing research on the control of cavity spot in the UK. While it is possible to list potential controls such as new fungicides, disease avoidance, exploiting enhanced germplasm or biological control, the need of growers now is for a 'quick fix'. The world literature directed us to calcium compounds, and the possibility to develop and maintain soil microfloras antagonistic to cavity spot pathogens. All calcium compounds tested gave some disease control, but calcium carbonate, which is both cheap and without operator risk, gave the best and most consistent control. Below we demonstrate the control possible from the use of calcium carbonate in soil where severe disease is commonplace. Present work considers the possibility of applying the compound well in advance of drilling to ensure that the soil has been conditioned by the time seeds are sown.

INTRODUCTION

Cavity spot is the major soil-borne disease of carrots in the UK, and as a result has received considerable support from the industry in the form of research funds from the Horticultural Development Council. In work, which has not yet been published, all existing marketed fungicides, which might affect cavity spot, have been screened together with a number of new molecules. None have given disease control anywhere near equivalent to that from metalaxyl (SL567 ® Novartis Crop Protection UK Ltd). Because of concerns over the future efficacy of metalaxyl through possible resistance in the pathogen, or the phenomenon of enhanced microbial degradation which has been confirmed in Western Australia (1) and the UK (Kenny & White, unpublished information), we have defined the future for control of cavity spot as being with non-synthesised fungicide options. Manipulation of carrot germplasm may have a long-term benefit, but will not be of help in the current decade (2). A survey of the world literature on cavity spot, also un-published, showed that calcium treatments gave the largest non-fungicide disease reductions. The mode of action was seen to be by the induction of a soil microflora antagonistic to cavity spot pathogens (3), and this may mean that growers can, from one application, build the ability to suppress cavity spot on more than one crop.

Some of our results are discussed below.

MATERIALS AND METHODS

The tests reported were made using soil from a known *Pythium violae* cavity spot site which was bulked and sieved to remove stones before being used in the tests. Pots (25 cm) were prepared with 1.5 kg pea gravel and then filled with soil already treated with test materials, or with soil to be treated by spraying. Sub-treatments were applications made one month before drilling, or immediately prior to drilling. There were eight replicates of every treatment. The treatments are shown in Table 1. Prepared pots were sown with 40 seeds of the cavity spot susceptible cv. Nanco and placed in a glasshouse in a formal randomised design. At completion of emergence, seedling stands were reduced to 20, and where appropriate metalaxyl was applied.

Plants were grown for around 130 days with normal glasshouse management before they were harvested, the roots washed, and then scored for cavity spot. A range of parameters of disease were used, but here we consider Incidence (percentage of roots with any cavities) and Severity (mean number of cavities per root). Data were subjected to analysis of variance in Genstat (Table 1). Percentages were transformed to angles prior to analysis. After harvest all remaining roots and debris were removed and the pots were left on the glasshouse bench until the following spring when the soil was turned and they were re-sown with cv. Nanco. No spray applications were made, so the only issue was to measure carry-over effects from the previous years treatments. At completion of emergence, seedling stands were reduced to 20 per pot and plants were grown, harvested, assessed and data was processed as described above.

RESULTS

Table 1 summarises results with calcium carbonate, calcium hydroxide or calcium monocarbamide applied one month before, or at drilling, with or without post-emergence application of metalaxyl (SL567).

Table 1. Control of cavity spot with calcium compounds

Treatment	Incidence	Severity
Control	77.5 (62.5)	1.80
$CaCO_3$* -before drilling	16.3 (21.6)	0.19
$CaCO_3$ -at drilling	35.0 (36.0)	0.93
$CaCO_3$ -before drilling + SL567	15.0 (19.3)	0.29
$CaCO_3$ -at drilling + SL567	40.0 (37.0)	1.00
$Ca(OH)_2$ -before drilling	37.5 (37.1)	0.79
$Ca(OH)_2$ -at drilling	38.7 (37.6)	0.93
$Ca(OH)_2$ -before drilling + SL567	25.0 (29.4)	0.41
$Ca(OH)_2$ -at drilling + SL567	27.5 (29.4)	0.43
Ca monocarbamide -before drilling	46.2 (42.7)	1.00
Ca monocarbamide -at drilling	48.7 (42.5)	1.09
Ca monocarbamide -before drilling + SL567	30.0 (32.4)	0.43
Ca monocarbamide -at drilling + SL567	68.7 (60.4)	1.55
SL567	47.5 (41.6)	1.23
LSD (P=0.05)	15.33**	0.37

* Calcium carbonate and calcium hydroxide were applied at 12 t/ha either one month before or immediately before drilling. Calcium monocarbamide was sprayed at 300 l/ha either one month before or immediately before drilling. SL567 (metalaxyl, 46.2 per cent) was applied as a spray at first true leaf stage (0.6 kg a.i./ha).

** LSD applies to figures in parentheses.

While cavity spot percentage in the untreated control pots was extremely high, with a high severity rating, disease in the calcium carbonate treatments made a month before drilling, with or without metalaxyl, were low. Clearly, the fungicide did not improve disease control over and above that from calcium carbonate. Disease control as measured by both parameters was significantly less when the calcium carbonate was applied a month before drilling. As cavity diameter is also recorded, we also note that the calcium carbonate treatment significantly reduced cavity size. Further, a subjective assessment indicated improved skin finish. For both calcium hydroxide and calcium monocarbamide there were highly significant disease reductions, which in most cases were improved by the use of metalaxyl.

Results from the re-sown crop were substantially similar, with 57.5 per cent incidence, 2.01 severity in the untreated controls reduced to a mean of 10.6 per cent incidence and 0.14 severity across the four calcium carbonate treatments. Across the four calcium hydroxide treatments mean incidence was 9.1 per cent and mean severity 0.17. For calcium monocarbamide the equivalent data was 19.7 per cent and 0.45.

The work with calcium carbonate has been taken to the field with a 10 t/ha application made immediately before drilling, with or without metalaxyl post-emergence. Applied alone, calcium carbonate reduced incidence and severity of cavity spot only at a post-strawing harvest, although at this harvest it was significantly more effective than metalaxyl applied alone. When calcium carbonate was applied with metalaxyl, cavity spot was highly significantly reduced at both early and late harvests.

DISCUSSION

It has been the UK experience that metalaxyl has served the industry well over almost two decades. However, control of cavity spot has been seen to decline in recent years and growers quite reasonably require new and effective methods. Disease avoidance using diagnostic technology (4) has been possible in the temperate conditions predominating in the UK, but not where weather conditions are more extreme. The researcher working on behalf of the grower has therefore been faced with the need to produce different control measures. In addition to being effective, these must be cost-effective, so for instance it would not be acceptable to demonstrate effective whole field fumigation because growers just could not afford to use it. The control measure must also not abuse the environment in any way or the retailers will not take the crop. The final requirement is that the grower wants the treatment now. Long-term solutions may be the subject of 'one step removed research' for the future, but for the present workers the direct question has been what the grower can do now. The first action should be wherever possible to use carrot cvs. with a reputation for having field resistance to the disease.

Part of the reason for the success of metalaxyl is that it is both highly active against cavity spot pathogens, and is highly soluble, therefore mobile in soil. Of the metalaxyl analogues generated in the 1980's, only furalaxyl (restricted to non-edible crops) had equivalent efficacy. Some analogues had no effect on cavity spot whatsoever. A wide range of fungicides with Oomycete activity have been screened *in vivo* and *in vitro* and none have shown acute activity against *P. violae* although some have controlled cavity spot caused by *Pythium sulcatum*. On this basis we feel that it is unlikely in the short term that a new fungicide highly effective against cavity spot will be identified.

Most UK carrot fields have natural infestation with the mycoparasite *Pythium oligandrum* (5). This has been shown in the laboratory to be highly effective in killing the cavity spot pathogens. However, the logistics of encouraging the mycoparasite without coincidentally increasing levels of cavity spot pathogens appear insurmountable.

This logic leads inevitably to what one can reasonably and practically do to control the disease, and from the world literature we have focussed in on calcium compounds. The results we have obtained confirm findings in an HRDC report (6) both in the high pressure pot test and in the field where disease pressure was lower. We have extended that work to consider applications made one or two months before drilling to allow soils to become conditioned. We have also taken application rates of both calcium carbonate and calcium hydroxide down to 3 t/ha with reducing disease control according to rate. At the time of writing, calcium carbonate appears to be the most useful compound, and it is likely that where fields do not have enhanced microbial degradation of metalaxyl, application of that fungicide would give additional benefit.

The current project is in its third year and studies continue on both the manipulation of calcium compounds and combination treatments with metalaxyl.

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NEMATODES IN CARROT PRODUCTION IN AUSTRALIA

F. Hay
Tasmanian Institute of Agricultural Research, University of Tasmania North West Centre, P.O. Box 447, Burnie 7320, Tasmania

SUMMARY

Plant parasitic nematodes such as root knot nematode (*Meloidogyne* spp.) and lesion nematode (*Pratylenchus* spp.) have been consistently associated with reduction in yield of carrot and deformities of the tap-root. A project sponsored by AusVeg Levy and the Horticultural Research and Development Corporation has recently begun to investigate improved control of nematodes in carrot production in Australia.

INTRODUCTION

Nematodes are microscopic unsegmented worms. Many species live in soil and most are beneficial to agriculture, playing a major role in decomposition of organic matter and re-cycling of nutrients. However, some species of nematodes are parasitic on plants and have been estimated to cause crop losses of around $A300 million pa in Australia (1). A number of nematode species have been associated with carrot in Australia (Table 1). This list is probably by no means comprehensive and it is likely that many other species are present.

Table 1. Species of plant-parasitic nematodes associated with carrot in Australia (2).

Ditylenchus dipsaci	*Helicotylenchus dihystera*
Meloidogyne arenaria	*Meloidogyne hapla*
Meloidogyne incognita	*Meloidogyne javanica*
Meloidogyne thamesi	*Paratrichodorus lobatus*
Paratrichodorus minor	*Pratylenchus crenatus*
Pratylenchus penetrans	*Pratylenchus pratensis*
Rotylenchus robustus	

EFFECT OF NEMATODES

Nematodes such as *Pratylenchus* spp. burrow into, and feed inside of roots. Large numbers can severely restrict root growth and reduce uptake of water and nutrients. In one study (3), the tap-root of carrot growing in organic soil infested with 100, 200 or 400 *Pratylenchus penetrans*/100 mL of soil developed abnormally in comparison to carrots in soil with no nematodes. The weight of the tap-root was reduced at all population densities and at the two higher densities, heavy branching of the tap root was evident. In another study (4) an initial density of 10 *P. penetrans*/100 mL soil caused 75 per cent of carrots to be forked, while 100 *P. penetrans*/100 mL of soil killed 40 per cent of plants. *Pratylenchus* spp. have a wide host range which includes many crop plants. A recent survey of nematodes in Tasmania (G.R. Stirling and F.S. Hay unpubl.) showed *Pratylenchus* spp. to be present in all 80 fields surveyed and high numbers to occur in many fields following a variety of crops (Table 2).

Table 2. Number of *Pratylenchus*/100 mL soil in fields following different crops in Northern Tasmania (G.R. Stirling & F. Hay unpubl.).

		No. per 100 mL soil		
Previous crop	No. fields	Average	Min.	Max.
Pasture	12	297	4	1965
Poppy	26	38	1	155
Onion	6	52	1	152
Pea	3	10	1	23
Broccoli	4	186	2	640
Cereal	13	101	4	292
Carrot	5	92	9	218
Potato	11	164	8	572

Root knot nematode (*Meloidogyne* spp.) is also common in many soils used for carrot production. This nematode burrows into the root and forms a sedentary feeding position, eventually maturing into a lemon-shaped stage that extrudes eggs into the soil. Root-knot nematode feeding causes symptoms in carrot which include galling, forking, stubbing and fasciculation of the roots, constrictions and twisting of the tap root, increased cracking of the epidermis and significant yield reduction (5).

In experiments in growth chambers (5), carrots in soil without nematodes yielded 62.6 g/plant, compared with only 40.6 g/plant when 240 *M. hapla*/100 mL soil were present (Table 3). The percentage of forked storage roots increased from 0 per cent when no *M. hapla* were present, to 59 per cent when exposed to 160 *M. hapla*/100 mL soil (Table 3). In microplots (5), the weight of carrot roots and the weight of marketable roots declined with increased pre-plant populations of *M. hapla* (Table 4). An average of 21.1 kg of marketable roots was obtained from plots with no nematodes and 1.8 kg from plots with an initial nematode density of 240 *M. hapla*/100 mL soil.

CONTROL

In the past, nematodes have been controlled effectively by nematicides. However, many nematicides have been removed from the market due to concerns regarding their effect on the environment and toxicity to animals. Some nematicides have also been shown to become less effective with continued use, due to enhanced biodegradation by soil micro-organisms.

Table 3. Effect of *Meloidogyne hapla* on growth and quality of carrot in growth chambers (5).

