



*Know-how for Horticulture™*

**Improving the  
reliability and  
consistency of  
processing beetroot  
production**

Heidi Martin  
QLD Department of Primary  
Industries and Fisheries

Project Number: VG00084

## **VG00084**

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**HAL Project VG00084**

**Improving the Reliability and Consistency of Processing  
Beetroot Production**

**(Completion October 2004)**

**Final Report**



**Heidi Martin *et al.***

**Queensland Department of Primary Industries and Fisheries**



(HAL Project VG00084)

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This report summarises the results of a four-year study investigating yield and quality decline in Australian processing beetroot crops. It provides information on the identification and management of soil-borne fungal diseases of beetroot and identifies prospective beetroot varieties that may be used as alternatives to the varieties currently grown by the industry.

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**(Completion October 2004)**

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## Media Summary

Soilborne fungal diseases threaten the viability of the Australian processing beetroot industry. The disease problems have been exacerbated in recent years because crops are now grown virtually year round, and under environmental conditions that favour disease outbreaks. The long beetroot growing-window has reduced the opportunity for farmers to rotate out of beetroot and if rotations are completed, they are generally only short, which further increases the disease problems.

This work was completed to help the Australian beetroot industry better manage its soilborne diseases and improve the quality and consistency of the product it grows. The problems faced by this industry are not unique to Australia, however nowhere in the world does there seem to be a single strategy that is completely efficacious in controlling soilborne diseases in beet crops and so we anticipated that an effective management strategy will almost certainly involve a combination of tactics. Our work indicates that the most prospective strategy will involve: 1) reducing the length of the growing window so that beets are no longer grown during the periods of highest disease risk, 2) utilising knowledge of disease species at particular sites to make more informed decisions about when blocks should be planted to minimise disease outbreaks, 3) Ensuring that all beet seed is treated with a Rizolex and Apron seed dressing combination prior to planting, and 4) Utilising crop species that are not hosts for the soilborne beet pathogens, as rotation crops (barley and dolichos seemed to be the best for sites with mixed disease infections).

In addition to increasing disease issues, the Australian beetroot industry relies on only a few standard beetroot varieties for its slicing product and only one baby beet variety. In recent years the industry has become concerned that these varieties are no longer providing the high quality, consistent product that the processor and consumer demands. We identified beet varieties that offer promise as alternatives to the current industry standards, and for more efficient production, suggest that the industry would benefit by switching to monogerm beet varieties.

## Technical Summary

Soilborne fungal diseases are killing the Australian beetroot industry. Infections of young plants reduce crop stands, and later infections attack developing beets, reducing quality and increasing processing costs. Additionally, this industry currently relies on only 3 slicing type beetroot varieties and 1 baby beet variety and anecdotal evidence suggests that the varieties are no longer meeting the quality requirements demanded by the processor or the consumer. We completed a 4-year study to investigate methods by which the industry might better manage its soilborne diseases and improve the varietal options of the industry.

We completed surveys of beetroot soils in the Lockyer and Fassifern Valleys and found that *Rhizoctonia* and *Pythium* species are the most important soilborne diseases. Furthermore, we determined which pathogens predominated in specific blocks of beetroot using glasshouse soil-indexing bioassays. Additionally, Dr Paul Scott (UQ Gatton) characterised the pathogenic *Pythium* isolates using molecular methods and found three main species: *P. aphanidermatum*, *P. ultimum* and *P. dissotocum*. Pathogenicity studies with the *Pythium* species indicated that disease severity is influenced by both temperature and the age of plants at inoculation. Furthermore, each *Pythium* species produced disease at specific temperature and plant age combinations.

Field and glasshouse fungicide trials showed that a combination seed dressing of Rizolex and Apron reduced disease, and was the best treatment out of more than 30 fungicides that were assessed. For best results, the dressing should be applied to seed as a slurry.

Glasshouse assessments of 22 crop types as alternate hosts for *P. aphanidermatum* and *Rhizoctonia* revealed that barley and dolichos were the least susceptible to infection by either pathogen.

A prospective management strategy for these soilborne diseases might therefore involve a combination of tactics. First, manipulation of planting dates so that sites with high inoculum potential are sown when environmental conditions do not favour the development of disease epidemics. Second, seed dressings with a Rizolex and Apron fungicide combination. Third, planting crops in rotation with beetroot that are poor hosts for the beetroot soilborne pathogens eg. barley, dolichos.

In terms of varietal improvements, we screened more than 90 beet varieties in field trials conducted in all parts of the growing window. We identified some alternatives to the current slicing type varieties and some of these lines are now being grown by this industry. In addition our research suggests that the industry would benefit by growing monogerm beet varieties.



## Introduction

The Lockyer and Fassifern valleys of south-east Queensland supply approximately 90% of Australian processed beetroot. In 2003, this region produced 28 700t of slicing beetroot and 2500t of baby beets. There are many factors that stand in the way of profitable, efficient production but an important one for this industry is crop establishment problems and quality reductions due to soil-borne diseases. Golden Circle P/L, the only company now processing beets in Australia, requires a consistent supply of quality raw product from May through December for processing to be completed efficiently and competitively. This has meant that the planting window has been extended so that beetroot are now being grown at times of the year when environmental conditions are not favourable for beetroot production. The extremities of the growing season, February-March and October –December, are typically extremely hot, and are periods of high risk for heavy rain, storm and hail events and losses due to soilborne fungal diseases.

As an additional complication, the number of growers supplying raw product to Golden Circle has been steadily declining in recent years, and now the cannery relies on fewer than 10 growers to supply the entire contract. Since there are fewer suppliers of raw product, each grower is required to plant more area to beets so that the total contract requirement can be met. Many of the growers have insufficient land to meet their contract requirements with the cannery, as well as plant other rotational crops. Consequently, on some farms a monoculture production system exists.

The specialisation of many farms to beetroot, often with short rotations, and the demands by the processor to extend the growing season, have been two critical factors that have led to the prevalence of soil-borne fungal disease issues in this industry. In the past 5 years, soilborne diseases have reduced crop yields and the quality of harvested product dramatically, particularly in crops planted in February-March or those harvesting October-December. Infections of young plants reduce crop stands and later infections attack developing beets, reducing quality and increasing processing costs.

In addition to an increased prevalence of soil-borne diseases, the industry relies on 3 slicing beet varieties (Detroit Dark Red, Garnet and Pablo) and only one baby beet type (New Globe). The beet growers have reported that the quality of Detroit Dark Red, Garnet and New Globe have declined in recent years and they no longer have confidence that these varieties can meet their processing needs. Despite this, no alternative replacement varieties have been identified.

Currently, the Australian beetroot industry is at a crossroad. It can either continue on its current path and risk failing completely, or it can implement changes to its production and processing practices so that its diseases can be better managed and the quality of its raw product improved. To change, members of the industry must have a clear understanding of the causes of the diseases and the management possibilities that are available and which are likely to reduce disease severity. They also must invest in a varietal assessment program so that alternative varieties to the current standard types may be identified. This project commenced in 2000 with the objective of identifying the diseases responsible for the losses and determining practical ways they should be managed, as well as improving varietal options for this industry.

## CHAPTER 1: Literature Review

At the start of this research program the project team completed a review of the scientific literature relevant to beet soil-borne diseases and beet production. The purpose of this review was several-fold. First, it allowed the problems facing the Australian beetroot industry to be viewed in an international context. Second, it brought the Australian industry members and the research team up to date with relevant research being conducted in other parts of the world. Third, it provided the project team and the Australian industry with direction when they came to develop their research strategy for managing beet diseases and improving beet quality and production in Australia.

Each member of the Queensland beetroot industry was provided with a copy of the literature review and a similar version of this document has been published in The Australian Journal of Experimental Agriculture ([www.publish.csiro.au/journals/ajea](http://www.publish.csiro.au/journals/ajea)) (Martin, 2003).

### Management Options for Soil-borne Diseases of Beetroot

#### 1. Introduction

##### 1.1 The Plant

Beetroot (*Beta vulgaris* var. *vulgaris*) or table beet, is a member of the Chenopodiaceae plant family, which encompasses a diverse range of both economically important species as well as numerous agricultural weeds. *Beta vulgaris* L. is the species of greatest economic importance within the genus *Beta*. This species is further divided into four important cultural types: sugar beet, fodder beet, Swiss chard and beetroot, each of which has been developed for a particular use. These plants are indigenous to the Mediterranean region and western and eastern Europe.

*Beta vulgaris* is either annual or biennial in its reproductive habit. Seed may be produced in the first year after planting or an extended period (50-120 days) of cool weather may be required to stimulate flowering. Seed is produced in regions with relatively low temperatures (0-10°C). Oregon, Utah and Arizona, in the United States, and France and Italy are important seed producing areas (Whitney and Duffas, 1986). Beet may be either self-sterile or self-fertile, and its seed may be either multigerm or monogerm. Monogerm seed can be planted at regular intervals in a row to produce an even stand.

Beet production, predominantly of sugar beet, is widespread. Beetroot is produced in The United States, The United Kingdom, northern and eastern Europe, Japan and Australia. From an economic standpoint, sugar beet is the most important cultural type and it accounts for the majority of beet production worldwide. For this reason, most of the available literature on beet relates to sugar beet, however much of this information also applies to beetroot as well as the other types.

## 1.2 *The Beetroot Industry in Queensland*

Most beetroot in Queensland is grown for processing, with only small areas planted for fresh market production. The Lockyer and Fassifern valleys of south-east Queensland supply approximately 90% of Australian processed beetroot. In 1995, this region produced 32000 t. Processing, carried out by Golden Circle Ltd., carries a high value-added component. The processed product is valued at about \$33M pa.

For competitive processing and marketing, a consistent supply of quality beetroot is required from May until December. Efficient field production through high production per unit area and utilisation of the processing plant through an extended harvest period is required to maintain the viability of the Queensland industry.

Inconsistent quality of raw product, particularly at the extremities of the growing season is currently threatening the profitability of the Queensland industry. There are many factors that impede efficient production, but an important one for this industry is pre- and post-emergence losses and beet quality reductions caused by soil-borne diseases (O'Brien, *et al.*, 1998).

## 2. **Soil-borne Diseases of Beetroot**

A complex of fungal pathogens is known to be capable of causing root rot disease of beet both in Queensland and in other parts of the world. Early in the season, disease reduces plant stands and later infections attack developing beets, reducing quality and increasing processing costs. Short crop rotations and demands by processors to extend the harvest period into times of high disease risk further exacerbate the problem.

### 2.1 *The Pathogens*

In Queensland, three genera of soil-borne fungi *Pythium* spp., *Aphanomyces cochlioides* Dreschl. (Hutton and O'Brien, 1986) and *Rhizoctonia solani* Kuehn have been reported as the predominant soil-borne pathogens involved in the beetroot root rot complex. The same fungi have also been recognised as pathogens of beet for many years in other parts of the world. Coons *et al.* (1946) differentiated acute and chronic phases of this disease complex. In the acute stage, young plants are killed during germination or a week or two after emergence from the soil. The seedlings that survive the initial attack often show disease symptoms on their main or lateral roots that are characteristic of the primary pathogen involved. The symptoms in the later stages of growth are manifestations of the chronic phase.