No. *M. hapla*/ 100 mL soil	Wt. storage root (g/plant)	Forked roots (%)
0	62.6a	0a
20	45.5b	0a
40	42.8b	2a
80	45.9b	8a
160	49.8b	59b
240	40.6b	57b

[1]Means within columns followed by the same letter are not significantly different (P=0.05)

Table 4. Effect of *Meloidogyne hapla* on growth and quality of carrot in microplots (5).

No. *M. hapla*/ 100 mL soil	Wt. storage roots (kg/plot)	Wt. marketable storage roots (kg/plot)
0	21.1a	21.1a
20	16.8b	10.8b
40	15.8b	6.9c
80	14.2c	4.3d
160	13.0c	1.3e
240	12.9c	1.8e

[1]Means within columns followed by the same letter are not significantly different (P=0.05)

Crop rotation is one of the most effective alternatives to chemical methods for controlling nematodes. The cropping sequence onion - small grain - carrot reduced *M. hapla* population densities below detectable levels and provided a 282 per cent increase in marketable yield compared to the yield obtained in the final year from a continuous carrot monoculture (6). Significant increases in yield and reductions in root knot nematode numbers were obtained by rotations with other crops prior to carrot (Table 5). A weedy fallow prior to carrot was not effective because some weeds are good hosts of *M. hapla* (Table 5).

Table 5. Effect of different cropping sequences on the yield of carrot in the last year and the number of *M. hapla*/100 mL soil prior to planting the final carrot crop (7).

Crop sequence	Marketable roots t/ha	No. *M. hapla*/ 100 mL soil
Barley-Onion-Carrot	56.8a[1]	0c
Onion-Barley-Carrot	47.4b	17c
Carrot-Barley-Carrot	34.0c	0c
Barley-Carrot-Carrot	33.1c	121a
Carrot-Onion-Carrot	23.0d	52a
Fallow-Fallow-Carrot	15.3e	242a
Carrot-Carrot-Carrot	2.2f	140a

[1]Means within columns followed by the same letter are not significantly different (P=0.05)

FUTURE STUDIES IN AUSTRALIA

Recently a three-year project entitled 'Improved Control of Nematodes in Carrot Production' was begun. This project is funded by HRDC and the AusVeg Levy and involves investigators in each State. The purpose of the project will be to lessen the impact of nematodes on carrot production by:

- Identifying or confirming the identity of nematodes which cause economic losses to carrot production in each State.
- Examining the relationship between pre-plant density of particular species of nematodes and yield/quality so that fields may be better categorised in terms of risk prior to planting.
- Determining the host range of important nematode species to determine the best crop rotation or green manure species to use before carrot.
- Investigating improved methods of chemical control, alternative methods such as biological control and identifying tolerant/resistant cultivars.
- Developing a package for integrated control of nematodes for the carrot industry in Australia.

ACKNOWLEDGEMENTS

We gratefully acknowledge funding by HRDC and AusVeg Levy.

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YIELD AND QUALITY LOSSES IN CARROTS INFECTED WITH CARROT VIRUS Y

L.J. Latham and R.A.C. Jones
Agriculture Western Australia, Locked Bag No. 4, Bentley Delivery Centre 6983, Western Australia.

INTRODUCTION

Carrots (*Daucus carota* var. *sativa*) are Western Australia's most important horticultural export crop with nearly 49,000 tonnes sent overseas in 1999/2000. Carrot virus Y potyvirus (CVY) has recently been identified as the causal agent of a devastating disease of carrots found in Australia (1). This virus is transmitted by aphids non-persistently and has a very limited natural host range. Symptoms in shoots of a range of carrot cultivars include chlorotic mottle, generalised chlorosis, necrosis and reddening on leaflet margins, increased subdivision of leaflets giving a feathery appearance, and stunted shoot growth. In 1999, in Western Australia, roots of carrot plants with CVY-infected shoots were found to have severe distortion and knobliness generating unmarketable carrots.

Carrots infected with CVY have been found so far in Western Australia, Victoria and Queensland. In Western Australia, the foliar symptoms of CVY in carrots were first noted in 1997 and a survey in 1998 revealed a high infection incidence (65 per cent) at one property out of 4 surveyed. By 1999 the situation had deteriorated with infection on more properties with high disease incidences. Entire crops due for harvest in spring north of the Perth metropolitan area were sprayed out with glyphosate due to infection with CVY.

Experiments were done in the glasshouse to confirm that the distortion and knobliness root symptoms are due to CVY and to determine the impact of time of infection with CVY on carrot yield and quality.

MATERIALS AND METHODS

A culture of CVY isolate WA1 was established in 1999 by transplanting infected carrots from a cv. Murdoch crop growing north of Perth into pots in the glasshouse. The virus culture was maintained in plants of carrot cv. Stefano by sap inoculation. This culture was used as a positive control in enzyme-linked immunosorbent assay (ELISA). The antibodies used to detect CVY in ELISA tests on carrot leaf samples were monoclonal antibodies specific to potyviruses (purchased from Agdia Inc., USA). All plants were grown in insect-proof, air-conditioned glasshouses and maintained at 15-20 ^{o}C. Carrot plants were grown in 55 mm tall plastic pipes in steam sterilised potting mix containing soil, sand and peat (1:1:1). For sap inoculations, CVY-infected leaves were ground in 0.1M phosphate buffer, pH 7.2, and the sap mixed with celite before being rubbed onto leaves. For aphid inoculations, wingless green peach aphids (*Myzus persicae*) were starved for 6 hours, placed on CVY-infected carrot leaves for a 10 minute acquisition access feed and then transferred to healthy plants (10 aphids/plant) for 1hour inoculation access feeds. Aphids were killed by spraying with a pyrethroid insecticide to terminate the inoculation access feed.

In experiment 1, 28 days after sowing, 15 carrot cv. Stefano plants were sap inoculated with CVY and 15 others using aphids; 15 plants were left as uninoculated healthy controls. In experiment 2, exactly the same treatments were applied to the same numbers of plants but at 56 days after sowing. Numbers of plants that became infected with CVY were determined by observing them for characteristic CVY leaf symptoms and testing tip leaf samples from all plants by ELISA 4, 6 and 8 weeks after inoculation.

The effect of time of infection on yield of individual carrot plants was assessed by harvesting pairs of plants consisting of one with infection and one healthy control from within each experiment. The shoots were cut off and kept and the roots then washed. Each plant was then assessed for shoot fresh weight, crown width, root length and root weight, and roots were rated for distortion on a 1-10 scale where 1 = perfectly formed carrots and 10 = severe knobliness and distortion. Data for the pairs of infected and healthy plants were subjected to *t*-tests.

RESULTS

With both inoculation methods at both times of infection, CVY symptoms in the leaves of infected plants first became apparent 3 weeks after inoculation. In experiment 1, CVY was detected in tip leaves by ELISA in 14/14 aphid-inoculated and 2/15 sap inoculated plants, while 0/15 control plants were infected. In experiment 2, CVY was detected by ELISA in 9/15 plants using aphids and 4/15 using infective sap; 0/15 control plants were infected. The symptoms that developed in shoots were chlorotic mottle, generalised chlorosis, necrosis and reddening on leaflet margins, increased subdivision of the leaflets giving a feathery appearance and stunted shoot growth. Those on the roots were green shoulders, severe distortion and knobliness with early inoculation but narrower, thinner carrots with only mild distortion and knobliness with later infection.

In experiment 1, significant decreases ($P<0.05$) due to CVY infection were obtained in shoot fresh weight (20 per cent), root length (24 per cent) and root weight (37 per cent) (Table 1). All carrot roots from infected plants had maximum misshapen rankings and were unmarketable due to the severe distortion and knobliness. In experiment 2, crown width (12 per cent) and root weight (32 per cent) were significantly decreased due to infection with CVY but there were no significant differences in root length or shoot weight. Although the misshapen rankings were still significantly greater than those of healthy roots, overall misshapen rankings were much smaller than in experiment 1.

Table 1. Effect of time of infection on carrot cv. Stefano plants inoculated with CVY by aphids.

	Shoot weight (g)	Crown width (mm)	Root length (mm)	Root weight (g)	Misshapen ranking[A]
			Experiment 1: Infected 28 days after sowing		
Healthy	35	45	146	175	2
Infected	28	40	111	110	10
% change	-20	-17	-24	-37	-
P	0.040	0.056 (n.s.)	<0.001	<0.001	<0.001
df	24	24	24	24	24
t	2.17	2.01	5.30	4.71	30.52
			Experiment 2: Infected 56 days after sowing		
Healthy	35	45	146	170	2
Infected	36	40	150	116	3
% change	-	-12	-	-32	-
P	0.834 (n.s.)	0.010	0.609 (n.s.)	0.001	<0.001
df	16	16	16	16	16
t	0.21	2.93	0.52	3.84	4.11

[A]1 = perfectly formed and 10 = severe knobliness and distortion
n.s. = not significant

DISCUSSION

These glasshouse experiments successfully reproduced the CVY-associated symptoms observed in the field in infected carrot tops and roots. Of particular concern are the severe root symptoms of distortion and knobliness that developed in plants infected 4 weeks after sowing. Root distortions were very severe and infected carrot crowns had a tendency to grow up out of the soil producing green shoulders to roots. These carrots were unmarketable. Although plants infected with CVY at the 8 week stage developed equally severe symptoms in the shoots and a similar amount of yield loss (32-37 per cent), symptoms in their roots were much less severe. Those carrots were possibly marketable but as a very low grade. When virus is spread by aphids in a carrot crop the plants become infected at different growth stages. Clearly early spread with much early infection will result in the most severe impact on marketable yield.

Spread of CVY is exacerbated by current cultural carrot cropping practices involving sequential sowings of new crops near to old ones all year round on the same farms. Aphids spread the virus from the older infected crops to the nearby new ones. Without a fallow break in carrot production that removes or diminishes the virus infection source, the amount of spread is likely to increase with each sequential sowing. Such a carrot production system is likely to be unsustainable in the long term without measures to minimise the virus infection source. Spraying with insecticides to kill aphid vectors is likely to be of minor benefit as they are generally ineffective against spread of non-persistently aphid-borne viruses. Pyrethroid insecticides with rapid 'knock-down' and persistent anti-feeding activity are most likely to help but measures designed to minimise the virus infection source are the key to control.

A research proposal has been submitted to the Horticultural Research and Development Corporation to develop an integrated disease management strategy for the control of CVY. It has a multi-pronged approach which aims to minimise the source of virus infection, maximise the suppression of virus spread within the crop and minimise and detrimental effect on yield and quality.

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INTEGRATED POSTHARVEST DISEASE MANAGEMENT FOR CARROTS

L.-H. Cheah
NZ Institute for Crop and Food Research Limited, Private Bag 11 600,
Palmerston North, New Zealand.

SUMMARY

Most of the storage rots are diseases originated in the field and carried over onto carrots after harvest. Physiological disorders also arise from poor handling of carrots between harvest and storage. Every step in the handling chain can influence the extent of disease and quality of the stored carrots. Control methods therefore should involve improved practices in the field, in the packhouse and in cool storage. The best approach to minimize the storage rots and quality loss is to integrate all the appropriate practices.

INTRODUCTION

Fresh, whole carrots fetch a premium in Asian markets. Sales have jumped from NZ$8 million to NZ$12 million over the past two years, and continued growth is expected. However, to retain and expand New Zealand's established markets in Japan, Hong Kong, Singapore, Thailand and Malaysia, we must supply a consistent, high quality product. Central to this, is the control of rots and other disorders in what we export.

MATERIALS AND METHODS

Field and packhouse surveys were carried out at time intervals to study the factors affecting the incidence of storage rot of carrots. Diseased samples were collected and brought back to laboratory for identification. The incidence of each disease was recorded.

RESULTS

Field survey showed that Alternaria leaf blight (caused by *Alternaria dauci*) and Cercospora leaf blight (*Cercospora carotae*) were the most common foliar diseases, while black ring (*Fusarium* spp.), Sclerotinia rot (*Sclerotinia sclerotiorum*) and violet root rot (*Helicobasidium purpureum*) were common root diseases.

Cool store monitoring showed that five storage rots (Sclerotinia rot, black ring, black root rot, bacterial soft rot and basal rot) were common diseases found on cool stored carrots. *Sclerotinia sclerotiorum* and *Thielaviopsis basicola* were found to be highly pathogenic. It was also found that the incidence of both rots increased when the storage temperature rose above 8° C.

DISCUSSION

Most of the storage rots mentioned above originate in the field and can be carried over onto postharvest carrots after harvest. Therefore, these rots should be able to be minimised through good field practices, chemical control, gentle washing of carrots and keeping them cool and wet at all times.

Good field practices Carrots should be grown in soil with excellent water drainage and using a planting density that allows good air circulation through the crops. Increasing air circulation within the leaf canopy by reducing plant density and by good weed control may also reduce the incidence of foliar infection by pathogens. Carrots grown in wet and heavy soils tend to develop irregular shaped roots and are susceptible to infection by soil-borne pathogens including bacterial rot.

Reduce soil pathogens by rotating carrot crops with non-susceptible plants.