#### 2.1.1 *Pythium*

The genus *Pythium* contains saprophytic, facultatively parasitic, obligately plant pathogenic, and mycopathogenic taxa (Kato *et al.*, 1990). Pathogenic *Pythium* species are important in both the acute and chronic phases of the disease, causing both pre- and post-emergence damping off problems in beet seedlings as well as root rots in older plants. Worldwide, twelve species of *Pythium* (including *P. ultimum* (Trow), *P. aphanidermatum* (Edson) Fitzp., *P. irregulare*, *P. debaryanum*, *P. salpingophorum*, *P. dissotocum*, *P. deliense* Meurs, *P. acanthicum* and *P. myriotylum* Drechs.) are known to attack beets (Windels and Kuznia, 1993). *Pythium ultimum* Trow and *Pythium aphanidermatum* (Edson) Fitzp. are generally considered to be the

most important pathogenic species. Serious losses due to *Pythium* have been reported in Minnesota and North Dakota (Kuznia and Windels, 1993; Brantner and Windels, 1998), Michigan (Mumford, 1968; Johnson and Halloin, 2000), California (Hancock, 1977); Colorado (Ruppel *et al.*, 1988); Arizona (Bretzel *et al.*, 1988); Finland (Vestburg *et al.*, 1982); England (Asher and Payne, 1989); Northern France and Yugoslavia (Asher and Payne, 1989).

In young seedlings *Pythium* spreads quickly from the roots to the stem, which becomes soft and watery before the seedling collapses. Root infection of mature plants causes death of sections of feeder roots. Excessive proliferation of secondary feeder roots may also be indicative of infection by *Pythium* (O'Brien, 1988). Aboveground symptoms also include wilting, yellowing and death of lower leaves (Williams and Duffas, 1986).

*Pythium* spp. are adapted to survive and proliferate in wet soils, particularly when moist conditions prevail for prolonged periods of time. The fungus spreads through the soil via motile zoospores. Thick-walled oospores enable long-term survival of the pathogen. In wet soils, seed treated with fungicides may not be able to withstand high disease pressure, resulting in poor stand establishment. Conditions that delay emergence, such as compacted soil or excessively deep planting, increase the time of exposure of germinating seed to possible infection by *Pythium*.

Relationships between soil temperature, soil moisture and organic matter are critical in the development of *Pythium* epidemics in the field (Hancock, 1977). Species-specific temperature requirements have been demonstrated in several studies (Hancock, 1977; Bretzel *et al.*, 1988; Kuznia and Windels, 1993; Raftoyannis and Dick, 2002). For example, in a field survey in North Dakota and Minnesota, Kuznia and Windels (1993) found that *P. aphanidermatum* caused more seed rot and damping off when soil temperatures increased from 14°C to 31°C, whereas the reverse relationship was observed for *P. ultimum*. Similarly, high soil temperatures (30 to 37°C during July and August) were identified as contributing to the uniformly low levels of *P. ultimum* in field soils of the San Joaquin Valley in California (Hancock, 1977), whereas the onset of disease caused by *P. aphanidermatum* in central Arizona coincided with the occurrence of temperatures of 27°C or more for at least 12 hours per day provided adequate soil moisture was available (Bretzel *et al.*, 1988). *P. aphanidermatum* caused significant damage of sugar beet roots at temperatures as high as 35°C in another recent *in vitro* study (Raftoyannis and Dick, 2002).

The importance of soil moisture for the onset of epidemics was demonstrated in California. Field populations of *P. ultimum* increased substantially at water potentials between -0.3 and -8 bars, whereas no population increases occurred under drier conditions. In this instance the disease increased rapidly in the autumn months (when temperatures were favourable) when moisture was available after irrigation (Hancock, 1977). In a similar study conducted in Arizona, the infection rate of mature sugar beet by *P. aphanidermatum* fell dramatically when the irrigation was cut off, even in the presence of soil temperatures conducive to infection (Bretzel *et al.*, 1988).

### 2.1.2 *Aphanomyces cochlioides*

*Aphanomyces cochlioides* causes an acute seedling blight and a chronic root rot of beets. This fungus causes only minimal pre-emergence damping off, but infection immediately after emergence produces a red discolouration of the cotyledons and young leaves. The fungus invades the hypocotyls of young seedlings, causing a brown discolouration that may extend up to the base of the cotyledons. The hypocotyls are weakened by this attack and the seedlings may fall over and die. Those that do survive are usually stunted. Below ground, the taproot also becomes withered, blackened and “wiry” in appearance. In a survey of 27 farms in the Lockyer Valley of SE Queensland, *A. cochlioides* was the pathogen most commonly isolated from diseased beetroot seedlings during 1979-1981 (Hutton and O’Brien, 1979). In Texas, this pathogen is also considered the primary cause of seedling disease in sugar beet (Rush and Vaughn, 1993).

Mature plants may also be affected and show yellowing and wilting of foliage and unthrifty top growth as well as black lesions on roots and large (up to 5cm diam.) depressed black lesions on the beets themselves (Hutton and O’Brien, 1986; Whitney and Duffus, 1986). Overseas, abundant lateral root development has been reported as a symptom of this disease, however in Queensland this symptom is more commonly associated with infection by *Pythium* spp. (O’Brien, 1988). The chronic phase of the disease has been reported in the United States, Canada, England, Germany and Japan as well as Australia.

This pathogen is similar to *Pythium* in its environmental requirements. High soil temperatures (20-28°C) and wet conditions favour infection. Plant infections are initiated by swimming zoospores that are released during wet weather or following irrigation. In a similar way to *Pythium*, this fungus also produces thick-walled highly resistant spores that allow long-term survival of the pathogen, even when the soil dries out. In England, the disease has been reported to occur most frequently in acid soils (Byford, 1975), however both in England and in parts of the United States, *Aphanomyces* is not an important cause of seedling disease, presumably because most seed is sown while soil is too cold to favour the pathogen. Increasing pressure on Queensland producers to sow beet crops during the summer months under warm, wet conditions, increases the risk of root rots by *Aphanomyces* and may explain the prevalence of this fungus in previous surveys of the Lockyer Valley (Hutton and O’Brien, 1986; O’Brien *et al.*, 1998).

### 2.1.3 *Rhizoctonia solani*

*Rhizoctonia solani* causes pre and post-emergence seedling death as well as a root, foliar and crown rot of beet plants. The fungus is found in agricultural soils throughout the world and it attacks many crop species, including beans, cabbage, lettuce, peas and potatoes. This pathogen is the most common and serious root disease of beet in the United States and it has been reported as an important disease in most other areas of the world where beet crops are grown (Whitney and Duffas, 1986). *Rhizoctonia* spp. have been classified by means of hyphal anastomosis reactions between isolates. In sugar beet anastomosis group (AG) 2-2 is the major AG world-wide causing crown and root rot.

As a seedling pathogen, *R. solani* causes some pre-emergence death but it inflicts most of its damage on seedlings that have already emerged. Infection is initiated below ground and extends up the hypocotyl, producing a dark pinched area near ground level (O'Brien *et al.*, 1998). The seedling often collapses at this point.

Later in the growing season, the same fungus may cause a crown rot on maturing beets. Initial diagnostic symptoms include brown to black cankers on petioles and crown tissues. Rotting proceeds towards the crown and roots of the plant and is accompanied by wilting and yellowing of the leaves (Abawi and Ludwig, 2000; Scholten *et al.*, 2001). Irregular, depressed dark lesions may develop on the surfaces of the beets. Fungal growth is often visible on the surfaces of these lesions (Whitney and Duffas, 1986).

*Rhizoctonia*, in the form of hyphae, survives in soil in colonised host tissues. Survival in the soil as sclerotia has also been reported in Japan (Hyakumachi and Ui, 1979) and in New York State (Abawi *et al.*, 1986). Under warm soil temperatures (25°C-33°C) the fungus grows through the soil and infects the plant through its leaves, petioles, crown and roots. The disease occurs in most types of soil, but is most severe in heavy poorly drained soils, especially in low areas where water collects (Whitney and Duffas, 1986). Since organic matter plays an important role in harboring the pathogen between crops, sowing too soon after plowing in a cover crop may lead to high levels of infection if the cover crop debris is not adequately broken down before the new crop is planted. This factor was identified as an important consideration for beetroot producers in the Lockyer Valley of SE Queensland (O'Brien *et al.*, 1998).

### **3. Control of the Soil-borne Pathogens of Beet**

#### **3.1 Pre-plant Treatment Options**

##### **3.1.1 Seed Treatments**

#### **Fungicides**

The three major soil-borne fungal pathogens that cause root rot in beetroot all cause losses early in the growth of the beet crop if environmental conditions are favourable. For this reason, control or reduction of the diseases through application of fungicides to the beet seed seems a plausible control method. In the case of beetroot however, the simultaneous association of three fungi with this disease in the field complicates fungicide control options, since fungicides frequently vary in their activity against different taxonomic groups of fungi. A single chemical with broad-spectrum activity against all the soil-borne fungi of beetroot is currently unavailable and is not likely in the foreseeable future (Leach and MacDonald, 1978). Knowledge of the identity of the pathogens involved is therefore important. A combination of two or more fungicides is often necessary to protect against the spectrum of anticipated pathogens. As an additional complication, the simultaneous application of several different fungicides to the seed increases the likelihood of toxicity to the young germinating seedling.

Since the mid 1970's trial work in several countries has been conducted to determine the best fungicide/s to use in the seed pellet to control these pathogens. Until 1981, most countries were relying on thiram to give control of both seed and soil-borne diseases. Thiram, a protectant fungicide, is relatively effective under low disease

pressure and is one of the least expensive fungicides available. Thiram is applied as a standard seed dressing to beetroot seed in Australia, however because of its mode of action, it only creates a localised zone of protection around the germinating seed. Thiram is also used in England to control deep-seated seed infection of *Phoma betae* in sugarbeet and beetroot seed. In this case, the fungicide (0.2%) is applied as a prolonged (24 hr) steep (Maude *et al.*, 1969). The steeping process not only provides good control of the pathogen, but also results in more rapid emergence (Durrant *et al.*, 1988).

Systemic fungicides, which can be absorbed during early seedling growth, should offer more extensive protection than thiram, particularly when infection takes place not through the root systems and the seed, but directly into the hypocotyl at some distance from the pellet, as is often the case with *Aphanomyces* infection. A range of systemic products have been examined for control of *Pythium* and *Aphanomyces* including captafol (Orthodifolotan), hymexazol (Tachigaren), metalaxyl (Apron, Ridomil) and propamocarb (Previcur) (Asher and Payne, 1989).

Metalaxyl has shown considerable promise as a beet seed dressing for control of *Pythium* spp both in Australia (O'Brien *et al.*, 1998) and overseas (Crosier *et al.*, 1986; Brantner and Windels, 1998). Since 1992, all sugarbeet seed sold to producers in the Red River Valley of Minnesota and North Dakota and in west-central Minnesota has been treated with metalaxyl (Brantner and Windels, 1998). Emergence of seedlings in this region is still often reduced by *Pythium* infections however, leading researchers to suggest and test the theory that variation in sensitivity of *Pythium* isolates to metalaxyl may be partly responsible (Brantner and Windels, 1998). They concluded, however, that the continued use of this fungicide as a seed treatment poses only limited risk for the development of metalaxyl-resistant isolates. This conclusion was based on the consideration that only a small amount of the fungicide is applied to the seed; it persists in the soil for only a short time and only a small proportion of the *Pythium* population in the soil is exposed to the treatment. However, they warned that if soil applications of metalaxyl are used in addition to seed treatments, the risk of selecting insensitive strains of the pathogen will increase and possibly reduce disease control.

Metalaxyl, although effective for *Pythium* control, shows no activity against either *Aphanomyces* or *Rhizoctonia*. For this reason, there has recently been a lot of interest in hymexazol as a seed treatment, since it has shown activity against both *Pythium* and *Aphanomyces* in trials in several countries (Byford and Payne, 1983; Payne and Williams, 1990; Heijbroek and Huijbregts, 1995).

In England and Finland, a rate of 10 g.a.i/kg of seed has been found to be optimal in field trials (Vestburg *et al.*, 1982; Byford and Payne, 1983). Since 1983, sugarbeet seed treated with hymexazol at 10g g.a.i./kg has been commercially available in England. Elsewhere in Europe the rates of hymexazol used for *Aphanomyces* and *Pythium* control vary widely, probably reflecting the different disease situations in the growing regions (Asher and Payne, 1989). In France, seed treated with 28 or 42 g.a.i/unit is available to growers in regions with serious problems. In The Netherlands, early in the season quantities of about 10 g.a.i/unit provide sufficient control, whereas by the end of the season rates of greater than 20 g.a.i/unit are necessary (Heijbroek and Huijbregts, 1995). Similarly, in England under conditions of severe disease pressure rates of 21 g.a.i/kg are required for maximum disease control (Payne and Williams, 1990).

Evidence from a large number of trials indicates that rates in excess of 20g.a.i/kg can slow emergence (Asher and Payne, 1989). If high rates are to be applied as single applications, as in England, any potential benefits must be balanced with the possible adverse effect of the chemical on seedling emergence. The alternative strategy, as adopted in France, is to provide seed treated with different rates for use where the disease is anticipated. This strategy may create logistic difficulties and would only be effective if sites prone to the disease and the environmental conditions favourable for its development each year can be predicted with some degree of accuracy (Asher and Payne, 1989).

Deviations between the actual rate of application and the target rate of application may occur and have been noted when hymexazol is incorporated in pelleted seed (Heijbroek and Huijbregts, 1995). These deviations have been attributed to the unstable nature of hymexazol and its tendency to degrade in the pellet. The composition of the pelleting mass and the addition of carbamate insecticides along with hymexazol may also influence the degradation. Heijbroek and Huijbregts suggest that an overdose of hymexazol should be applied to pelleted seed to compensate for the degradation and mention the importance of sowing the seed soon after pelleting to limit its extent (1995).

Several fungicides have been reported to show efficacy for control of *Rhizoctonia solani* when applied to beet seed. In the western United States, most beet seed is treated with pentanitrochlorobenzene (PCNB) (Quintozene) to protect against *Rhizoctonia* infection (Whitney and Duffas, 1986). Tolclophos methyl (Rizolex) has also been found to be effective against *R. solani* both in Australia (O'Brien *et al.*, 1998) and overseas. In a glasshouse assessment of fungicidal seed dressings, toclophos methyl gave complete protection against *Rhizoctonia* infection when it was applied as a slurry (2g/kg seed) to monogerm beetroot seed (O'Brien *et al.*, 1998). This chemical is currently registered for use on potatoes in Australia.

Pencycuron (Monceren) is another chemical with specific activity against *R. solani* (Yamada, 1986). In experimental trials, dry seed dressings of Monceren at 0.5-1.5g a.i./kg seed were promising, particularly when combined with Euparen (Yamada, 1986).

### **Seed Priming Treatments**

Seed priming is a pre-sowing treatment in which seed germination processes are initiated and stopped prior to radicle emergence. Seed priming typically increases the rate, uniformity, and percentage of seed germination, resulting in improvement of stand and often of yield. It is usually of greatest benefit under environmental conditions that are suboptimal for seed germination and emergence, such as cool, wet conditions (Osburn and Schroth, 1988). The duration of the priming treatment can range from less than 24 hours (Guedes and Cantliffe, 1980) to several weeks (Khan *et al.*, 1980). Various priming techniques have been developed including osmopriming, in which seeds are allowed to imbibe in an aerated osmotic solution such as polyethylene glycol (PEG) or inorganic salts. The osmotic potential of the solution regulates the amount of water uptake by the seeds, thus enabling the completion of the early phases of germination under controlled conditions (Osburn and Schroth, 1988). Osmoprimed seed is available commercially in the United States for some small seeded vegetables and also has been produced experimentally for a number of crops including sugar beet and some grain crops (Osburn and Schroth, 1988). Solid matrix



priming is a relatively recent development and uses a solid carrier to regulate water availability to seeds. This type of priming has been shown to be as good or better than osmopriming with regard to speeding seedling germination (Harman *et al.*, 1989; Rush, 1991).

Beetroot seeds are slow and often asynchronous in their germination. These characteristics interfere with the early establishment of a uniform, vigorous stand of seedlings, particularly in cold, wet soil (Khan *et al.*, 1983). Several U.S. studies have indicated that osmopriming beetroot seed in PEG improves the emergence rate, the final stand and total yield of beetroot crops (Khan *et al.*, 1983; Khan and Taylor, 1986).

In addition to improvements in germination rate and emergence, osmopriming with PEG or NaCl (Taylor *et al.*, 1985; Osburn and Schroth, 1988; Osburn and Schroth, 1989; Rush, 1992) and solid matrix priming with water and hydrous silicate clay (Rush, 1991; Rush and Vaughn, 1993) have both been reported to significantly reduce pre-emergence damping off in beets caused by *Pythium* spp. *Pythium* spores germinate in response to nutrients diffusing from imbibing seeds (Osburn and Schroth, 1988). Priming treatments leach soluble exudates from the seed and as a consequence seed colonisation by the pathogen is reduced when the seed is rewetted. In addition, indigenous bacteria, present on the seed coat, that multiply in the osmotic solution during seed treatment may prevent colonisation of the seed by *Pythium* spp. (Taylor *et al.*, 1985).

Studies on the effect of seed priming on post-emergence damping off caused by *Aphanomyces cochlioides* indicate that seed priming treatments are ineffective for control of this pathogen (Rush, 1992; Rush and Vaughn, 1993). In comparison, a Californian field study indicated that osmopriming sugarbeet seed in either PEG or NaCl gave comparable or better control of *Pythium* spp. than treating the seed with metalaxyl and when combined, the osmoprimed and fungicide seed treatments resulted in even greater disease reductions (Osburn and Schroth, 1989). In the same study, pre-emergence damping off caused by *Rhizoctonia solani* was also reduced by osmopriming. This pathogen is not controlled by metalaxyl and therefore planting osmoprimed seed in soils known to be infested with *R. solani* may offer additional protection against this pathogen when the standard fungicide seed dressings are inadequate.

Although the efficacy of osmopriming beet seed has been demonstrated in the numerous studies discussed above, several technical difficulties have been encountered with current methods. Osmotic solutions require continuous aeration and a large volume of priming solution is required per quantity of seed. As well as this, the use of high concentrations of PEG in solution has low oxygen solubility and diffusivity (Mexal *et al.*, 1975). These complications will need to be adequately addressed if osmopriming of beetroot seed is to be commercially feasible.

### **Biological Seed Treatments**

Most of the available literature on control of soil-borne beet pathogens with biological treatments relates to the biological control of *Pythium ultimum*. Only very limited consideration has been given to the possibility of biological control of either *Aphanomyces cochlioides* or *Rhizoctonia solani* in beet crops. Indeed, as for

fungicide seed treatments, the discovery of a single broadspectrum biological control agent with activity against the three major soil-borne pathogens of beets is unlikely.

*Pythium ultimum* was considered by Osburn *et al.*, to be an ideal candidate for biological control because the susceptible period for the host is relatively short and high populations of the biological control organism would not be required for extended periods of time (1989). They identified two bacterial strains: *Pseudomonas fluorescens-putida* (R20) and *Pseudomonas putida* (ML5), which, when inoculated onto sugarbeet seed resulted in marked reductions in colonisation by *P. ultimum* and gave comparable control to fungicides (metalaxyl or fenaminosulf) in suppressing damping off by *P. ultimum* in greenhouse experiments. Williams and Asher (1996) also assessed potential bacterial biological control agents for *P. ultimum* and *A. cochlidioides*. In this case, however, the level of protection fell short of that achieved with standard fungicide seed treatments. In other studies, *Pythium oligandrum* was identified as a potential biological control agent of *P. ultimum*, *Aphanomyces cochlidioides* and *Rhizoctonia solani* in sugar beet, however control levels provided by this organism were inferior to those achieved with fungicide drenches and failed to control any of the pathogens when the disease pressure was high (Whipps *et al.*, 1993). In addition, the control achieved with *P. oligandrum* was shown to vary with the type and amount of inoculum applied as well as the method of application, and only controlled damping off over a narrow pH range (pH 7.0-7.5) (Holmes *et al.*, 1998).

*Trichoderma hamatum* was also shown promise as a biological control agent for *Rhizoctonia solani* in beet seed (Lewis and Papavizas, 1987a; 1987b), reducing the survival of the pathogen by about 90% after one week. In this instance, however, the timing of application of the biological control agent proved to be important for good control of the pathogen. If the control agent was added to soil prior to the presence of the pathogen, the pathogen survival was not reduced. Also, the age of the inoculum greatly affected the ability of *T. hamatum* to limit survival and growth of the pathogen in soil. Young, actively growing inoculum was effective whereas inoculum consisting mainly of resting spores was not (Lewis and Papavizas, 1987a). An alginate pellet formulation of *T. hamatum* was developed to assist with application, however the storage of the pellets for more than 6 weeks at 5 or 25°C reduced their effectiveness against *R. solani* (Lewis and Papavizas, 1987b).

The literature would suggest that at this stage, seed applications of biological control agents for control of soil-borne beet pathogens is unlikely to represent a feasible commercial proposition since the control levels achieved are generally inferior to those currently provided by fungicides, and environmental variables markedly influence the efficacy of biological treatments.

## **Fumigation**

Methyl bromide (CH<sub>3</sub>Br) has for many years been the most widely used and effective fumigant worldwide. This compound will be phased out of use by 2005, under the Montreal Protocol, because it is an ozone depleting chemical (Ohr *et al.*, 1996). Assessment of potential replacements for methyl bromide has been the focus of much research effort. In beet production, aside from efficacy constraints, many fumigants are also not economically feasible (Harveson and Rush, 1994). It seems likely that a beneficial response to fumigation would need to be observed across several cropping

cycles and/or to crops grown in rotation with beet for these economic constraints to be overcome.

Metham sodium is currently the only commercially available alternative to methyl bromide and it is widely used in Australia and overseas for control of a range of soil-borne diseases in horticultural crops including *Pythium* spp. (Roberts *et al.*, 1988; Stephens *et al.*, 1999) and *Rhizoctonia solani* (Wicks *et al.*, 1996; Stephens *et al.*, 1999). Unfortunately, metham sodium is prone to biodegradation (Matthiessen, 1999). Biodegradation is a phenomenon whereby soil micro-organisms that metabolise a pesticide are stimulated to dominate the soil microbial population by repeated applications of the chemical. This is particularly a problem with modern pesticides because they are not halogenated and are therefore more prone to breakdown via microbial activity (Matthiessen, 1999).

Other potential fumigants have been trialed but as yet, remain uncommercial. Harveson and Rush evaluated the fumigant Telone II (1,3-dichloropropene) for control of soil-borne pathogens of sugar beet because of its cost efficiency and efficacy at low rates. Yields were significantly increased in fumigated plots in a field study (1994). Methyl iodide has also been evaluated as a potential methyl bromide replacement and was found to be as effective or more effective than methyl bromide as a fumigant for control of soil-borne fungi, including *Rhizoctonia solani* (Ohr, *et al.*, 1996; Becker, *et al.*, 1998). Unfortunately, the relative cost of methyl iodide compared to other fumigants was not discussed in these publications and would need to be investigated in any future consideration of this product. Benzaldehyde was also shown to reduce the viability of *R. solani* and reduce populations of *Pythium aphanidermatum* in a laboratory study (Wilson *et al.*, 1999). This chemical is considered a desirable alternative to methyl bromide because it is inexpensive and its breakdown products (CO<sub>2</sub> and H<sub>2</sub>O) are harmless to the environment.