Early detection of disease in the field and removal of diseased plants before formation of sclerotia is recommended. Do not spread infected soil through movement of machinery or animals.

Chemical control soil fumigation with chemicals, (e.g. metham sodium or methyl bromide) can be prohibitively expensive for carrot crops and will not always give effective control of soilborne diseases. Biofumigation using *Brassica* crops that contain high level of glucosinolates (e.g. broccoli residues) may offer an alternative method of control. Field application of copper fungicide and mancozeb at weekly intervals gives excellent leaf blight (*Alternaria dauci*) control and also reduces black ring (*Fusarium* spp) incidence. Application of copper fungicide may control bacterial blight (caused by *Xanthomonas campestris*) and Sclerotinia rot.

Ground storage Carrots are more susceptible to decay and rot when "over mature", presumably when left in the soil for too long. We found that ground storage has exposed carrot crops to violet root rot (*Helicobasidium purpureum*) and black ring (*Fusarium* spp). We also found an early spring harvest of ground-stored carrots had a higher incidence of root rots in storage than from winter harvests. We recommend early harvest if disease is detected in the field.

Pre-wash handling Harvested carrots should be kept in shady place or covered to prevent dehydration and quality loss. During transportation, carrots should be covered with a tarpaulin. Overhead water sprinklers should be used to keep the carrots cool and wet so that the soil on the carrots is easy to remove during washing.

Washing Gentle washing probably reduces the incidence of storage rots and skin browning. We found tumbling damages carrots more than spray-brushing.

Washing water should be used once or changed often, as combining damaged carrots with soil and water may allow storage rots to establish.

Grading Carrots washed and graded before storage have significantly less decay than carrots stored directly from the field.

Washed carrots are conveyed to a size grader (graded by diameter and length) and then along a wide belt for visual grading. Any diseased and damaged carrots should be removed. Grader and operators should be well trained so that they can carry out the grading properly.

Sanitation Chlorine is one of the most commonly used

sanitizing agents for general disinfection of micro-organisms in carrots. Its advantages are that it leaves no chemical residue and is cost effective. We recommend using chlorine at 100 to 200 ppm in the hydro-cooler to prevent build-up of microbial numbers in the recirculating water. The pH of the chlorine solutions should be maintained between 6.5 and 7.0.

Maintaining hygiene in the hydro-cooler is important as is regular cleaning of the grading and packing plant, as wet, hydro-cooled carrots traveling over grading belts at the pack house may become recontaminated.

Other chemicals – for example a mixture chlorine/ bromine (e.g. Nylate) or peroxide (e.g. Oxonia) – can also effectively control storage rots.

Cooling This problem is one of the major causes of storage rots in export carrots, especially during warmer months (late summer-early autumn).

Rot activity is minimized by cooling carrots as quickly as possible and storing them as close to 0 °C as possible.

We suggest cooling below 5° C, within 24 hours of harvest; and once cooled, don't allow carrots to warm again. Remember, once carrots are packed in export boxes they take a long time to cool, and reefers can take days, even weeks, to cool warm carrots.

Reefers must be packed so airflows are maintained around the load and 'short-circuits' are avoided.

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Session 6

CARROT VEINING

E.M. Davison and A.G. McKay
Agriculture Western Australia, Locked Bag 4, Bentley Delivery Centre 6983, Western Australia

INTRODUCTION

Growers in Western Australia (WA) have been recently concerned with a symptom variously know as veining or varicose veining. Affected carrots have one or two, light coloured, axial swellings that spiral down the root. Stefano (Maestro) is the variety that has been most severely affected.

EXTENT OF THE PROBLEM

Where does it occur? Symptomatic carrots have been seen on growers' properties throughout the carrot growing area of WA, however, its incidence varies between properties. It may be severe on one property, and non-existent on a nearby property. The incidence does not appear to be related to soil type or cropping history.

When does it occur? Although the incidence of veining was most noticeable in June, July and August 2000, inspection of packhouse record sheets shows that a small number of consignments had veined carrots in them as early as May 1999. There was a peak of veined carrots in November and December 1999 (Fig. 1), but only two out of three growers had veined carrots during these months.

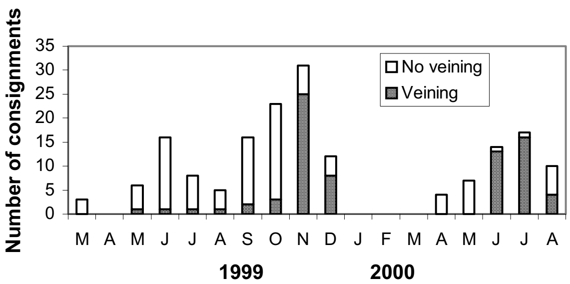

Figure 1. Carrot consignments with veining (pooled data from three growers.

Which carrots are affected? Measurements of carrots from a number of properties, has shown that the probability of veining in mature carrots increases with increasing diameter. Veining was also associated with an elongated, rather than a circular core.

WHAT IS THE CAUSE?

Is it the seed? DNA analysis of five Stefano seed lines has not shown any detectable differences.

Veining is unlikely to be the result of genetic variation between different seed lots.

Is it a disease? The symptoms are not those of a fungal, bacterial or nematode disease. A sample of 90 veined carrots was tested for cucumber mosaic virus and potyvirus, no virus was found.

Veining is unlikely to be a disease.

Is it caused by herbicides? There does not appear to be any correlation between the symptom and herbicide usage.

Veining is unlikely to be the result of herbicide damage.

Is it related to nutrition? Crops with a high level of veining have always been vigorous. Leaf analyses have shown high levels of potassium (potash) in veined, compared with unveined carrots. Other nutrient levels have been normal.

Root analyses have shown that calcium is lower in veined roots compared with unveined roots. There is no difference in the level of other nutrients.

Investigation into the involvement of root calcium in veining is continuing.

ACKNOWLEDGMENTS

We thank growers and packhouses for carrot samples, J. Speijers for statistical advice, P. O'Brien and G. MacNish for carrying out the DNA analysis of seed lines, L. Latham for virus testing, and P. Murphy for cutting up hundreds of carrots.

MINOR USES OF AGROCHEMICALS

P. A. Taylor
Crop Protection Approvals Ltd, Suite 5, Level 1, 5 Everage St., Moonee Ponds 3039 Victoria

SUMMARY

The problem of minor uses of agrochemicals, whereby few or no crop protection products are legally available to growers, is not confined to "minor" crops. It is a consequence of business economics in the agrochemical industry, quality assurance schemes and clumsy legislation. Crop Protection Approvals Ltd is a non-profit company that is owned by various vegetable industry bodies around Australia. Funded by grower levies, the HRDC and other industry contributions, the company is commissioning field trials and chemical analysis to enable permits/registrations of products for minor uses. The company is currently managing a program of more that 200 residue trials on a wide range of products and crops.

INTRODUCTION

Today's markets for vegetables and other horticultural produce are extremely sensitive to issues relating to pesticides, in particular to pesticide residues and misuse. It is essential that the consumer is protected, and is seen to be protected, by adequate safeguards in regulations governing the use of agrochemicals. On the other hand, farmers also need to be able to produce clean, marketable crops, which will give reasonable returns on their investments.

Business economics dictate that agrochemical companies cannot support the costs of registering products for uses that will not provide a return on the investment. Quality assurance systems insist that growers use only products that have maximum residue limits (MRLs) listed in the ANZFA Food Code. Growers are faced with grave problems because not enough products are registered for use in their crops. There are additional, confusing problems that arise because the MRLs set by the National Registration Authority (NRA), during the evaluation of minor use permit and registration submissions, may take 6 months or more to appear in the Food Code. The increasing need for alternative products that are IPM-compatible or that have different modes of action (to cope with the emergence of pesticide resistance) exacerbates the problem, again because of the prohibitive cost of registering new, “softer” products.

MATERIALS AND METHODS

Crop Protection Approvals Ltd (CPA) is a non-profit company, owned by the vegetable growers associations of Australia and New Zealand. CPA Research Pty Ltd is it's wholly owned subsidiary, responsible for commissioning trials and laboratory analyses to collect data on pesticide residues.

The objectives of the organisation are:

1. To provide an efficient and fast service in helping primary producers meet their crop protection needs, by coordinating data generation and collation activities and making applications on their behalf to the NRA to issue Minor Use Permits.
2. As an agent of primary producers, negotiate with regulatory authorities and the agrochemical industry to improve the processes and systems for issuing permits/approvals for minor uses of pesticides.

Funded by grower levies, the HRDC and other industry contributions, the company, through CPA Research Pty Ltd, is commissioning field trials and chemical analysis to enable permits/registrations of products for minor uses.

Industry requests for Minor Use Permits (or registrations) are collected by Vegetable Industry Development Officers and channeled to Crop Protection Approvals Ltd. After preliminary evaluations to filter out duplications of active ingredients, existing registrations and products that are about to meet their demise, the list of requests is passed back for prioritisation. The prioritised list is then consolidated into projects and costed after consultation with the NRA on data requirements. A submission is then made to the HRDC for funding. Contributions are also sought from agrochemical companies and these funds are also matched by the HRDC.

The required residue trials and analyses are contracted out to consultants and laboratories by CPA Research Pty Ltd. Contractors must follow CPA protocols and reporting procedures.

When the data are available, CPA Research applies to the NRA for minor use permits.

The results (permits issued and other information relevant to minor uses) are communicated back to industry through a regular newsletter, the rural press, and on the CPA web page http://www.cpaltd.com.au. This site also gives access to permit documents.

RESULTS & DISCUSSION

The company is currently managing a program of more that 120 residue trials on a wide range of products and crops for the vegetable industry. Current carrot requests are shown in Table 1. The company is also managing more than 80 residue trials to generate data to defend horticultural uses of endosulfan. As the largest buyer of contract trials in Australia, the company has been able to achieve significant cost savings for its client industries.

There have been problems, however, in the following areas:

1. Long delays in NRA responses to requests on data requirements.
2. Mixed messages from different sectors of the NRA. For example, we are requested to obtain a minor use permit for cucumbers, but are advised by the NRA to apply for cucurbits. Our application is then rejected by the NRA because uses on the cucurbit group are not considered to be minor.
3. Long delays in the NRA's response to permit application (6 months).
4. Failure of the NRA to apply its own legislated definition of "minor uses". The NRA has, until recently, persisted in defining uses according to whether the crop is one it considers being minor or major. However, the legislative definition is one where the returns from the sale of the product are inadequate to justify the expense of registering it. Thus, there are minor uses in "major" crops.

In spite of these problems, the establishment of Crop Protection Approvals Ltd represents a great step forward towards solving the problems surrounding minor uses of pesticides. The company is expanding its activities to the management of crop protection projects for other industries. We are looking to provide information services to horticulture, such as international MRL standards in countries that we export to. We are extending our activities to include New Zealand.

Table 1. Requests for minor use permits for carrots.

Item code	Product	Problem	Active constituent	Status
ECR565	Endosulfan	Not specified	endosulfan	In progress
AVG595	Phosphorous acid	Damping off	phosphorous acid	Prioritised
AVG637	Rugby	Nematodes	cadusafos	Prioritised
AVG526	Sumisclex	Sclerotinia rot	procymidone	In progress

THE IMPORTANCE OF PESTICIDES AND OTHER PEST MANAGEMENT PRACTICES IN U.S. CARROT PRODUCTION

R. M. Davis[A], E. J. Sorensen[B], and J. Nunez[C]
[A]Department of Plant Pathology, University of California, One Shields Avenue, Davis, California, 95616, USA
[B]Washington State University Cooperative Extension, 1016 N. 4th Avenue, Pasco, Washington 99301, USA
[C]University of California, Kern County Cooperative Extension, 1031 S. Mt. Vernon Avenue, Bakersfield, California 93307, USA

INTRODUCTION

In 1998, a joint project of the U.S. Department of Agriculture and the state land-grant universities was undertaken to collect and summarize data describing the use of specific pesticides and non-pesticide pest control practices and their impact on carrot production in the U.S.

METHODS

A team of scientists from California, Colorado, Florida, Michigan, Texas, Washington, and Wisconsin familiar with chemical and non-chemical control of weed, insect, and disease pests affecting carrot production in the U.S. was assembled. These states accounted for approximately 94 per cent of U.S. carrot production. Questionnaires were developed and distributed to the team and to cooperators in each state to gather the needed information.

Data collected included individual pesticides and non-pesticide practices currently used by the carrot industry in each state and the target pests of these pesticides or practices. Also included were the timing of these applications, treatment rates, the percentage of the acres grown that are treated with each individual practice, and the effect on yield if the pesticide or practice were lost relative to substitute pesticides or practices currently available to growers.

RESULTS AND DISCUSSION

The most important diseases of carrots are Alternaria leaf blight, nematodes, and cavity spot (Table 1). Most of the diseases listed cause significant economic losses in one or more states.

Table 1. Ranking of economically important carrot diseases by impact on yield in the U.S.

Disease	Rank
Alternaria leaf blight (*Alternaria daucii*)	1
Nematodes (*Meloidogyne* spp.)	2
Cavity spot (*Pythium violae*)	3
Pythium brown rot, dieback, forking and stubbing (*Pythium* spp.)	4
Bacterial leaf blight (*Xanthomonas campestris carote*)	5
Damping-off (*Pythium* spp. & others)	6
Black rot (*Alternaria radicina*)	7
Powdery mildew (*Erysiphe polygoni*)	8
Cercospora leaf spot (*Cercospora carotae*)	9
Bacterial soft rot (*Erwinia* spp.)	10

The fungicides used in the U.S. on carrots are listed in Table 2. Thiram, applied as a seed dressing for the control of damping-off, is used on more acreage, 88,128 acres, than any other material. Iprodione (Rovral), applied primarily for the control of Alternaria leaf blight, is used on 45,666 acres and metalaxyl (Ridomil) is applied to 44,557 acres for the control of cavity spot.

Table 2. Fungicide use on carrots in the U.S.

Herbicide	Acres treated	
	%	Acres
Thiram	83.5	88,128
Ipropione	43.2	45,666
Metalaxyl	42.2	44,557
Chlorothalonil	29.8	31,496
Copper	15.8	16,704
Sulfur	10.4	10,982
All fungicides	90.3	95,314

Non-chemical control practices were a significant part of disease management in all states. Scouting was used on 100% of the carrot acreage in the U.S. (Table 3). Crop rotation was used on 96 per cent of the carrot acreage. Although accounting for only 29,241 acres, all states reported the use of resistant varieties for the control of Alternaria leaf blight.

Table 3. Non-chemical control practices for disease management in U.S. carrot production.

Practice	Acres involved	
	%	Acres
Scouting	100.0	105,600
Crop rotation	96.0	101,376
Crop debris destruction	64.0	67,584
Economic thresholds	62.1	65,544
Sanitation	55.3	47,038
Treating seed (hot water)	44.5	47,038
Resistant varieties	27.7	29,241
Field selection	24.2	25,553
Irrigation management	18.7	19,757
Fertilizer management	15.3	16,180

Insects are erratic pests in most carrot fields. In general, they are not a major problem, although they can cause significant damage in individual fields. Leafhoppers, cutworms, aphids, and wireworms are common insect pests in most carrot producing states (Table 4). Saltmarsh caterpillar and whiteflies are economically important only in California.

Table 4. Ranking of economically important carrot insect and mites by impact on yield in the U.S.

Disease	Rank
Leafhoppers (*Macrosteles quadrilineatrus* & others)	1
Cutworms (*Agrostis* spp. & *Peridroma* spp.)	2
Saltmarsh caterpillar (*Estigmena acrea*)	3
Whiteflies (*Trialeuroes* spp., *Bemisia* spp., & others)	4
Aphids (Various species)	5
Flea beetles (*Systena blanda*)	6
Grasshoppers (*Melanoplus* spp. *Camnula* spp., & others)	7
Wireworms (*Limonius* spp.)	8
Carrot weevil (*Listronotus oregonensis*)	9
Armyworms (*Spodtrea* spp.)	10

Compared to many other commodities, a relatively small percentage of the carrot acreage in the U.S. is treated with insecticides. Esfenvalerate (Asana) is used on more acreage, 23,924 acres, than any other material (Table 5). It is use for the control of leafhoppers, cutworms, weevils, and other insect pests.

Table 5. Insecticide use on carrots in the U.S.

Herbicide	Acres treated	
	%	Acres
Esfevalerate	22.7	23,924
Diazinon	9.2	9,733
Methomyl	6.8	7,136
Malathion	6.2	6,580
All insecticides	41.5	40,328

Non-chemical control practices for insect control are used sporadically by the carrot industry (Table 6). Scouting, however, was reported by all states on all acreage. Weed control for management of aphids, whiteflies, and leafhoppers was used on more than 37 per cent of the U.S. acreage.

Table 6. Non-chemical control practices for insect and mite management in U.S. carrot production.

Practice	Acres involved	
	%	Acres
Scouting	100.0	105,600
Weed control	37.8	39,948
Crop rotation	14.3	15,142
Timing of planting	8.9	9,400
Crop debris destruction	6.4	6,780
Cultivation	6.4	6,780

In the seven states surveyed, nearly 50 different weeds are considered important pests of carrots. Of these, nutsedge and pigweeds are considered the most troublesome (Table 7). Pigweeds were the only weeds of economic importance in every state surveyed.

Table 7. Ranking of economically important carrot weeds by impact on yield in the U.S.

Weed	Rank
Nutsedge (*Cyperus* spp.)	1
Pigweeds (*Amaranthus* spp.)	2
Russian thistle (*Salsola iberica*)	3
Mallow/Cheeseweed (*Malva* spp.)	4
Shepherdspurse (*Capsella bursa-pastoris*)	5
Nightshades (*Solanum* spp.)	6
London rocket (*Sismbrium irio*)	7
Bermudagrass (*Cynodon* spp.)	7
Crabgrass (*Digitaria* spp.)	8
Canarygrass (*Phalaris* spp.)	9
Goosefoot (*Chenopodium* spp.)	9
Wild oats (*Avena fatua*)	9
Groundsel (*Senecio* spp.)	10

Relatively few herbicides are registered for use on carrots. However, herbicides are used on more than 98% of carrot acreage in the U.S. Linuron (Lorox), tirfluralin (Treflan), and fluazifop-P-butyl (Fusilade) are the most widely used materials (Table 8). Linuron and fluazifop-P-butyl are used in all states surveyed. Linuron and treflan control many annual broadleaves and grasses. Fluazifop-P-butyl is effective on annual grasses and some perennial grasses.

Table 8. Herbicide use on carrots in the U.S.

Herbicide	Acres treated	
	%	Acres
Linuron	88.2	93,126
Trifluralin	62.1	65,574
Fluazifop-P-butyl	30.5	32,190
Metribuzin	11.1	11,689
All herbicides	98.1	208,898

Cultivation is a key component of weed control in every state and 95 per cent of the U.S. carrot acreage is cultivated (Table 9). Hand weeding is used on about 17 per cent of the acreage.

Table 9. Non-chemical control practices for weed management in U.S. carrot production.

Practice	Acres involved	
	%	Acres
Scouting	100.0	105,600
Cultivation	95.0	100,312
Hand weeding	17.7	18,717
Irrigation management	13.9	14,667
Crop rotation	13.3	14,006
Field selection	11.8	12,496
Timing of planting	10.4	10,982
Cover crops	10.1	10,654

Nationwide, if labeled clearances for all fungicides were lifted, an annual loss of approximately 24 per cent of the total U.S. yield would likely result (Table 10). Although a number of non-chemical practices would be implemented, all states reported losses regardless of alternative management practices. The yield loss for all insecticides would be more than 12 per cent.

The loss of all herbicides would be a yield loss of nearly 48 per cent, a loss greater than that caused by the loss of all fungicides and insecticides combined. In most states, mechanical cultivation would be the main substitute for lost herbicides. Non-chemical control practices are already a part of every integrated weed control program for carrots, but are most effective when combined with herbicide applications.

Table 10. Impact of the loss of all fungicides, insecticides, and herbicides on the production of carrot in the U.S.

Pesticide	Impact on yield	
	%	Pounds
All fungicides	-24.0	-8,364,766,000
All insecticides	-12.3	-4,275,871,000
All herbicides	-47.6	-16,612,089,000

Since there are so few pesticides registered for use on carrots the loss of any single chemical would be significant. The loss of linuron, in particular, would be disastrous to the U.S. carrot industry. The impact on total carrot yield in the U.S. for this one herbicide would be a loss of over 32 per cent. The loss of metalxyl would negatively impact U.S. carrot yield by 13 per cent.

Wherever carrots are grown in the U.S. a variety of diseases, insects, and weeds reduce both yields and market value of roots. Control of these pests depends on an appropriate combination of pesticides and other pest management practices.

Session 7

IMPROVING INDUSTRY EFFICIENCY

N. Delroy,
Agribusiness Research & Management, 13 Adelaide Street, Busselton 6280, Western Australia

Our businesses are primarily in the winegrape growing and processing arena, with our carrot and onion production operation being in its infancy. I am therefore going to outline, primarily based on our winegrape production experience, some of the key factors that we consider important in analysing, developing and running a primary production business efficiently.

There are four corner stones that we keep in mind in assessing project development and running of our businesses:

- To have a **vision** on how to compete in the global environment.
- To find and exploit clear **competitive advantages** we may have.
- To create real **customer value** in our products and service.
- To **influence the business and natural environment** within which we operate.

1. DEFINING THE BUSINESS STRATEGY.

First we need to have a **Vision** for the Business:

- Our vision is simple and not operational, it is "To provide our shareholders with an attractive return whilst being recognised by our customers as their preferred supplier of grapes"
- This vision encapsulates creation of shareholder value and maximising product value and minimising marketing risk by getting closer to our customers.

Secondly we examine the factors that contribute to competitiveness in the business. This includes:

- identifying our customers, the product they want (grape varieties and volume, style) and the services we can provide with the product.
- Identifying the best environment to operate in.
- Identify issues that contribute to the **structural efficiency** of the business such as:

  cost and suitability of land and water

  availability of labour and other resources such as power

  the possibility of attaining an economy of size

All too often with rural enterprises poor strategic decisions are made at project conception and establishment that lead to poor structural efficiency of the business so that no matter how good you are, operationally you can't achieve best practice.

For example, with carrots, to maximise capital utilisation efficiencies it would be advantageous to produce in a moderate maritime climate on free draining soils so that year round production is possible. Having access to water in an aquifer that is shallow and inexpensive to pump and the ability to use centre pivots that require low water operating pressures both contribute to a structural efficiency in low energy costs to irrigate.

opportunity we construct very detailed financial models as accurately as possible. The construction of these models helps us determine information we still need to collect, allows us to do sensitivity analysis and better understand the real drivers of the business and the expected returns. It also gives us the capability of refining our business strategy. If we proceed and develop the business then we update and improve the models so that we always have a good understanding of the drivers of the business.

2. OPERATING THE BUSINESS

The aim is to develop and maximise the efficiency of the business within the constrains of the environment within which the business operates. To provide a framework for this we do this within some key operational objectives that we set, the most relevant of which in the context of this paper are:

- "To move the business forward through innovation and logical incrementalism. By moving forward in incremental steps, gaining more information as we go and going further if this proves suitable, and if not, retreating and seeking another path"

- "To provide an environment that encourages innovation and also encourages employees to work with commitment, enthusiasm and in safety"

In our businesses we use both outcome measures (feedback or **lag indicators**) such as monthly financials against budget and performance drivers (predictive or **lead indicators**) such as activity based costings and key performance indicators (KPIs) to measure and drive business performance within the objectives. Lead indicators enable site managers and operations managers to have nearly instant feedback on the efficiency and effectiveness of tasks. Key performance indicators that measure efficiency (eg.

vines pruned per man hour, harvester machine hours per hectare) and effectiveness (eg. yields on target, fruit quality required achieved, disease control effectiveness) are the key operational drivers in our business.

The following factors are important:

- The activity being measured is materially important to the overall performance and the long-term success of the business.
- There is commitment to the initiatives.
- Potential problems are sorted out by utilising pilot programs.
- There is incremental development of the systems over time based on previous successful applications.
- Training and coaching for all concerned is critical.
- The data collected is utilised and seen to be utilised by benchmarking the KPIs against previous performance and where possible with the same activities in other operations and the data is utilised in other processes and systems such as the budgeting.

For example, all pruning records, are kept on each individual's productivity and overall productivity in terms of vines pruned per man hour. Where possible all work is paid on piece rates which we find leads to a 20-100 per cent productivity improvement. Pruning rates and costs are benchmarked between workers and between vineyards throughout the season. This is utilised to identify more productive techniques in pruning and over the past five years has resulted in significant improvements in the pruning systems and processes.

What we have noticed in our organization is that the utilisation of well chosen lead indicators not only results in reduced costs, better quality and a more customer focused approach, but the process of **performance measurement** and the culture it develops results in many of the improvements in the business being developed at the "coal face". It is important to recognise these innovations and improvements as this further enhances the commitment and ownership to these systems and their further development within the business.

In addition to the use of KPIs and benchmarking we also put a lot of emphasis on the provision of information and technology to operational staff to give them the capability to make good management decisions. This is done through:

- Production of technical manuals that include information on nutrition, integrated pest and disease management, spray technology and calibration, pruning methodology, canopy management, irrigation to produce quality fruit, tips for managing an efficient vineyard, financial controls, KPIs, benchmarking, and so on.

- Operation manuals. For example, we produce a detailed manual for each operation on the design, layout, operation and maintenance of the irrigation system.

- Input from external technical staff (Viticulturists). Qualified viticulturists work with operations staff with each viticulturist servicing eight to ten operations.

- Training courses, field days, group discussions. Vineyard staff attend a range of training courses, external field days and internal workshops to improve skills.