### **Biofumigation**

The problem of biodegradation of metham sodium and the relatively high cost of this chemical has prompted researchers to investigate other non-synthetic methods of fumigation. The term biofumigation has been coined and adopted to describe the concept of using *Brassica* plants to control soil-borne pests and diseases in other crops (Matthiessen, 1994).

The ability of brassica amendments to reduce some fungal and nematode populations has been attributed to their production of gluconsinolates (Lewis and Papavizas, 1971b). These compounds are released when *Brassica* plants are physically broken up and during the breakdown of *Brassica* residues in soil. Gluconsinolates are precursors of isothiocyanates. Metham sodium is an isothiocyanate (Matthiessen, 1994).

Biofumigation effects on many soil-borne pathogens have been reported in a range of cropping systems. For example, dried cabbage residue reduced soil populations of *Fusarium oxysporum* f.sp. *conglutinans* (Ramirez-Villapudua and Munnecke, 1988) and superior growth of wheat following *Brassica* crops was attributed to suppression of soil-borne fungal pathogens, including *Rhizoctonia solani* (Kirkegaard *et al.*, 1996). Damping-off of sugarbeet caused by *Aphanomyces cochlioides* was reduced by soil amendments of eight *Brassica* species (mustard, brussel sprouts, kale, collards, cress, cabbage, turnip and kohlrabi), in a glasshouse study (Lewis and Papavizas,

1971a). Similarly, *Aphanomyces euteiches*, the causative agent of root rot of pea, was suppressed by volatiles, released during the breakdown of cabbage tissue in the laboratory (Lewis and Papavizas, 1971b). Field experiments in which white mustard (*Sinapis alba*) grown after peas significantly reduced root rot (*A. euteiches*) in pea plants grown the following year, further supported these early glasshouse experiments (Muehlchen *et al.*, 1990).

Although there are numerous reports in the literature highlighting the benefits of biofumigation, several studies investigating biofumigation for control of soil-borne *Pythium* diseases have not been promising (Kirkegaard *et al.*, 1996; Stephens *et al.*, 1999). Recently, *Pythium* spp. have been shown to be relatively insensitive to volatiles from mustard (Wong and Kirkegaard in Matthiessen and Kirkegaard, 1996).

The degree of fungal suppression by *Brassica* crops depends on the species, age and type of *Brassica* tissue, which influences the type and concentration of glucosinolates evolved; as well as the sensitivity of the pathogen. Recently in Australia, more than 100 different brassicas were assayed for glucosinolate production (Sarwar and Kirkegaard in Matthiessen and Kirkegaard, 1996) and seed of the most promising types is now being commercially produced for use in biofumigation.

### **Crop Rotations**

The potential benefits of rotating beet crops with *Brassica* species have been already been discussed under the section on Biofumigation (section 3.1.1, pg 16).

When beet is grown on the same ground more than once in 3 years, it generally does not reach its full yield potential (Schauffle and Winner, 1979). Yield losses have been attributed to increases in soil-borne pathogen populations with increasing frequency of beet cultivation. For this reason, 3-5 year rotations out of beet is standard industry practice in beet cropping regions in the US (Herr, 1987; Rush and Winter, 1990).

Preceding cropping sequences have been shown to influence levels of disease caused by *Pythium* spp., *Aphanomyces cochlioides* and *Rhizoctonia solani* in beet crops in numerous pot and field studies.

In a Finnish glasshouse study, leguminous plants such as pea, field bean or red clover tended to raise the inoculum density of *Pythium* in soil and keep the level of damping-off unchanged or slightly elevated, when compared to continuously cultivated sugarbeet. In comparison, gramineous plants had the opposite effect, increasing emergence and the numbers of healthy plants and decreasing the inoculum density of *Pythium*. In this study, the influence of preceding crops on different soil types varied greatly, with sandy soils being more prone to increases in *Pythium* populations (Vestburg, 1987).

Losses due to *Aphanomyces* are most severe when beets are grown immediately following lucerne (Deems and Young, 1956; Mumford, 1968; Schneider and Robertson, 1975). Striking effects on disease incidence resulted from cropping soil thoroughly infested with *A. cochlioides* to lucerne, corn, oats and sugarbeet in an Ohio field trial. Sugarbeets maintained a 95-100% inoculum potential throughout the season. Cropping to corn and oats reduced disease. Corn was the most effective rotation in terms of *Aphanomyces* control, decreasing disease incidence to 10% after three months and maintaining disease at low levels. Oats decreased disease to 25%

during the first four months, however disease levels increased markedly once the oats were “ploughed down”. Lucerne did not decrease *Aphanomyces* incidence to levels below those in soils continuously cropped with sugarbeet (Deems and Young, 1956).

Crown rot caused by *Rhizoctonia solani* was also more severe where beets followed lucerne than where beets followed corn, soybeans or navybeans, in 5 year field rotations in Michigan (Schneider and Robertson, 1975). Similarly, cotton, fallow and sunflower were superior to lucerne as rotations to precede beet in *Rhizoctonia* infested soil in Texas (Rush and Winter, 1990).

In terms of *Rhizoctonia* control, tomato is also a poor crop to plant before beet, as is potato. High *R. solani* populations were shown to develop saprophytically on tomato crop residues in an Ohio field trial. Tomato is not considered to be a particularly good host for *R. solani*, however, after harvest the fruit and vines support the pathogen, allowing it to persist until the following spring (Herr, 1987). Two year rotations between beet and potato were also favourable for *R. solani* survival and development, presumably because the pathogen is able to survive between crops on undecomposed potato debris (Schuster and Harris, 1960).

### 3.2 *Post-plant Treatment Options*

#### **Fungicides**

The vast majority of research on fungicide treatments for the soil-borne pathogens of beetroot has been directed towards pre-plant seed applications. Since much of the damage by these pathogens is initiated during the early stages of plant development, this concentration of research effort is understandable since seed applications represent one of the best options for combating early infections. The main pathogens of beet do, however, cause appreciable losses and quality reductions of mature beets under appropriate environmental conditions, and hence fungicide applications following seedling emergence may offer some benefit.

In Australia, no systemic fungicides are currently registered for use on beetroot as post-emergence treatments. In the US, metalaxyl (Ridomil) is available for use as a supplemental in-furrow treatment applied at planting, however it is not commonly applied because early *Pythium* spp. infections are normally adequately controlled by seed dressings (Brantner and Windels, 1998).

A range of chemicals have been trialed experimentally for control of late *Rhizoctonia solani* infections. In three year field trials, single applications of triadimefon, triadamenol, the experimental protectant fungicide Bay NTN 19701 and the experimental systemic fungicide Bay HWG 1608 suppressed *Rhizoctonia* root rot of sugarbeets. Earlier applications, applied at the cotyledon to 4-6 leaf stage tended to be more effective and gave season-long protection (Ruppel and Hecker, 1987).

Triadimefon was also promising when applied to crowns and bases of plants in field plots artificially infected with *R. solani* (Schneider and Potter, 1983). In these experiments, chlorothalonil (2.49-2.64 kg/ha) and triphenyltin hydroxide (TPTH) (0.10-0.33 kg/ha) applications also suppressed *Rhizoctonia* infections. Preliminary assessments of PCNB and pencycuron were also promising, with pencycuron giving outstanding control of *Rhizoctonia* when applied as a crown application to sugarbeet. (Schneider and Potter, 1983).

More recently, the new strobilurin chemical azoxystrobin was effective in reducing *Rhizoctonia solani* infections in a number of crops including sugarbeet (Zens, *et al.*, 1999) and celery (O'Neill *et al.*, 1999). This chemical warrants further assessment for control of other beet pathogens.

### **Host Resistance**

In the U.S., beetroot breeding programs have been conducted at the University of Wisconsin-Madison and New York State Agricultural Experiment Station, Geneva. Unfortunately, only limited reference to variety releases from both programs could be found in the literature (Goldman, 1996; Marx, 1986). The inbred lines released from the Wisconsin breeding program have been used in the production of hybrid beet seed throughout the world. A list of releases from this program has been published (Goldman, 1996), however it gives no information on the relative susceptibility of each variety to soil-borne pathogens. A principle objective of the Geneva breeding program was to develop breeding material with tolerance or resistance to root rot. Some advanced breeding lines from this program have shown evidence of tolerance to *Pythium* root rot in field evaluations (Marx, 1986), however it is unclear at this stage, due to a paucity of information in the literature, whether any of these lines are now commercially available.

### **Irrigation Management**

Wet soils favour the development of root rot epidemics in beets. There has been little consideration in the literature of the possibility of manipulating irrigation for the purpose of disease control in this crop. Piccinni and Rush found that sugar beets irrigated every 4 weeks had the lowest disease incidence and highest yield when grown in soils infested with Beet necrotic yellow vein virus (BNYVV) and Beet soilborne mosaic virus (BSBMV). In this study, sugarbeets irrigated every 2 or 3 weeks had significantly higher levels of disease than those irrigated every 4 or 5 weeks (2000).

Positive correlations between levels of *Aphanomyces* root rot and soil matric potential was also observed in a glasshouse study (Rush and Vaughn, 1993). In this instance, seedlings in pots irrigated only at pre-planting were significantly less diseased than those irrigated for emergence after planting.

In reality, manipulation of irrigation as a disease management tool in commercial cropping situations is unlikely to be a feasible option, however these studies have been mentioned as they help to highlight the importance of soil moisture in the development of soil-borne disease epidemics in beet.

## CHAPTER 2: Identification and Characterisation of Soil-borne Pathogens

### Introduction

In Australia, 3 genera of soil-borne fungi, *Pythium*, *Aphanomyces cochlioides* and *Rhizoctonia solani*, have been reported as the predominant soilborne pathogens involved in a beetroot root rot complex since the 1980s (Hutton and O'Brien, 1986; O'Brien *et al.*, 1998; Tesoriero, 1993). The same 3 genera have also been recognised for many years as pathogens of beet in other parts of the world (Mumford, 1968; Vestbury *et al.*, 1982; Whitney and Duffas, 1986; Asher and Payne, 1989). Since the mid-1990s, when soilborne diseases were last studied in detail in Australia, the severity of disease losses has increased substantially on Australian beet farms (Figure 1). In this project, we sought to understand the nature of this increase. We collected samples of diseased beets and soil samples from affected blocks, and isolated and characterised the organisms responsible for beet diseases.

### *Disease Indexing of Beetroot Soils*

#### Materials and Methods

We used a modified version of the beetroot disease indexing test developed by O'Brien *et al.* (1998) to determine the disease potential of soils collected from beet farms throughout south-east Queensland. Fungi recovered from soils were identified to genus level by morphological features using light microscopy, and some were further characterised to species level by Dr Paul Scott (formerly of The University of Queensland, Gatton) via molecular analysis (refer to page xxx). The pathogenicity of the fungi (their ability to cause disease to beetroot) was determined in glasshouse bioassays with beetroot seedlings (refer to page xxx).

For the disease indexing tests, soil samples were collected from 39 beetroot blocks. For each sample, 20L of soil was collected by bulking together approximately 40-50 small sub-samples collected in a W pattern over each field from the top 10cm of soil. Each sample was thoroughly mixed and large clods removed. A sub-sample was autoclaved to provide a sterile control, which was used in 2 pots. The remaining soil was used to fill 20 pots.

In each pot a 30mL layer of medium grade (grade 3) vermiculite was covered with 100mL of soil. The soil was watered and then 12 beetroot seeds (cv. Detroit Dark Red) were sown in each pot. A layer of fine grade (grade 1) vermiculite was then added to cover the soil. An additional 2 pots of sterile UC mix were prepared for each test.

The test seed was left untreated, or was dressed with one of three fungicide treatments:

- a) Tachigaren 70 WP (7g /kg seed)
- b) Rizolex WP (8g/kg seed)
- c) Rizolex WP (8g/kg seed) + Apron (1mL/kg seed)



**Figure 1:** Symptoms of soilborne diseases of beetroot in south east Queensland



Wilting of plants due to *Rhizoctonia*



Plants collapse before harvest



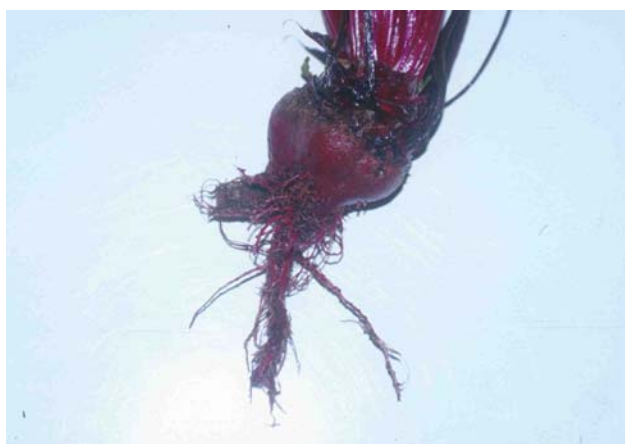
“Damping off” soon after emergence



Poor taproots of infected seedlings (left)  
Healthy seedlings (right)



Misshapen roots can be due to early disease infection or poor varietal characteristics



“Hairy” roots may indicate infection by *Pythium*



*Rhizoctonia* infection of mature beets



*Sclerotium* causes secondary rot of mature beets



Five pots were sown with seed dressed with each fungicide and 5 with untreated seed. Untreated seed was sown into the pots of sterile soil and UC mix. After sowing, the pots were kept in a glasshouse, they were watered twice daily and fertilised with a general liquid fertiliser once per week.

After the seedlings started to emerge, the pots were assessed twice weekly. The total number of seedlings and the number of dead seedlings in each pot was recorded and the dead seedlings were removed. Isolations on non-selective culture media (1/2 strength potato dextrose agar) were completed for a selection of the seedlings removed from the pots, so that the organisms responsible for the seedling death could be identified. Information about sample sites is given in Table 1:

**Table 1:** Cropping history and block location details for a selection of blocks sampled for soil indexing tests

<b>Grower</b>	<b>Sample</b>	<b>Location Description</b>	<b>Collection Date</b>	<b>Time Planted to Beetroot</b>	<b>Time in Fallow</b>	<b>Time Planted to other Crops</b>
John Brent	A	Macs Farm Block 4. Northern side of block in line with middle of shed on southern side	18/06/03	2 x 16 weeks	20 weeks	-
John Brent	B	Home Farm Block 1. First block on right side of Brents Rd. Sampled in line with pump 10m into block	18/06/03	16 weeks	5 months	3 months (forage sorghum)
Moira Farms	A	Sample taken 20m in from headland at the end of the block directly behind sheds	30/04/03	6 months	6 months	-
Moira Farms	B	Sample taken 10m in from roadway and in line with the house on the hillside on the opposite side of the road	30/04/03	1 month	11 months	-
Glenn Lerch	A	Shed Block 4. First block past dam, sampled 10m in from road end	22/04/03	6 months	5 months	1 month (sorghum)
Glenn Lerch	B	Creek end of farm. Sampled 20m from NE corner of house	22/04/03	6 months	4 months	2 months (millet)
Peter Lerch	A	Sample taken in line with the two closely spaced power poles and 10m in from the headland	1/05/03	-	5 months	7 months (sorghum and sweetcorn)
Peter Lerch	B	Sample taken 20m into the block, directly in front of house	1/05/03	6 months	6 months	-
Litzow/Reddacliffe	A	Sampled 20m on western side of hydrant located in middle of the block	19/06/03	4 months	2 months	6 months (sorghum)
Litzow/Reddacliffe	B	Sampled 20m in from end of block & 20m to the south of the pump in the field opposite that of Sample A	19/06/03	5 months	7 months	-
Neumann	A	Home farm in line with third hydrant past the end of the sheds and approx. 20m in from roadway	25/03/03	5 months	7 months	-
Neumann	B	Sample taken approx. 20m in from pump on the side of Qualischefski Road	25/03/03	2.5 months	3 months	6.5 months (onions)
Voight	A	Sampled from middle of the block in line with the pump shed	26/05/03	not determined	not determined	ND
Voight	B	Sampled 10-20m into the block in line with the first power pole from the creek end	26/05/03	not determined	not determined	ND
Zelinski	A	Sampled half-way between power pole and pump shed	27/02/03	32 weeks	5 weeks	sweetcorn
Zelinski	B	Block 29. 10m west of second hydrant from creek	27/02/03	-	6 months	potato

## Results

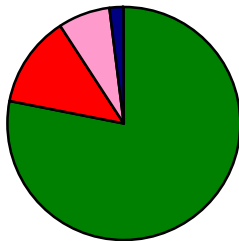
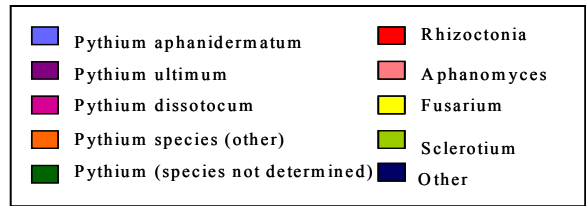
A summary of disease severity information for the soil samples is given in Table 2:

**Table 2:** Severity of disease that developed in soil indexing tests

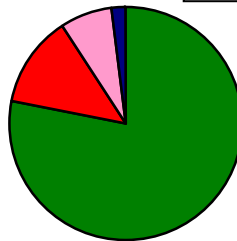
Soil Sample	Location Description	No. dead seedlings removed	% of seedlings that died
Moira #4	Block at Laidley behind John Berlin's house	368	92
Neumann #2	Site of variety trial 2, 2001	400	89.89
Hauser	East side of house & sheds, Gatton - Forest Hill Rd	351	84.58
Neumann #3	Qualischefski's block	369	81.1
Litzow #1	First field behind Voight's, Gatton - Forest Hill Rd	351	78
Voight #2	Off Gatton - Forest Hill Rd (opposite Litzow House)	297	67.5
Voight #3	Off Gatton - Forest Hill Rd (opposite Litzow House)	323	59.81
Voight #1	Site of fungicide trial 1, 2001	254	57.08
G.Lerch #4	Block on east side of Forest Hill - Blenheim Rd.	276	56.33
Neumann #1	Site of variety trial 1, 2001	295	56.19
G. Lerch #3	West side of Forest Hill - Blenheim Rd	216	46.45
Neumann	Sample A	231	45.74
Moira #2	Van de Weyer Rd (Forest Hill)	214	40.76
Zelinski	Site of commercial scale variety evaluation 2002	192	40.42
Litzow #2	Site of variety trial 2002	165	38.82
Litzow #3	First block on Hall Rd, Forest Hill.	180	38.71
Voight #4	Block Gatton - Forest Hill Rd.Opposite Litzows house	150	37.5
Moira#1	Site of fungicide trial 2, 2001	178	37.08
Neumann	Sample B	151	35.95
Zelinski	Sample A	148	31.49
Zelinski	Sample B	134	27.63
Brent	Sample B	114	25.33
Litzow	Sample A	109	23.7
Brent	Sample A	109	22.24
P. Lerch	Corner of Forest Hill - Blenheim & Woodland Rds	90	21.95
G. Lerch	Sample A	85	19.54
G. Lerch	Sample B	78	18.35
Moira Farms	Sample A	84	18.06
P. Lerch	Sample A	88	17.96
P. Lerch	Sample B	70	16.28
Moira Farms	Sample B	78	16.25
G.Lerch #5	Lesters Lane (Laidley South)	53	12.62
Voight	Sample B	52	11.3
Moira #3	Site of commercial scale variety trial 2002	44	9.89
G. Lerch #2	Site of fumigation trial 2002. After fumigation	27	5.74
Litzow	Sample B	23	4.79
Brent	Home farm block 5	18	4.44
Voight	Sample A	13	3.17
G. Lerch #1	Site of fumigation trial 2002. Before fumigation.	14	2.83

**Figure 2:** Fungi isolated from diseased seedlings grown in disease indexing soil samples

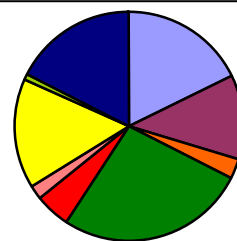
**Sites with Extreme Disease Potential**