The systems, processes and available technology are all put together to not only reduce costs but also to maximise yields, quality and customer service. The aim is also to achieve a culture within the organization that we are a "leading edge, efficient operation" and that "this is the way things are done around here". Once this culture is accepted, new employees quickly pick up the vibe and measure up or they don't stay.

In summary I believe there are three key factors in getting it right in the agricultural businesses we are in. These are, getting the **structural efficiencies right**, having a **culture of measured performance improvement** in the business and finally, focusing on **getting closer to the customer** to increase the value the customer places on our products and service.

CARROT EXPORTS TO JAPAN

J. Gayton, Marketing Manager – Asia,
Field Fresh Tasmania, Forth Rd, Forth 7310, Tasmania

SUMMARY

Carrot exports to Japan have increased over the past seven years from 9,266 tonnes in 1993 to 50,490 tonnes in 1997. The total value of imports has increased from ¥18 million (~A$225,000) in 1993 to more than ¥1.5 billion (~A$15 million) in 1997. The volume imported from Australia has increased slightly, but has been declining as a proportion of the total imports. There is a large variation from year to year depending on the Japanese domestic crop and the value of the yen. Domestic production has ranged between 569,000 tonnes and 634,000 tonnes in the same period. The effect of a slightly reduced area of production, together with a generally strengthening yen, have resulted in an increased demand and supply of imported carrots. The major supply sources are New Zealand, China, Taiwan and Australia.

There is a small but growing niche in supplying supermarkets directly or via the wholesale market. The majority of carrots imported from Taiwan and China are used for processing while New Zealand and Australia supply both sectors. The processing sector uses large Nantes and Kuroda carrots suitable for dicing and slicing. The fresh market is only interested in Japanese varieties. "Koyo" is the most popular variety grown in Japan. CCO-018 is the equivalent variety used in Australia, New Zealand and China.

The challenge for exporters is to choose the segment best suited to their capabilities and to be familiar with the requirements of the Japanese specifications and market timing.

THREATS TO FUTURE EXPANSION

Japan imports less than 10 per cent of its fresh vegetable requirements. It is a significant producer of very high quality vegetables from a diverse geographical and climatic range. There are a number of non-tariff barriers to export including strict phytosanitary regulations, a national preference for Japanese-grown produce, strong government support for regional areas and strong relationships between suppliers and retailers. The quality expectations are very high and generally there is a requirement for Japanese varieties.

New Zealand and China pose the major competition for Australian carrot exports to Japan. Exporters in New Zealand who have suffered from declines in onions and squash are looking at carrots as an alternative. Reports of annual increases of 30 per cent in production can only lead to over-production and weak prices in Japan and Asia generally. The effects were felt in the 2000 season. Increased production and improvements in quality from China will pose a serious challenge to Australian exporters and Japanese growers.

Chinese grown vegetables have attracted a lot of interest from traders in Japan, Hong Kong and Singapore due to the low production and shipping costs. Shandong Province a major production area for garlic, onions and carrots is only three days sailing time to Japan. A NZ exporter has set up a joint venture there to grow and export Japanese carrots and onions to Asia and Japan. The quality is reported to be acceptable to these markets. This may be the greatest challenge for the Australian carrot export industry. The sudden increase in export volumes from China to Japan from 178 tonnes in 1997 to 21,000 tonnes in 1998 and 23,700 tonnes in 1999 illustrates the potential China has to be a supplier to the Japanese market. The effect on price was predictable with a drop from ¥ 65/kg in 1997 to ¥38/kg this year.

OPPORTUNITIES IN JAPAN

The challenge for exporters of carrots to the Japanese and Asian markets is to increase the value rather than the volume. This requires developing close relationships with end users and a willingness to be innovative and flexible.

Exporters of fresh fruit and vegetables to Japan must address the issue of food safety, identification and traceability, sustainable production, organic production and promotion if they expect to service supermarkets.

There is a need to develop strong supply chain links with supermarkets in Japan and to offer them a point of differentiation. More than price, such things as uniformity of size, reliability of supply, flavour, colour, guaranteed food safety, low chemical inputs (or organic), packaging and a good working relationship with the buyer are essential elements to a successful business.

CONCLUSIONS

The Australian carrot industry must develop strategies which allow it to become preferred suppliers to Japanese and Asian markets. This may mean forming alliances interstate and/or with New Zealand, Chinese or even Japanese producers to guarantee year-round supply. Supply chain developments must help to minimise risk and better coordinate production with demand as well as providing feedback to growers and exporters to enable continuous improvement.

Food quality and safety issues, as well as environmental awareness, are now important aspects of a customer's purchasing decision. Australia needs to back up its image as a clean, green producer with facts, and promote this at the consumer level. We need to ensure quality exceeds customer's expectations and continue to innovate with better service and quality.

PUTTING RESEARCH RESULTS INTO PRACTICE FOR CARROT PRODUCERS

D. Blaesing
Serve-Ag Research, PO Box 690, Devonport 7310, Tasmania

SUMMARY

A study was conducted to analyse information relevant to the development of a strategic technology transfer plan for the Australian carrot industry. Results from the work were presented in two parts in a final report to HRDC:

1. Foundation of the strategic plan (the study);
2. The strategic plan.

INTRODUCTION

Carrot producers do not have easy, timely access to the same pool of information. It is a rather complex task to compile and adapt carrot information from a wide range of sources, due to time constraints and varying availability of these sources (eg. computer based systems, libraries, etc)

A uniform information system for carrot growers would improve the adoption of new technologies.

MATERIALS AND METHODS

The industry structure in Australia's carrot producing states was investigated, using published data and personal communication with stakeholders. The project leader participated in industry meetings, visited growers and surveyed carrot producers, using semi structured, exploratory interviews and questionnaires. Carrot researchers nationally were contacted to gain an understanding of their projects.

RESULTS AND DISCUSSION

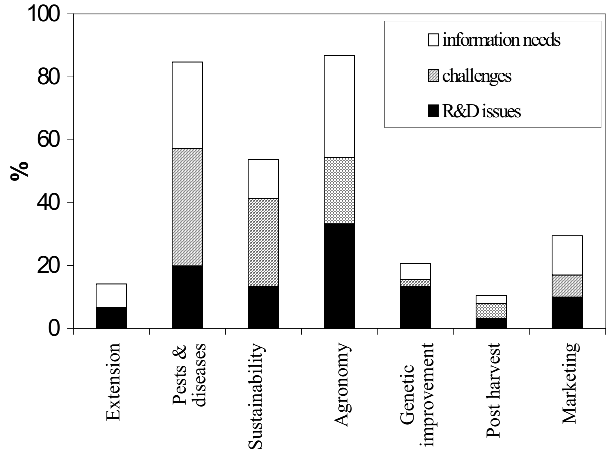

Figure 1. R&D issues, information needs and major challenges mentioned by carrot producers

Figure 1 highlights that growers would like to see more agronomy research conducted, and this area also had high information needs, similar to 'Pests & diseases'. However, as a challenge, 'Agronomy' rates lower than 'Pests & Diseases' and 'Sustainability', which were seen as long term concerns. 'Marketing' related issues were of major concern to growers in Queensland and Victoria. In Western Australia, Tasmania and South Australia, 'Pests and Diseases" and 'Agronomy' were mentioned most frequently.

Table 1 illustrates that growers mainly utilise their own observation and experience or consultants, to gain information. These sources were given high and medium quality ratings respectively. 'Specific sources', even though rated highly, are used by few, probably because they require some effort, or even luck, to find.

Table 1. Utilisation and quality rating of information sources for carrot growers.

Information source	Utilisation	Quality
Own observation	High	High
Specific, one-off sources	Low	High
Experience, own knowledge	High	Medium
R&D papers, newsletters	Medium	Medium
Private consultants	High	Medium
Workshops & field days	Medium	Medium
Marketing company staff	Medium	Medium
Growers, employees, family	Medium	Medium
Magazines, rural press	Medium	Medium
Grower associations	Medium	Low
Rural merchants	Medium	Low
Internet	Low	Low
Television & radio	Low	Low

The high level of self-reliance may be due to the difficulty of accessing high quality external sources. This lack of access may not necessarily be due to the absence of sources, but rather to difficulties in finding them, and their continuity (eg. stability of personnel in extension). The Internet was not used regularly, and not rated highly in this study. The low level of training in computer usage in general, and in Internet 'exploitation' in particular, may explain this. Internet information on carrots, if found via a search engine, still has to be 'sieved'. Therefore, the Internet was considered as cumbersome, time consuming and of limited use for solving specific problems. Still, all growers showed interest in an easy to locate, informative Australian carrot site

Criteria most frequently mentioned as important for acceptance of an information source, were 'relevance' and 'reliability'.

Quality ratings (Table 1) showed that growers value 'own observation' or 'specific sources' highly. The 'specific sources' were either particular researchers, or specially valued industry people, who had proven particularly useful. Generally, the broader focused the source, the lower its quality rating. Most growers stressed that they would like to receive more relevant information, through concise newsletters or articles. They would also value increased opportunities to discuss specific issues one to one with knowledgable, trustworthy individuals. Field days and workshops are appreciated as an opportunity to meet with other industry members, while learning about new developments. Growers would like to see these events focused on pertinent topics rather than covering a broad range of issues.

It is obvious from Figure 2 that growers do not often contact researchers to gain information. This may be explained by constraints in communication with researchers, as mentioned by growers. About one third of producers said that they never actually see a researcher, especially not on their farm. The technical language used

by most scientists was also frequently referred to. Some growers indicated a perceived lack of relevance of research, or lack of research altogether.

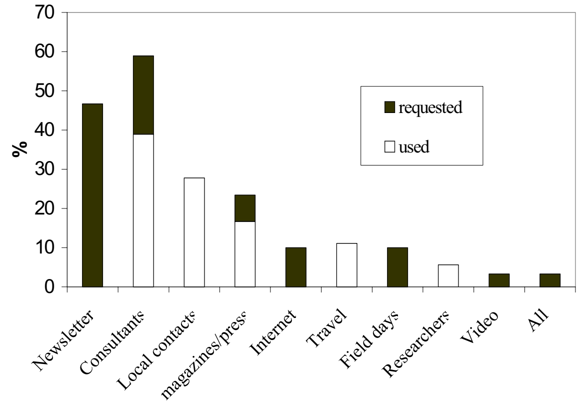

Figure 2. Sources used by growers searching for information, and methods of providing information requested by growers.

Researchers seem to have an image of aloofness and impracticability, which together with the 'language barrier', may hinder growers from approaching them. Researchers' contact details and areas of expertise are often not known to growers and are hard to obtain. Nonetheless, all growers were keen to improve communication, even if only to find out how their levy payments were used.

The Plan

In the report to HRDC, the technology transfer vision, the Plan's mission and its strategic goals precede the documentation of the Plan. A broad range of strategic issues has also been listed ahead of the Plan. These have to be addressed to facilitate the process of putting research results into practice.

Recommendations for the Plan's implementation are as follows:

A technology transfer team with one member per state will be set up. The technology transfer team will be responsible for the Key Activities listed below. The Key Activities have two components, A) and B), which will commence concurrently.

A) Addressing information needs

1. Collating relevant information.

The technology transfer team will call for assistance from researchers, extension specialists, consultants, etc. In the first instance, priority will be given to topics previously identified as essential by growers.

2. Dissemination of information and investigation of electronic media.

A newsletter and other written information will be prepared. Electronic media will be investigated and used.

3. Set up of regional networks.

Regional producer focussed networks (Carrot Crunch Action Groups) will be set up to link research, extension, product/machinery supply and production. The group will focus on solving pertinent issues in their region.

4. Utilisation of extension specialists, and researchers.

The Carrot Crunch Action Groups will facilitate communication between producers, people involved in extension, researchers, and other groups as required.

5. Assessment of the quality of the information materials and systems.

The Carrot Crunch Action Groups will provide feedback on the contents and format of written information, to the technology transfer team.

6. Monitoring of changes in information needs and appropriate action.

B) Improving the chance of technology adoption

This activity will consider present differences in technology transfer and attitudes between regions. The approach to improving technology adoption will be adapted accordingly.

1. Addressing of known priority issues.

Strategic issues, which have already repeatedly been highlighted, as impediments to technology transfer and adoption, in previous studies, will be addressed as soon as possible. They relate to training, knowledge, skills, awareness, communication and cooperation of all relevant sectors. They will be addressed regionally through Carrot Crunch Action Groups.

2. Prioritising and addressing further strategic issues from the plan.

Criteria to be considered when rating issues are their relevance to technology transfer and adoption, urgency, the chance of success, the costs associated with change, the time frame required, and resources available.

ACKNOWLEDGMENTS

HRDC and Grower Levies funded the study. The steering committee members for the project were: A. Fulton, TIAR, A. McKay, Agriculture WA; P. Ulloa, IDO, Victoria; K. West, HRDC Root Vegetable Committee, Queensland; M. Quadir, Agriculture NSW; B. Nicols, Root Vegetable Committee, SA. Individuals who provided information and support 'on the ground' were. E. Davison, Agriculture WA; R. Coles and T. Wicks, SARDI; L. Bilston and S. Bray, IDOs, Queensland; N. Harvey and C. Thelander, QFVG; S.-A. Henderson, AgVic.; H. Kuipers, Agriculture NSW; T. Kourmouzis, Serve-Ag Technical Services; G. O'Connor, Serve-Ag Agronomy Services. Above all, the contribution of growers, who sacrificed their time in meetings, interviews, surveys and field visits, is greatly appreciated. Without their support this study could not have been undertaken.