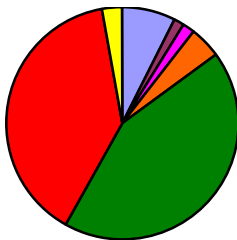
Moira # 4



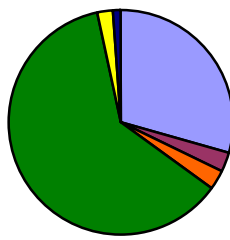
Neumann # 2



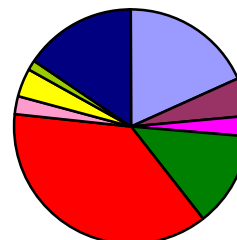
Hauser



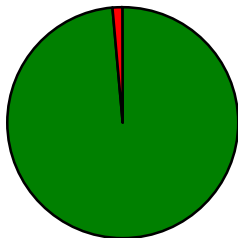
Neumann # 3



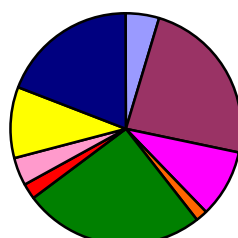
Litzow # 1



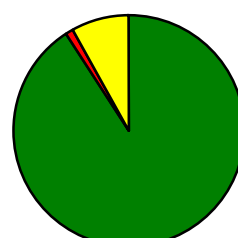
Voight # 2



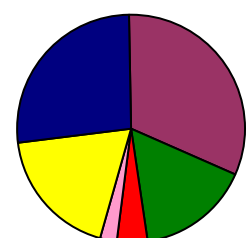
Voight # 3



Voight # 1

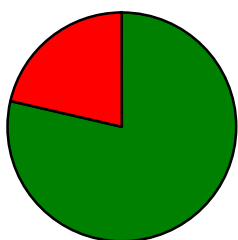


G. Lerch # 4

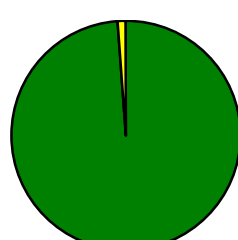


Neumann # 1

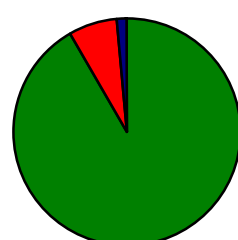
**Sites with High Disease Potential**



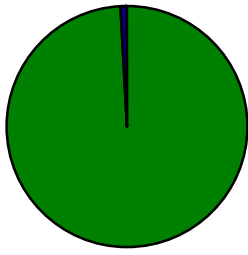
G. Lerch # 3



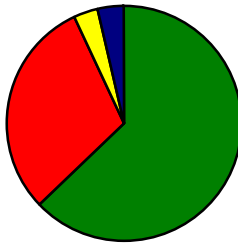
Neumann A



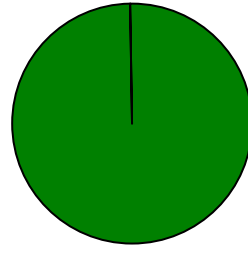
Moira # 2



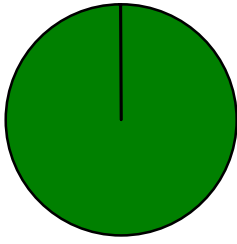
Zelinski



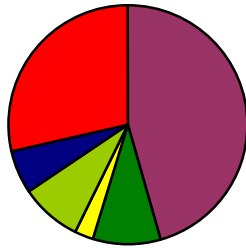
Litzow # 2



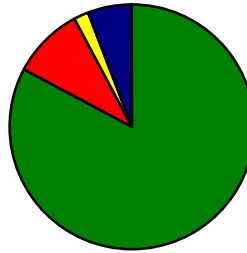
Litzow # 3



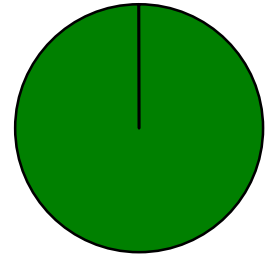
Voight # 4



Moira # 1

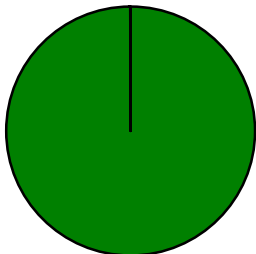
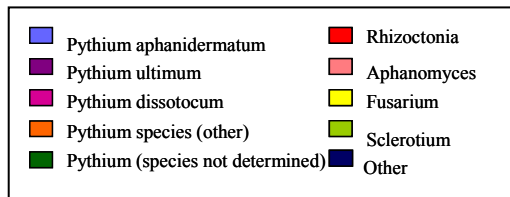


Neumann B

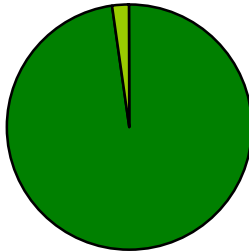


Zelinski A

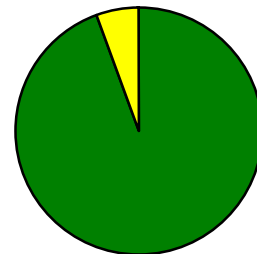
**Sites with Moderate Disease Potential**



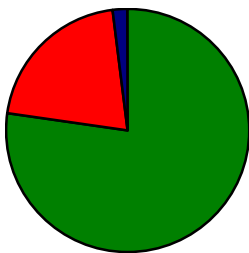
Zelinski B



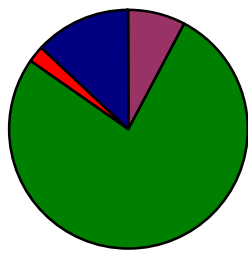
Brent B



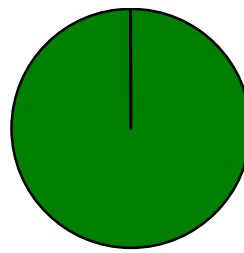
Litzow A



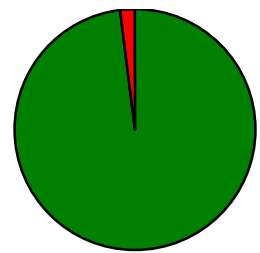
Brent A



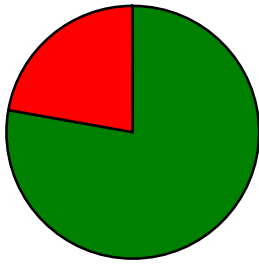
P. Lerch



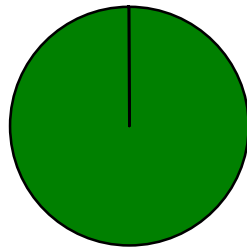
G. Lerch A



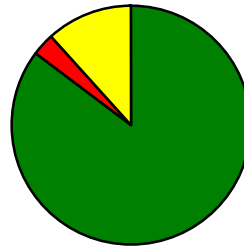
G. Lerch B



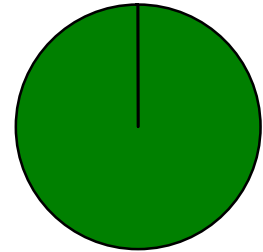
Moira A



P. Lerch A

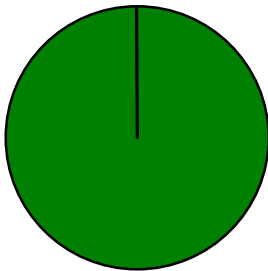
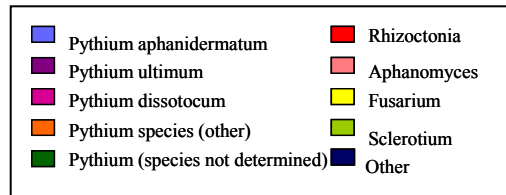


P. Lerch B

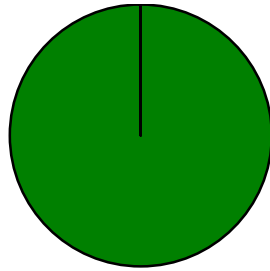


Moira B

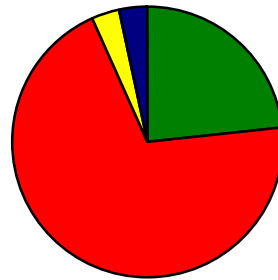
**Sites with Low Disease Potential**



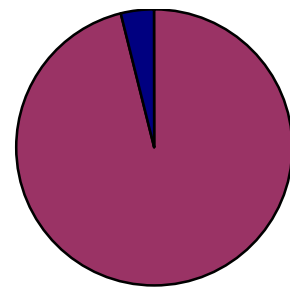
G. Lerch # 5



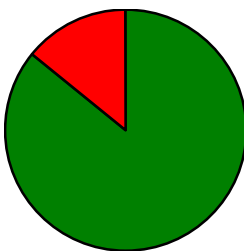
Voight B



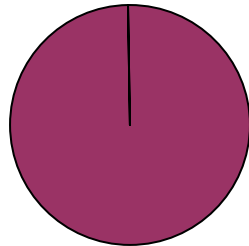
Moira # 3



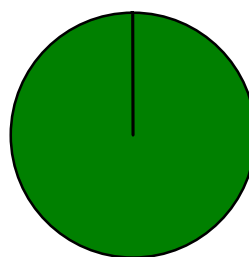
G. Lerch # 2



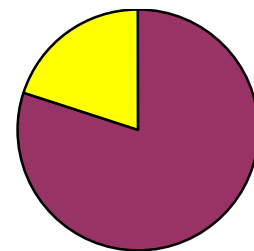
Litzow B



Brent



Voight A



G. Lerch # 1

The disease potentials of the soils varied widely, with up to 92% of seedlings dying in the most extreme instance (Moira #4) and losses as low as 2.83% in the best block (G.Lerch # 1). It is worth emphasising, that the indexing tests give an indication of the potential of a disease epidemic developing **if environmental conditions are favourable**. The soil indexing tests are completed under conditions highly conducive to disease infection (relatively high soil temperatures, and continual high soil moisture), so that disease development is maximised. A site with a high disease potential will not develop a disease epidemic unless the environmental conditions are conducive to

infection at the time a susceptible crop is planted. *Pythium* species and *Rhizoctonia* were the most commonly recovered organisms from the dead plants in the soil indexing tests (Figure 2).

**Figure 3:** The Apron + Rizolex seed dressing gives the greatest disease control in an indexing test on a soil containing pathogenic *Pythium* and *Rhizoctonia*



### ***Identification of species of Pythium***

Traditionally, *Pythium* spp. have been identified by differences in morphological features. This method is time-consuming, cumbersome and sometimes open to subjective interpretation. More recently, DNA-based methods have been developed to identify the relevant *Pythium* spp. In contrast, DNA-based methods are rapid and unambiguous, and in many cases do not rely on the culture and propagation of the suspected pathogen. We provided 137 cultures of *Pythium* to Dr Paul Scott (University of Queensland, Gatton) for DNA analysis. The cultures selected were from 15 sites and were isolated from the soils in index tests as well as from ad hoc. samples of diseased beetroot. A more detailed account of this work is soon to be published in *Australasian Plant Pathology* (Scott *et. al*, in press.).

Briefly, 3 predominant *Pythium* species were identified: *Pythium aphanidermatum*, *P. ultimum* and *P. dissotocum*. The majority of the isolates (approx. 51%) were *P. ultimum*, 30.7% were *P. aphanidermatum* and 6.6% were *P. dissotocum*.

## ***Pathogenicity Testing***

### **Materials and Methods**

Not all fungi associated with diseased plants may be responsible for causing the disease symptoms. For this reason, we needed to test if the fungi we isolated from the dead seedlings in our index tests and from other plant samples, were pathogenic (able to cause disease) on beetroot plants. To do this we inoculated healthy beet plants in the glasshouse with fungal inoculum prepared from pure cultures, and assessed the plants for disease symptoms.

To prepare inoculum, 14-day-old cultures grown on half-strength PDA at 25°C were flooded with de-ionised water and scraped with a glass rod. A 200mL inoculum suspension was prepared from each culture. Beetroot seedlings (cv. Detroit Dark Red) were grown in 70 mm plastic pots filled with sterile UC mix. Four seeds were sown per pot and pots were watered twice daily and fertilised with Aquasol<sup>®</sup> liquid fertiliser twice per week. No fungicides were used on the seedlings during the tests.

To test the pathogenicity of each fungal isolate, 14-day-old and 28-day-old seedlings were drenched with inoculum (50mL per pot). Control plants were drenched with de-ionised water (50mL per pot). All pots were randomly arranged on benches in a glasshouse and the plants were assessed for disease symptoms two and four weeks after drenching. At each assessment, the total number of seedlings and number of sick and/or dead seedlings was counted in each pot. Sick and dead seedlings were removed after each assessment.

Root/hypocotyl tissue sections from a selection of symptomatic seedlings were surface sterilised in a 1% sodium hypochlorite solution and cultured on PDA. Resulting colonies were examined microscopically to confirm they were morphologically identical to the cultures used to produce the inoculum suspensions.

### **Results**

Species of *Pythium* and *Rhizoctonia* were the most common pathogens identified. Of 275 *Pythium* isolates, 157 were pathogenic to beetroot seedlings, and for *Rhizoctonia*, 59 isolates of 78 were pathogenic (Figures 4,5 & 6). *Pythium aphanidermatum* isolates were more pathogenic to younger seedlings. Only 3 of 34 *P. aphanidermatum* isolates killed greater than 50% of plants inoculated at four weeks of age compared to 13 of 34 that killed greater than 50% of plants that were inoculated at one week of age. The pathogenic *P. ultimum* isolates were equally pathogenic to plants regardless of the age at which the plants were inoculated.

Pathogenic *Fusarium* isolates were also recovered, but were far less frequent (18/71). *Fusarium* was more often a saprophyte of diseased tissue than the causal agent of the disease. *Sclerotium* was recovered occasionally from some sites. Usually it was associated with beets that were growing poorly because of attack by other pathogens or extreme growing conditions (lack of water/high temperatures). In pathogenicity tests only 1 of 9 *Sclerotium* isolates was pathogenic, and this isolate was only weakly pathogenic to young plants. A suite of other fungi belonging to the genera *Macrophomina*, *Bipolaris*, *Exserohilium*, *Phoma*, *Helminthosporium*, *Colletotrichum*,



*Rhizopus* and *Nigrospora* were also recovered from beet soils and symptomatic plants. None of these were pathogenic to beet seedlings in pathogenicity tests.

**Figure 4:** Seedlings infected by a pathogenic *Rhizoctonia* (right) have blackened, rotted roots compared to healthy seedlings (left)



**Figure 5:** *Pythium aphanidermatum* is highly pathogenic to young beetroot seedlings



**Figure 6:** Not all *Pythium* isolates associated with beetroot are pathogenic. Plants inoculated with non-pathogenic *Pythium* remain healthy (left), while a pathogenic *Pythium* isolate kills young seedlings (centre). Uninoculated control (right)



A summary of the major pathogens associated with specific beetroot blocks is provided in Table 3.

**Table 3: Pathogenic fungi associated with specific blocks of beetroot**

Sample	Location Description	Pathogenic Fungi Found	Pathogenicity <sup>1</sup>	Main Pathogens at Site <sup>2</sup>
Brent	Home farm block 5	<i>Pythium ultimum</i>	moderate-high on both young and older plants	<i>Pythium ultimum</i>
Moira # 1	Site of Fungicide trial 2, 2001	1. <i>Rhizoctonia</i> 2. <i>Pythium ultimum</i> 3. <i>Pythium</i> (species not determined)	1. moderate-high on both young and older plants 2. high on young plants, weak on older plants 3. moderate-high on young plants, non-pathogenic to older plants	<i>Rhizoctonia</i> <i>Pythium ultimum</i>
Moira #2	Van de Weyer Rd (Forest Hill)	1. <i>Rhizoctonia</i> 2. <i>Pythium</i> (species not determined)	1. high to young plants, weak-moderate to older plants 2. moderate-high on young, non-pathogenic to older plants	<i>Pythium</i> (species not determined)
Hauser	East side of house & sheds, Gatton - Forest Hill Rd	1. <i>Pythium aphanidermatum</i> 2. <i>Pythium ultimum</i> 3. <i>Rhizoctonia</i>	1. high to young plants, moderate to older plants 2. moderate to young plants, weak-moderate to older plants 3. moderate to young plants, weak to older plants	<i>Pythium aphanidermatum</i> <i>Pythium ultimum</i>
G.Lerch # 2	Site of fumigation trial 2002. After fumigation	1. <i>Pythium ultimum</i>	1. weak to young plants, moderate to older plants	<i>Pythium ultimum</i>
G. Lerch # 3	West side of Forest Hill – Blenheim Rd	1. <i>Pythium</i> (species not determined) 2. <i>Rhizoctonia</i>	1. weak-moderate to young plants, non-pathogenic to older plants 2. high to young plants, moderate to older plants	<i>Rhizoctonia</i>
P. Lerch	Corner of Forest Hill - Blenheim & Woodland Rds	1. <i>Pythium</i> (species not determined)	1. moderate-high to young plants, weak to older plants	<i>Pythium</i> (species not determined)
Litzow # 1	First field behind Voight's, Gatton – Forest Hill Rd	1. <i>Pythium aphanidermatum</i> 2. <i>Pythium dissotocum</i> 3. <i>Pythium</i> (unknown species)	1. high to young plants, weak-moderate to older plants 2. moderate to young plants, non-pathogenic to older plants 3. moderate to young plants, non-pathogenic to older plants	<i>Pythium aphanidermatum</i> <i>Pythium</i> (unknown species)
Litzow # 2	Site of variety trial 2002	1. <i>Rhizoctonia</i>	1. high to young plants, moderate-high to older plants	<i>Rhizoctonia</i>
Neumann # 1	Site of variety trial 1, 2001	1. <i>Pythium ultimum</i> 2. <i>Pythium</i> (species not determined) 3. <i>Fusarium</i> 4. <i>Rhizoctonia</i>	1. moderate-high to young plants, high to older plants 2. high to young plants, moderate-high to older plants 3. moderate-high to young plants, non-pathogenic to older plants 4. moderate-high to young plants, moderate to older plants	<i>Pythium ultimum</i> <i>Pythium</i> (species not determined) <i>Rhizoctonia</i>
Neumann # 2	Site of variety trial 2, 2001	1. <i>Rhizoctonia</i> 2. <i>Fusarium</i>	1. high to young plants, weak-moderate to older plants 2. moderate-high to young plants, non-pathogenic to older plants	<i>Rhizoctonia</i> <i>Fusarium</i> <sup>3</sup>
Neumann # 3	Qualischefski's block	1. <i>Rhizoctonia</i> 2. <i>Pythium aphanidermatum</i> 3. <i>Pythium</i> (unknown species) 4. <i>Pythium dissotocum</i> 5. <i>Pythium ultimum</i> 6. <i>Pythium</i> (species not determined)	1. high to young plants, moderate-high to older plants 2. high to young plants, weak to older plants 3. high to young plants, weak-moderate to older plants 4. moderate-high to young plants, non-pathogenic to older plants 5. weak-moderate to young plants, non-pathogenic to older plants 6. high to young plants, weak to older plants	<i>Rhizoctonia</i> <i>Pythium</i> (species not determined)
Voight # 1	Site of fungicide trial 1, 2001	1. <i>Pythium ultimum</i> 2. <i>Pythium aphanidermatum</i> 3. <i>Pythium dissotocum</i> 4. <i>Pythium</i> (species not determined)	1. weak-moderate to young plants, high to older plants 2. moderate to young plants, weak-moderate to older plants 3. non-pathogenic to young plants, weak-moderate to older plants 4. high to young plants, moderate to older plants	<i>Pythium ultimum</i> <i>Pythium</i> (species not determined)
Voight # 2	Off Gatton - Forest Hill Rd (opposite Litzow House)	1. <i>Rhizoctonia</i> 2. <i>Fusarium</i> 3. <i>Pythium aphanidermatum</i> 4. <i>Pythium ultimum</i>	1. high to young plants, moderate-high to older plants 2. moderate to young plants, non-pathogenic to older plants 3. moderate-high to young plants, moderate-high to older plants 4. moderate to young plants, weak to older plants	<i>Rhizoctonia</i> <i>Pythium aphanidermatum</i>
Voight # 3	Off Gatton - Forest Hill Rd (opposite Litzow House)	1. <i>Pythium</i> (species not determined)	1. high to young plants, non-pathogenic to older plants	<i>Pythium</i> (species not determined)
Zelinski	Site of commercial scale variety trial 2002	1. <i>Pythium</i> (species not determined)	1. moderate-high to young plants, moderate-high to older plants	<i>Pythium</i> (species not determined)
Moira # 4	Block at Laidley behind John Berlin's house	1. <i>Pythium</i> (species not determined)	1. moderate-high to young plants, non-pathogenic to older plants	<i>Pythium</i> (species not determined)
Neumann	Sample A	<i>Pythium</i> (species not determined)	1. high to young plants, weak to older plants	<i>Pythium</i> (species not determined)
P. Lerch	Sample A	<i>Pythium</i> (species not determined)	1. non-pathogenic to young plants, weak-moderate to older plants	<i>Pythium</i> (species not determined)
Moira	Sample A	<i>Pythium</i> (species not determined)	1. non-pathogenic to young plants, moderate to older plants	<i>Pythium</i> (species not determined)
G. Lerch	Sample A	<i>Pythium</i> (species not determined)	1. moderate to young plants, weak to older plants	<i>Pythium</i> (species not determined)
. Lerch	Sample B	<i>Pythium</i> (species not determined)	1. weak-moderate to young plants, weak to older plants	<i>Pythium</i> (species not determined)

<sup>1</sup>Pathogenicity rating scale (% plants dead): weak=1-15%, weak-moderate=16-30%, moderate=31-50%, moderate-high=51-75%, high=76-100%. Young plants inoc. 2 wk after sowing. Older plants inoc. 4wks after sowing<sup>2</sup>Based on frequency of isolation from diseased plants in soil indexing assays<sup>3</sup>Pathogenic *Fusarium* recovered from diseased plants in variety trial, not from soil indexing assay

## *Variability in Pathogenicity of Pythium Species with Temperature and Plant Age*

### **Introduction**

Broadly, *Pythium* is often purported to be a more severe pathogen of young plants. Damping off symptoms are most often associated with *Pythium* infection in a range of hosts. In our pathogenicity testing in which we inoculated 2-week-old and 4-week-old beetroot plants however, some of the *Pythium* isolates were more pathogenic to the older seedlings and others were equally pathogenic to seedlings of both ages (Table 3). In addition to plant age, soil temperature is another factor that influences the severity of *Pythium* epidemics in the field (Hancock, 1977). Different pathogenic *Pythium* species are reported to require different temperatures for epidemic development in beetroot. For example, in a field survey in North Dakota and Minnesota, Kuznia and Windels (1993) found that *Pythium aphanidermatum* caused more seed rot and damping off when soil temperatures increased from 14 to 31°C, whereas the reverse relationship was observed for *Pythium ultimum*.

In view of the fact that there are several different pathogenic species of *Pythium* on beetroot in Australia, species-specific temperature requirements may be an important consideration in a disease management strategy. In particular, there may be an opportunity to manipulate planting dates depending on which pathogens are present at particular sites. For example, sowing beets into soils in which species favoured by relatively high temperatures predominate, should be avoided during the hottest months of the growing season. We completed a controlled environment cabinet study to determine the influence of plant age and temperature on disease severity, for the three most common *Pythium* species in local beetroot soils: *Pythium aphanidermatum*, *Pythium ultimum* and *Pythium dissotocum*.

### **Materials and Methods**

Pots of beetroot seedlings (cv. Detroit Dark Red) of 6 different ages (3, 10, 14, 21, 28 and 35 days after sowing) were drenched with inoculum of one of three *Pythium* species (*P. aphanidermatum*, *P. ultimum* or *P. dissotocum*) or water (control) and were maintained at one of six different temperatures (10, 15, 20, 25, 30, 35°C) for four weeks. Each pot contained 10 plants. Twenty-four pots of seedlings of each age were drenched with each treatment. Four pots of each age/drench combination were incubated in each of 6 controlled environment cabinets at a different temperature, such that each incubator contained 24 pots of plants. Pots were watered twice daily and the humidity in each cabinet was set at approx 90%.