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References to publications used in preparing the technology transfer plan are given in the full report, "Technology Transfer to the Australian Carrot Industry", available from HRDC.

Session 8

QA SERVICE PROVIDERS, DON'T FORGET THE CUSTOMER!

P. Ulloa. Vegetable Industry Development Officer
Vegetable Growers Association – Victoria, PO Box 4126, Knox City 3152, Victoria

STRATEGY IS MORE IMPORTANT THAN QA

The purpose of Quality Assurance (QA) is to provide confidence that suppliers are able to consistently meet customer requirements. Retail chains have been particularly interested in suppliers willing to work with quality specifications and that are able to demonstrate that their products are safe for consumption.

From the grower's point of view, the QA issue has always been, or it should have been, about being responsive to customer's requests. Deciding to implement a formal (audited) quality system should always be part of an overall strategy and general direction for the business.

A grower with no interest in supplying one of the major retail chains should not feel compelled in any way to establish a formal QA system. On the other hand, a strategy that includes a supermarket chain, must necessarily consider the need for QA. Those growers who complain about having to implement QA, when they acknowledge they are targeting major retailers, do not make much sense.

Many Victorian vegetable growers who implemented QA years ago have acknowledged that they have been able to prosper financially. It would be incorrect to assume that the prosperity enjoyed is the result of the QA implementation. The prosperity has been the result of an effective business strategy, of which, QA has only been a part.

NO NEED FOR SO MUCH PAIN

Many Victorian growers have also complained that not only the QA implementation process has been difficult, but also the maintenance of the systems have become increasingly painful. Even the growers that have enjoyed some prosperity have said that the price they have paid is very high.

A survey conducted among Victorian fruit and vegetable growers identified several QA aspects that growers considered unacceptable. The following is a list of some of the most common complaints:

- Unprofessional conduct of some auditors
- Grower rights not clearly defined
- Lack of specific and universally applied requirements for all certified growers
- Too much personal interpretation about requirements
- Issues beyond quality and food safety discussed during audits
- Lack of system for dispute resolution

Without going into too much detail on the causes of all these problems, it is clear that any effective QA program for the industry must provide more than just a generic standard. Policies are also needed to ensure the original and most important purpose of QA implementation is achieved. Any QA program that fails to provide those polices will cause unnecessary pain to all stakeholders.

Unfortunately, the survey results demonstrate that the industry has already suffered the consequences of that lack of leadership.

FREE MARKET FORCES TO THE RESCUE

Growers that still think that QA will eventually go away are mistaken. As long as quality and particularly food safety remain a priority for major retailers, QA will always be there in one form or another. For those who accept QA as part of their overall business strategy, the situation is beginning to look better.

Competition is providing vegetable growers with more alternatives that promise to deliver real benefits to those businesses that need a formal QA system. In the past, having more than one QA program available was seen as a source of confusion for the industry. Unfortunately, a monopolistic situation usually causes an unwillingness to improve the service provided.

Today, we have several QA programs competing for clients in the horticultural industry. The following are some of the programs that have been very active in servicing clients in our industry:

- SQF 2000
- WVQMS (for Woolworth suppliers)
- Fresh Care
- HACCP certification
- HACCP 9000
- ISO 9000

It would not be appropriate to suggest that in absolute terms one of these programs is better than the others. All these programs have some distinctive characteristics that can make them more suitable in specific situations. The greatest benefit is that competition is forcing these programs to improve the service and reduce the cost to growers.

THE CUSTOMER IS THE KING

Today, we have many growers in Victoria with a deep understanding of quality and food safety systems. They can easily assess if the service they receive from a QA program and its associated auditing companies represent value for money.

Competition is allowing growers to select the combination of QA program/auditing company that will best fit their long term strategy. If growers are not happy with the service provided, they can change the auditing company, QA program, or both.

As long as growers are following good farming practices, QA should not be an open book to keep adding more and more requirements. That has never been the intention of customers and other responsible stakeholders. Requirements should always reflect the real level of risk associated to fresh produce. Market forces should now take care of any QA program or auditing company that is not able to assist in achieving that goal.

INDUSTRY PROMOTION: WHAT SHOULD WE DO?

C. Simpson
Fresh Finesse, Suite 29 Crossways Centre, 180 Rokeby Road, Subiaco 6008, Western Australia

INTRODUCTION

What is currently being done?
What can be done?
What are you going to do?

CURRENT ACTIVITIES

Generic Fruit and Veg Promotions – *7 a day, 2 fruit and 5 veg every day*

- Retailers
- State and Federal Health Departments
- Queensland Fruit and Vegetable Growers
- Nutrition Australia
- National Heart Foundation

Specific Promotion of Carrots

- Retailers
- Nutritionists
- Food Writers
- Health Department of WA
- Yellow Brick Road

WHAT CAN BE DONE?

Specific Product Promotions

- Mushrooms
- Avocados
- Potatoes

Who are our consumers?

- Shoppers
- Food service including school canteens
- Children

What do we know about our consumers?

- Each person is eating 11 kg of carrots a year or about one a week[1]
- Average daily consumption of all fruit and vegetables is 4.1 serves of the 7 recommended by nutritionists[2]
- 85% of meals are prepared from scratch[3]
- School canteens – a $350 – 400m industry[4]

Fresh Finesse Carrot Shopper Survey[5]

- 57% buy carrots every week
- 44% serve carrots plain cooked
- 20% would eat more carrots if they tasted better
- 28% believe they could not eat more carrots than they do already.

- Opportunities for partnerships and joint promotions.
- Less Government funding.
- AUSVEG Industry Strategic Development Plan: to develop an industry promotion package designed to increase consumption of Australian vegetables.

Table 1. Typical Advertising Budget

Cost	Element
$500,000 - $1m	Advertising Agency TV/Radio advertising Press advertising Billboards/outdoor posters PR Season Launch Retail education/promotions Posters and recipe cards
$200,000	TV/Radio advertising Press advertising Billboards/outdoor posters PR Retail education/promotions Posters and recipe cards
$100,000	Press advertising Billboards/outdoor posters PR Retail promotions Posters and recipe cards
$20,000	PR Media coverage Retail promotions Posters and recipe cards

Table 2. Typical PR Budget

Details	Cost	Typical Value
Regular radio and press coverage	$10,000 per annum	$100,000
Retail promotions – 100 in-store demonstrations	*$10,000	100 -500% sales increase
500 Posters and 20,000 recipe cards	*$6,000	

* opportunities to reduce costs with joint promotions

WHAT ARE YOU GOING TO DO?

It's over to the industry.

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OPPORTUNITIES FOR VALUE ADDING

L. Simons, C. Tran and V. Reyes
Food Science Australia, Private Bag 16, Werribee 3030, Victoria

Evaluation of consumer trends from the Cassandra project has identified several key determinants that will drive product development opportunities for the next decade. Critical to the success of meeting market demands is to identify technologies and the enabling science to required for capturing such opportunities. A variety of opportunities exist for value-adding of carrots from minimally to fully processed products and as low to high-value ingredients utilised in food manufacturing.

Fresh-cut carrot products (ie. carrot batons, baby peeled carrots, shredded carrots) provide a healthy convenient alternative for consumers, or are used in food manufacture and food-service to reduce labour savings. The formation of “white blush” on the surface of peeled carrots is a major factor limiting consumer acceptance of minimally processed carrot products. Evaluation of control measures was undertaken at Food Science Australia. The novel combination of edible coating and acid treatment was observed to inhibit the white-blush formation and maintain acceptable microbiological quality of mini-peeled carrots up to 4 weeks at 4 °C, compared with 1 day for water dipping and 8 days for acidic dipping.

Extrusion technology has been identified as an opportunity for utilising waste carrot pulp for the production of high dietary fibre snack foods. Further value-adding opportunities exist, such as cooked in the bag (retorted) products combining sauces (ie honey glazed), carrot-based dips and fried carrot chips.

Dried carrot and can be used as a food manufacturing ingredient, while further value-adding can be achieved with the extraction of carotene. These can be utilised for colouring and nutraceutical applications, such as vitamin and fibre enrichment of beverages and foods. Food Science Australia has developed micro-encapsulation processes which have been commercially successful for the protection of omega-3 fatty acids (fish oils). This technology can also be applied to other high-value ingredients such as carotene for improving stability and functionality in food systems.

Poster Papers

DIURNAL FLUCTUATIONS IN SPLITTING SUSCEPTIBILITY OF CARROT TAPROOTS

A.J. Gracie and P.H. Brown
School of Agricultural Science, University of Tasmania PO Box 252-54, Hobart 7001, Tasmania

INTRODUCTION

Carrot taproots that split (longitudinal fracture in the phloem parenchyma) during growth or mechanical harvesting and processing, are unsaleable. Since it is common for 10 to 20 per cent of a carrot crop to split it is a serious problem in carrot production. While differences in susceptibility to splitting between genotypes (1), maturity and agronomic practices such as irrigation, fertiliser regimes and spacing trials (2, 3) have been reported, only a small proportion of research in this area has assessed possible mechanisms for this splitting phenomenon. In this work diurnal fluctuations in splitting susceptibility, water relations and tissue properties were examined.

MATERIAL AND METHODS

Mature carrots were used in all experiments. Diurnal fluctuation was measured in relation to: susceptibility to splitting (using a modified hand held penetrometer); leaf water potential (4); and taproot phloem water potential, osmotic potential and turgor pressure (3). These measurements were taken pre-dawn and at regular intervals until 4 pm. In addition diurnal fluctuations in carrot diameter were recorded using a linear variable differential transformer (5). The effect of temperature on susceptibility to splitting was examined at pre-dawn (splitting susceptibility high) and midday (splitting susceptibility low). Hand harvested carrots were placed immediately in water with temperatures ranging from 5 to 25 °C. When the carrot core temperature reached equilibrium with the water, susceptibility to splitting was recorded.

RESULTS AND DISCUSSION

Carrots were found to be most susceptible to splitting pre-dawn, with susceptibility decreasing over the day, before increasing again in the evening. Although temperature has previously been shown to influence phloem tissue properties of segments of carrot tissue (6) in this study the susceptibility to splitting of intact carrot taproots was not significantly affected by temperature, the greatest effect being the time of day the carrots were harvested. It was noted that the diurnal fluctuations in splitting susceptibility corresponded to periods of expansion in carrot root diameter. Since turgor pressure in the phloem tissue did not vary significantly diurnally, while leaf water potential declined after sunrise before increasing late in the afternoon, it is proposed that splitting susceptibility is linked to changes in tissue structural properties associated with phases of carbohydrate storage in the carrot root. The relationship of tissue properties, rather than turgor pressure, in the phloem parenchyma cells and the susceptibility to splitting is consistent with the findings of Hole *et al* (7) and McGarry (1).

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SUSTAINABLE CARROT PRODUCTION: WORKSHOPS AND ESTABLISHMENT OF PRIORITIES

S.A. Henderson
Agriculture Victoria – Sunraysia Horticultural Centre, PO Box 905, Mildura 3502 Victoria, (03) 5051 4500

SUMMARY

"Sustainable Carrot Production: Workshops and Development of Priorities" was a HRDC funded project to established to provide a clear direction for research and development funding in the carrot industry. It was orientated particularly towards developing project ideas that will make the carrot industry more sustainable in the long term.

The project enabled many growers in the carrot industry to have their say on what was important to them and how they would like their levy money spent. For many workshop participants this was the first such opportunity.

METHOD

A series of workshops were held over a three month period in Victoria, South Australia, Tasmania, Queensland and Western Australia. Representatives from New South Wales were present at both the Queensland and South Australian workshops. Participants at the workshops included growers, industry personnel and researchers.

The objective of the workshops was to identify and prioritise research and development needs, to be addressed over the next three to four years.

Research needs were prioritised by:

1. Brainstorming and group discussion to define the current impediments to a sustainable industry.

2. Developing project ideas, outputs and outcomes so that research projects will be clearly targeted and meet the expectations and needs of growers.

3. Prioritising each project based on the impact it will have on the industry and feasibility of carrying it out successfully.

The workshops were also an opportunity for researchers to report back to growers on how their current projects were progressing. This was achieved by inviting local researchers to come and speak at the workshops. A workshop report summarising all current HRDC carrot projects was given to all participants.

RESULTS

A broad range of issues were put forward at the meetings, ranging from irrigation requirements to disease control and market research. Some regions had quite specific problems based on their production system or market, although the majority of priority research issues identified were common to at least two or three states- if not all states.

A number of issues not related to research and development were raised by the workshop participants including promotion of carrots to increase market share. Non trade barriers such as quarantine restrictions were also raised as a concern.

The issues raised in each state, in priority order were:

South Australia

- Techniques to increase water use efficiency
- Investigate ways to clean up disease contaminated seed
- Registration in Australia of chemicals available overseas
- Spread of Celery Mosaic Virus CeMV (now known to be Carrot Virus Y)
- Improvements to technology transfer to access interstate and overseas research.
- Carrot breeding project to overcome low seed vigour
- Genetic modification of carrots to minimise crop protection inputs
- Recommendations for nutritional requirements of carrot crops on different soil types
- Irrigation recommendations when using saline water
- Market research into consumer preferences
- Herbicide resistance in weeds

Tasmania

- Lack of knowledge on the identification and treatment of disease and nematodes
- Nutritional requirements for growing carrots on Tasmanian soils
- Poor seed quality due to contamination with disease
- Predictive tools to determine disease thresholds
- Reduce production costs by investigating alternative chemicals and cultural practice
- Information on optimal crop rotations for Tasmanian conditions
- Investigate alternatives to chemicals for example green manure crops
- Reduce soil compaction
- Market research into Tasmania's competitive advantage

Queensland

- New carrot products - ie. juice, pre-cuts etc. to overcome domestic market oversupply
- Market research into consumer preferences for taste, shape, colour, size
- Ways to reduce white blush on carrots after washing
- Limited access to overseas and interstate research
- Communication breakdown in marketing chain
- Market research into product sale methods

Victoria

- Too much reliance on chemicals - investigate alternatives like bio-fumigation and optimum timing for chemical application
- Investigate the new species of cavity spot causing fungus and what carrot varieties may be resistant
- Domestic oversupply of carrots; investigate how the levy may be spent to improve this situation

Western Australia

- Irrigation and nutrition information including method and timing of applications
- Post harvest handling requirements
- Chemical breakdown in soil –the possibility of using organics to overcome this breakdown problem
- Difficulties in accessing overseas information, growers have different needs in how information should be presented
- Recommendations for crops to rotate with carrots
- Poor seed quality due to disease infection and trueness to type
- Urban sprawl
- Which windbreaks are most effective

DISCUSSION

The topics mentioned in this summary are those that participants saw as most important to them in the coming years. There was much discussion and concern over the fact that many of the topics were seen to be regionally specific. There was a fear that these needs would not be researched as current focus was on national projects. Interestingly often the topics that one state feared were regionally specific turned out to be topics in other states also.

Some topics and solutions were seen to be long term such, for example genetically modified carrots. Many were seen to be problems that could be solved quickly, such as improving technology transfer and access to overseas research.

Research providers must now focus on these topics in order to help HRDC and the carrot industry achieve solutions.

ACKNOWLEDGMENTS

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The HRDC Root Vegetable R & D committee are thanked for their guidance.

BROOMRAPES – THE LEECHES OF THE PLANT WORLD.

S.G. Lloyd[1,2], G. Power[1,3] and G. Shea[1,4].
[1]Agriculture Western Australia, Locked Bag 4, Bentley Deliver Centre 6983, Western Australia
[2] Crop Improvement Institute, <slloyd@agric.wa.gov.au>
[3] HortGuard™ Coordinator, Boyanup Rd, Bunbury <gpower@agric.wa.gov.au>
[4] GrainGuard™ Executive Officer, Dryland Research Institute, Merredin <gshea@agric.wa.gov.au>

The broomrapes (*Orobanche* spp.) are parasitic plants that attack the roots of a number of important broadleaf crops including pulses and oilseeds, as well as pasture legumes and a wide range of vegetables and ornamental plants. They were identified as exotic weed threats under both the HortGuard™ and GrainGuard™ initiatives. Broomrapes do not attack cereals or other grasses. They have no chlorophyll and can only survive by attaching to a host plant. Of the numerous broomrapes worldwide, five are particularly weedy and cause heavy crop losses. One of these, branched broomrape (*O. ramosa*), has been found in South Australia and is under a containment/eradication program.

The other species are Egyptian broomrape (*O. aegyptiaca*), nodding broomrape (*O. cernua* var. *cernua*), crenate broomrape (*O. crenata*) and *O. cumana* (no common name); they are not known to be in Australia. If these weedy *Orobanche* were introduced, carrots and other major crops would be seriously affected and export markets could be threatened. Pest broomrapes are found in Mediterranean countries, Europe, Asia, Africa and America.

Branched broomrape was found on cereal growing properties in the Murray Bridge district in South Australia in 1992. It is the subject of an intensive surveillance and eradication campaign, however infestations are now spread over some 1,300 ha. Two other *Orobanche* spp. are found in Australia: *O. cernua* var. *australiana*, which is a rare native never recorded as attacking crops, and common broomrape (*O. minor*), which is common and widespread throughout southern Australia.

Note that branched broomrape and other pest broomrapes could be confused with common broomrape (*O. minor*) which does not cause any economic damage - it attacks several common pasture plants, weeds and garden plants including clover, capeweed, flatweed, nasturtiums and petunias. Common broomrape has rarely been recorded as attacking carrots in Western Australia. The features that distinguish branched broomrape are its bluish flowers and branched stems.

Attack by branched broomrape can cause significant yield loss or even death of the host plant. This depends on various factors including the susceptibility of the crop species, the degree of parasitisation and the time of sowing. Parasitised potato plants, for example, may produce the same number of tubers as healthy plants, but these may be only a few centimetres in diameter. Tomato fruits from parasitised crops may be full sized, but greatly reduced in number so harvesting is not economically viable. Even if crop yield is not greatly affected, the produce may not be saleable. Celery and cabbage plants, for example, may have large yellow blotches, while carrots cannot even be used for processing as most of the sugars have been stripped by the parasite and they are fit only for stock fodder.

An effective way to control pest broomrapes is soil fumigation, with methyl bromide being the most successful. Some herbicides control pest broomrapes but they are not selective to most crops and therefore may kill the host as well. In other countries, some broomrapes have overcome the resistance that has been bred into certain crops. Pest broomrapes have been predicted to develop herbicide resistance. For severe infestations, the only viable option may be to switch to growing non-host crops such as cereals, cotton, orchard crops or vines.

As well as carrots, horticultural crop hosts of branched broomrape include: beans, broccoli, cabbages, capsicums, cauliflowers, celery, eggplant, melons, onions, peas, potatoes, sunflowers and tomatoes. Branched broomrape will also parasitise several weeds including capeweed, clover and wild turnip. It is also the only broomrape to attack cannabis and fibre hemp. Broadarea crops affected are canola, chickpeas, field peas, lentils and possibly lupins.

Broomrape germination can be stimulated by the presence of any broadleaf plant roots, but broomrape seedlings will only survive if they attach to a suitable host. After attachment, branched broomrape has a prolonged period of growth below ground before the flowering stem emerges. Branched broomrape usually starts to emerge in early spring, but can start emerging in August under favourable conditions. The plants are most conspicuous during flowering which is likely to begin about two weeks after they emerge and last for about two weeks. Emergence and flowering can continue into summer in irrigated crops.

Emergence of the flowering stem is the most common sign, by which time it is too late to save the crop. Prior to emergence of the flowering stem, broomrape attack may be indicated by reduced crop vigour, unusual discoloration such as yellowing, reduced flowering or crop death. Digging up affected crop plants to expose attached broomrape plants will provide a sure diagnosis. Once they have flowered, broomrape plants will continue to produce seed even if they become detached from the host. One broomrape plant can produce up to 500,000 seeds. All broomrape seeds are minute, like dust, and can be spread by contaminated soil, produce, machinery, livestock or clothing. The seeds can remain dormant in the soil for 10 years or more.

In Western Australia, growers should report suspected branched broomrape or other pest broomrapes immediately to the nearest office of Agriculture Western Australia. In other States, please contact your State department of agriculture or primary industries.

THE PLANT PATHOGENIC FUNGI IN CARROT WASH WATER AND SETTLING POND DISCHARGE

M.I. Mebalds
Institute for Horticultural Development, Private Bag 15, Scoresby Business Centre 3176, Victoria

SUMMARY

Diverse methods of carrot washing around Australia has lead to a range of water quality outcomes and implications for water recycling. A common thread however is that soil-borne plant pathogens are often found in waste water resulting from washing soil from carrots. Settling ponds rarely removed plant pathogens from water. Other water treatments are required if the water is to be reused on crops or produce.

INTRODUCTION

The Australian carrot industry is diverse in nature and has a wide range of water handling systems for washing of product. The industry uses large quantities of water just washing carrots. Substantial water savings may be made by recycling the wash water, however, the water must be safe for use form a food safety and product safety perspective. Human and plant pathogens must be removed if the water is to be recycled. Water treatment and re-use of waste waters varies across the industry. Some growers use settling ponds to clarify water before disposal. A survey of fungi found in source, waste and settling pond discharge waters used in the carrot industry is presented here to discuss the implications for re-use of such water on-farm.

MATERIALS AND METHODS

Water samples were collected in March and June from two carrot farms that washed carrots and put waste water through a series of settling ponds before discharge. The presence of fungi in source, wash and settling pond discharge water was assessed by plating out two 0.5 mL aliquots of sample water from a dilution series from 0 to 10^{-3} onto potato dextrose agar, malt extract agar and water agar. All fungi growing on plates were identified at least to genus level. Fungi that were considered to be potentially pathogenic were identified to species level.

RESULTS AND DISCUSSION

The fungal population in water obtained from source, wash effluent and settling pond discharge was variable, *Penicillium* spp. were the most commonly isolated fungi followed by C*ladosporium cladosporoides* (Table 1). The natural populations of other fungi in the water samples were rather small so that reliable comparisons of populations between water sources cannot be made however the trends can be noted.

There was only one sample with *Pythium* spp. present and was from the settling pond discharge. This indicates that the water in the settling pond may be a source of *Pythium* spp. inoculum for crops or produce, depending on the end use of the water.

Of concern is the trend to increased isolations of *Geotrichum candidum* from settling pond water compared to source and wash waters. This may indicate that *G. candidum* is adapted to survival in water. *Phoma* spp. were isolated from wash and settling pond water. This indicates that the fungus originated from soil washed off the carrots and survived the settling pond treatment. *Mucor* spp. however were present in all water sources and were not affected by settling pond treatment.

Table 1 Incidence of fungi in source, wash and effluent waters used in washing carrots.

Fungus isolated	Number of colonies isolated/mL		
	Source Water	Wash water	Settling pond water
Acremonium spp.	12	3	8
Alternaria alternata[P]	6	9	2
Aspergillus niger[P]	3	1	1
Cladosporium cladosporoides	28	98	57
Fusarium oxysporum	2	6	10
Fusarium solani	0	5	1
Fusarium sporotrichiodes[P]	0	1	0
Geotrichum candidum[P]	1	1	6
Gliocladium sp.[P]	0	1	0
Mucor spp.[P]	10	7	10
Penicillium spp.[P]	144	52	86
Phoma spp.[P]	0	6	7
Pythium sp.[P]	0	0	2
Trichoderma sp	7	15	15
Verticillium nigrescens	6	3	3

P Indicates that the fungus has the potential to cause post-harvest diseases (1)

The results indicate that settling ponds do not decrease the number of plant pathogens in water and that if this water is to be re-used for washing produce or irrigating carrot crops, then a disinfestation treatment is required.

Further work with higher populations of fungi should be undertaken to give a better indication of the population dynamics of fungi within settling ponds.

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INVESTIGATIONS OF RESISTANCE OF CARROTS (*DAUCUS CAROTA SATIVUS* HOFFM.) TO *ALTERNARIA DAUCI* (KÜHN) GROV. ET SKOLKO

T. Nothnagel, P. Straka and P. Scholze
Institute for Horticultural Crops, Federal Centre for Breeding Research on Cultivated Plants, Neuer Weg 22/23, 06484 Quedlinburg, Germany

This project has been determining whether there is any genetic resistance against *Alternaria dauci* in carrot lines. A laboratory test has been developed as the basis for this resistance screening. This test is the result of experiments on the pathogenesis and expression of *Alternaria* diseases. Histological investigations have helped to characterise the different types of expression.

The *Alternaria* isolates were maintained on carrot-leaf agar at 18-20 °C with day light conditions. Host arcades were inserted to preserve the aggressiveness. By means of protein, isozyme and RAPD analyses the isolates were characterized and compared with other *Alternaria* strains. The analyses served to confirm the genotypic stability during the maintenance steps.

The variety 'Bolero' was used in all experiments as a standard to ensure the comparability and reproducibility. The preliminary results suggest physiological as well as seasonal or environmental influences of the expression of resistance. The development of a set of standard carrot lines is absolutely necessary for the future.

More than 150 carrot lines have been tested so far. Significant differences were observed between plants, but none were absolutely free of damage. Single plants with either low or high susceptibility were self-pollinated and the progenies will be tested successively in the future. The development of F_2 populations segregating for *Alternaria* resistance is in progress. This is being used as the basis for analysis of the genetic background and inheritance of these traits, as well as marker development and mapping.

TWO GENETIC LINKAGE MAPS OF CARROT, *DAUCUS CAROTA* L.

P. Straka and T. Nothnagel
Institute of Horticultural Crops, Federal Centre for Breeding Research on Cultivated Plants,
Neuer Weg 22/23, D-06484 Quedlinburg, Germany

Linkage maps are an important tool for marker assisted breeding, but their quality depends on the density and character of mapped markers. Two maps have been developed of two F_2 populations (MK8, MK9) obtained from crosses between two male sterile lines of cultivated carrots *D. c. sativus* with the wild species *D. c. gadecaei* and *D. capillifolius.*

Twenty-three morphologic traits were observed during the vegetative and generative developmental phases of plants and harvested seeds. Ten isozyme systems were tested for using as markers. Further, 16 primer and four primer combinations were used in RAPD- and AFLP-analyses for marker selection. A total of 23 morphological traits, nine isozyme-markers, 188 RAPD-markers, 81 AFLP-markers and four microsatellites were obtained for both populations and incorporated into the linkage analysis. The Chi-squared test was used to estimate the goodness of fit of segregation of these markers to expected Mendelian ratios. The MAPMAKER 3.0 program was used for linkage analysis and map construction (1). The Kosambi function was used for the calculation of genetic distances in centiMorgans (cM) (2). Markers for these two carrot populations are shown in Table 1.

Out of 128 markers analysed in the MK8 population, 79 (62 per cent) could placed in 10 linkage groups. The MK8 map contains 12 morphologic traits, 3 isozyme-markers, 39 RAPD-markers and 25 AFLP-markers. Forty-nine markers have not been mapped so far. The total length of the genetic map was 1420 cM, with an average distance between markers of 18.4 cM.

A map of the MK9 population contains 143 markers, including 11 morphologic traits, four isozyme-markers, 82 RAPD-markers, 42 AFLP-markers and four microsatellites in 15 linkage groups. Twenty five per cent of the markers could not be assigned to any of the linkage groups. The total length of the map was 1780 cM, with an average distance between the markers of 12.4 cM.

Table 1. Obtained and mapped morphological and molecular markers of carrot.

Progeny	Marker type	Observed marker			Mapped marker		
		T	M	P	T	M	P
MK8 (n=92)	Morpho-logical	20			12		
	Isozyme	3			3		
	RAPD	75	37	38	39	24	15
	AFLP	30	19	11	25	16	9
	Total	**128**			**79 (62 %)**		
MK9 (n=99)	Morpho-logical	17			11		
	Isozyme	6			4		
	RAPD	113	43	70	82	34	48
	AFLP	51	26	25	42	21	21
	Micro-satellite	4			4		
	Total	**191**			**143 (75 %)**		

T: total; M: maternal; P: paternal

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CARROT DISEASES IN NORTH WEST TASMANIA.

H. Pung and P. Cox
Serve-Ag Research, PO Box 690, Devonport 7310, Tasmania

SUMMARY

A study was conducted to identify and record the different types of diseases affecting carrot pack-outs in Tasmania. This study has resulted in the publication of a carrot disease guide, which shows the type of diseases recorded, their symptoms, their effects during storage, and their associated organisms and field conditions.

INTRODUCTION

In recent years there has been a rapid expansion of both fresh and processing carrot production on the north-west coast of Tasmania. A consequence of this expansion is the appearance of a number of diseases, which can severely downgrade or reduce carrot packout and the profitability of carrot growing.

There has also been an increase in the incidence of a range of pathological disorders that affect post-harvest storage. With the increasing utilisation of ground for root crops, it is anticipated that disease problems will increase as the industry expands. Little is known about these diseases, their symptoms, and their causal agents, making it impossible to devise any control program.

This project, funded by HRDC, and supported by the Tasmanian carrot industry, was aimed at identifying and recording the diseases that occur in Tasmania.

METHODS

Over a three-year period, field inspections and sampling of paddocks were conducted for diseased carrots, prior to or during harvest. Samples of carrots rejected due to disease, either in the packing lines or after storage, were also collected for diagnostic testing to determine the causal organisms. Where possible, field conditions and practices that may be associated with a disease were recorded. Photographic records of each of the diseases were also taken.

RESULTS AND DISCUSSION

Based on the field survey studies, a summary of current knowledge on the types of diseases, causal organisms, and their associated field conditions and practices, has been compiled and is listed in Table 1.

A disease guide was compiled to help growers and processors to identify the types of diseases they are likely to encounter in carrot crops throughout Tasmania. This guide should enable growers and processors to distinguish between different types of diseases, based on their symptoms.

Growers, consultants and processors within Tasmania are now using this guide, which has also been distributed to growers and carrot researchers in other states of Australia.

Table 1: Carrot root diseases recorded in Tasmania.

Disease	Causal Agent/Condition
Corky Crown Rot	*Streptomyces* spp. Usually associated with potatoes as previous crops.
Smooth Crown Rot	*Fusarium* spp., *Rhizoctonia solani*, *Sclerotinia sclerotiorum.* Wet conditions favour this disease, which increases in severity over time.
Scab	*Streptomyces* spp. Usually associated with potatoes as previous crops.
Sclerotinia	*Sclerotinia sclerotiorum*. Poor temperature management after harvest increases risk of *Sclerotinia* rot.
Tiger Stripe or Ring Rot	*Phytophthora megasperma* and *Pythium* spp. Usually associated with poor water drainage.
Cavity Spot	*Pythium sulcatum*. Incidence increases with multiple carrot cropping.
Black Ring	No specific pathogen. A range of fungi or bacteria has been found in association with this rot. Disease is worse after slashing of foliage prior to harvest in autumn.
Forking	Caused by a range of organisms or factors that will damage root tips, e.g. fungal pathogens, plant parasitic nematodes, insects, soil compaction, chemical residues.
Sour Rot or Tip Rot	*Geotrichum* spp. and/or a range of secondary fungi or bacterial invaders have been found in association with this rot.
Violet Root Rot	*Rhizoctonia crocorum.* Associated with poor drainage.

ACKNOWLEDGEMENTS

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EFFECT OF LYGUS BUG INFESTATION ON CARROT SEED YIELD AND QUALITY

C. Spurr, P. H. Brown and N. Mendham
School of Agricultural Science, University of Tasmania PO Box 252-54, Hobart 7001, Tasmania

INTRODUCTION

There is potential for a significant hybrid carrot seed industry in Southern Australia, with production currently occurring in states of South Australia and Victoria and, in the past, in Tasmania. Whilst some hybrid carrot seed crops grown in these areas have produced high yields of quality seed, many have produced poor yields of seed of low germinability. To date little research has been conducted on the reasons for these problems in Southern Australia. This study aims to identify and investigate some of the major factors involved.

RESULTS AND DISCUSSION

One area of investigation is the involvement of insect pests. Research has shown that Lygus bug (*Lygus oblineatus* and others; family Miridae) infestation is a major cause of embryoless seed in the Umbelliferae and may also cause a reduction in seed yield. Whilst the species involved are not known in Australia, another sap sucking bug, Rutherglen bug (*Nysius vinitor*; family Lygaeidae), is commonly observed on carrot seed heads from anthesis to maturity. In order to determine the impact of Rutherglen bug on carrot seed production an experiment was undertaken in which Nantes type hybrid seed parents were caged from pollination to maturity with two treatments: exclusion of all insects; and inclusion of Rutherglen bug at levels commonly observed in the field (two to five per umbel). An additional treatment consisting of plants exposed to normal field conditions was also included. The effects of these treatments on seed yield and quality are reported and their implications for seed production and future research are discussed.

MAJOR PESTS AND DISEASES OCCURRING IN CARROT CROPS IN FRANCE AND MAIN RESEARCH PROGRAMS

F. Villeneuve[(a)], M. Bossis[(b)], D. Breton[(c)], E. Brunel[(b)], N. Diare[(c)] and F. Rouxel[(b)]
[A]Ctifl, centre de Lanxade, BP 21, F 24130 La Force France – e.mail : villeneuve@ctifl.fr
[B]Unité Mixte de Recherche Biologie des Organismes et des Populations appliquée à la Protection des Plantes [BiO3P], INRA - Domaine de la Motte - B.P. 35327 - F - 35653 Le Rheu cedex, France
[C]Sileban /Inra BiO3P - Domaine de la Motte - B.P. 35327 - F - 35653 Le Rheu cedex

French carrot production totals about 650 000 tonnes, making it the European leader followed by Great Britain and the Netherlands. Because of the diversity of these areas in terms of climate, soil and production techniques, France is supplied with carrots year round, but it is also prone to specific phytosanitary problems as a result, particularly since crop rotation and the number of years of carrot production vary considerably from one area to the next.

I – SOIL-BORNE DISEASES AND PESTS

Soil-borne diseases and pests currently pose the greatest problem when it comes to using environment-friendly protection techniques. The two main problems, of equal weight, are nematodes and *Pythium*, followed by *Rhizoctonia solani* and the carrot fly (*Psila rosae*).

1°) Pythium Recent studies conducted have demonstrated the complexity of root rot diseases due to soil-borne fungi, which involve several species of *Pythium*, and the expression of different types of symptoms at various stages of cultivation .

It is therefore important to be able to identify the species concerned in the different production areas, and to dispose of the tools required to diagnose them in plants and, if possible, in the soil.

Among the different potential trap plants tested, the young carrot plant seems the most suitable, but the problem of quantifying the infectious potential of soil has not been solved. However, combining nested PCR with biological trapping is a significant advance in research on this method

2°) *Rhizoctonia solani* Although this fungus had already been reported in France, its prevalence and widespread implication in various symptoms were demonstrated in the central region of France in 1993. Today, it is the most prevalent soil-borne disease in the Landes region.

Initially, it was decided to study the possibility of either film coating with active substances having a specific action against *Rhizoctonia*, or applying a local treatment. These proved to be encouraging both in bio-assays and under practical conditions.

An initial study also showed that among the different groups of anastomosis identified on the carrot in France, groups AG 2-2 III B and AG 4 are the most frequent.

At the present, little is known about the different anastomosis groups involved, or about the intra-specific variability. However, epidemiological studies are currently underway.

3°) Nematodes The 'nematode' problem varies according to the different production areas in France.

Studies conducted in the 1980s showed that in the west of France, the most frequently observed damage is caused by the cyst species: *Heterodera carotae*. Initial investigations in the south-west have revealed the presence of other species of nematodes belonging to the *Meloidogyne* and/or *Pratylenchus* genera. So far, three lines of research have been pursued:

- The possibility of limiting populations of *H. carotae* using the trap carrot technique;
- The search for carrots which are resistant to *H. carotae;*
- A study of the harmful effect of *Pratylenchus* on the carrot.

4°) Carrot fly : *Psila rosae* Carrot fly (*Psila rosae*) is a common pest occurring in carrot crops. To improve protection by optimising treatment, a trapping technique based on colour attractiveness has been developed. The currently accepted threshold in France and in many of the European countries to trigger treatment is one fly per trap per day for one week.

The results obtained since 1991 for the monitoring of trapped flies shows that the treatment threshold needs to be modulated according to the flight concerned. The thresholds proposed at present are as follows:

- First flight from April to July: 1 fly/trap/day over a period of 4 days and 0.5 flies/trap/day over a period of 10 days
- Second and third flights: 0.4 flies/trap/day over a period of 4 days (August to November)

II – AIR-BORNE DISEASES AND PESTS

1°) The main aphid : *Cavariella aegopodii* In France, the carrot aphid is regularly present, even if only in moderate amounts. The first flights arrive early, which means that young seedlings can be infested by the end of April. The carrot aphid is detrimental to young plants which wither and die. However, this aphid is a vector of carrot motley dwarf virus (a complex of carrot mottle and carrot red leaf viruses (CmoV + CRLV)).

The annual flight pattern is extremely stable. It consists of two periods of activity, the first of which is regularly greater than the second. The first flight generally occurs from mid-April to mid-June. The second flight occurs in autumn, from mid-September to mid-November.

2°) Alternaria : *Alternaria dauci* In France, *Alternaria* is considered to be the main leaf disease of carrots even if there is a risk of it being confused with other fungi. Before the Landes production area was developed, parasite problems caused by *Alternaria dauci* were easily arrested by a few leaf applications. The incidence of this disease in the South West of France is such that today varietal resistance must be combined with protection strategies based on risk forecasting models and alternation of the active ingredients used.

Along with the use of low sensitivity varieties, a study is being conducted to validate a risk forecasting model which would enable more effective treatment to be carried out.

CONCLUSION

New economic and environmental data are causing disruption among carrot producers, who mainly practise intensive production. Recent developments are numerous: the environmental aspect and, more and more often, the ethical aspect are being taken into consideration by the politicians, consumers are looking for greater safety and French and European regulations are changing. This is why extensive research is being undertaken in the field of crop protection. The focus is on a multidisciplinarian approach in order to develop technical practices which will lead to biological equilibrium. To achieve this, epidemiological studies must be continued not only for *Rhizoctonia solani*, but also for *Alternaria dauci*. In other cases, risk forecasting methods need to be improved. In any case, alternative protection trials will need to be carried out which are based as little as possible on synthetic chemistry.

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