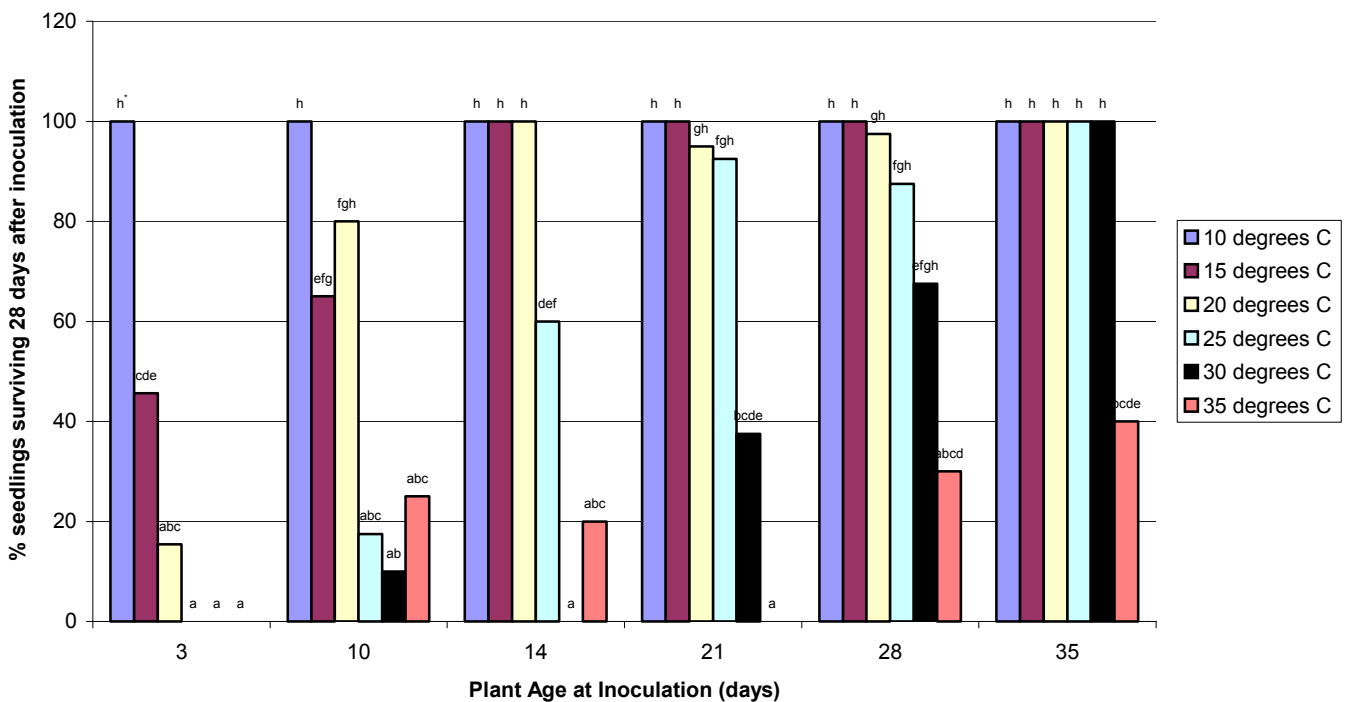
The *Pythium* isolates used were: #1339 (8) *P. aphanidermatum* ex. mature wilting beets (Peter Lerch), #1623 (10) *P. ultimum* ex. soil variety trial 1, 2001 (Merv Neumann) and #1688 (16) *P. dissotocum* ex. soil Qualischefski block (Merv Neumann). Inoculum was prepared by scraping 7-day-old *Pythium* cultures in sterile de-ionised water (1 plate/200mL water). Each pot was drenched with 50mL of inoculum and the pots were allowed to drain before they were transferred to the cabinets.

Pots were assessed weekly. Dead seedlings were counted and removed. At the final assessment time the shoots were cut from the plants and the shoots and roots were weighed separately.

## Results

*Pythium aphanidermatum* was the most pathogenic of the three *Pythium* species. Infection by *P. aphanidermatum* developed only at temperatures of 15°C or above. Young plants were more susceptible to infection. At 15°C disease developed only in 3- and 10-day-old plants. Significant levels of disease developed in 10- and 14-day-old plants at temperatures  $\geq 25^\circ\text{C}$ , but temperatures of 30°C or greater were needed for the pathogen to infect 21-day-old-plants. For 28- and 35-day-old plants, significant levels of disease developed only when the temperature reached 35°C (Figure 7).

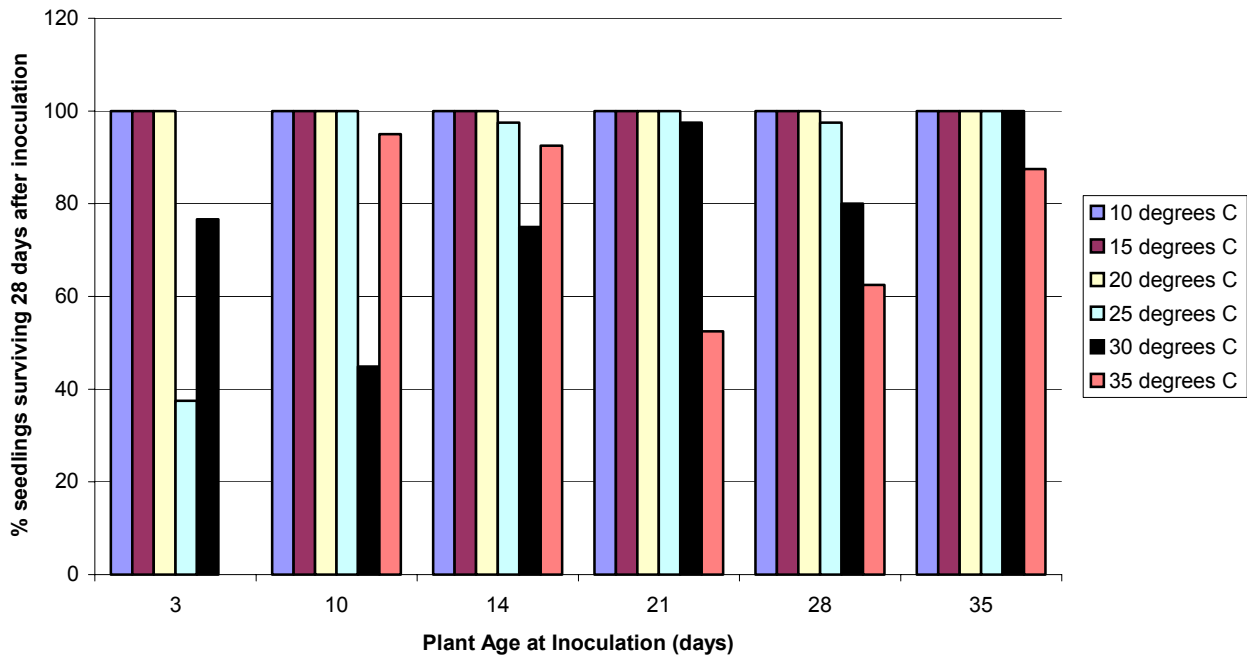
**Figure 7:** The severity of disease caused by *P. aphanidermatum* is strongly dependent on both plant age and temperature



\* Bars with the same letters are not significantly different at the 5% level

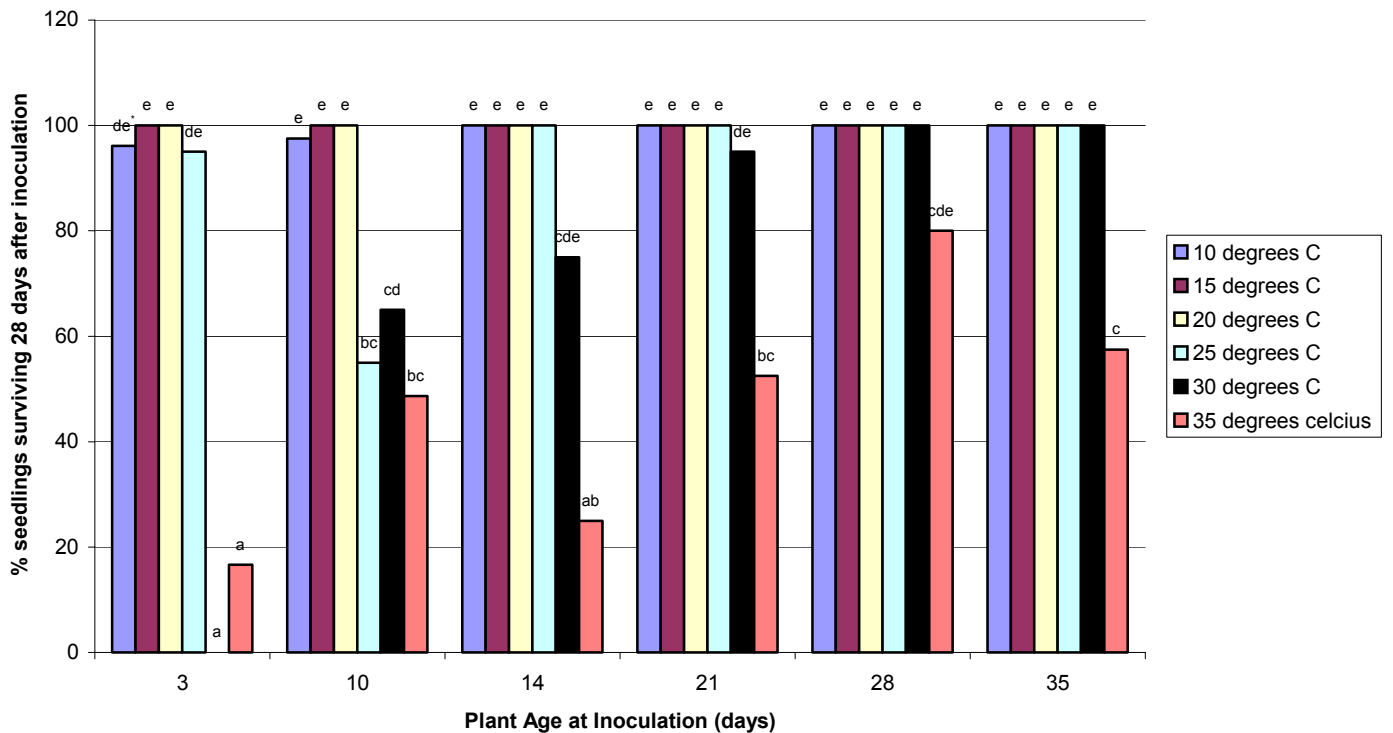
*Pythium ultimum* and *P. dissotocum* were less pathogenic than *P. aphanidermatum*. For *P. ultimum*, no clear relationship existed between disease severity and the plant age x temperature interaction (Figure 8).

**Figure 8:** No clear relationship exists between plant age x temperature and the severity of disease caused by *P. ultimum*



*Pythium dissotocum* infected plants at temperatures of 30°C or greater. Three-day-old plants were susceptible to infection at 30°C, and plants of all ages were susceptible at 35°C.

**Figure 9:** Beetroot plants were susceptible to infection by *Pythium dissotocum* at  $\geq 30^\circ\text{C}$



\* Bars with the same letters are not significantly different at the 5% level

For Queensland beetroot growers, it may be possible to limit disease epidemic development in blocks where pathogenic *Pythium aphanidermatum* occurs, by delaying planting until the winter months when soil temperatures are lower. Similarly, losses due to *P. dissotocum* may also be reduced on sites known to contain this pathogen by delaying sowing to the cooler months. Sites where this technique may be useful are Voight #1, Voight #2, Litzow #1, Neumann #3 and Hauser (Table 3).

### ***Pathogenicity of Pythium aphanidermatum and Rhizoctonia to crops other than beetroot***

#### **Introduction**

Cropping beets at high frequency increases soil-borne pathogen populations, resulting in yield losses. For this reason, 3-5 year rotations out of beet is standard industry practice in beet cropping regions in the United States (Herr, 1987; Rush and Winter, 1990). If an alternate crop is to be grown with the objective of reducing the levels of beet pathogens in the soil however, the alternate crop must not itself be a host for the beet pathogens, otherwise the pathogen inoculum level in the soil may be increased by planting the rotational crop. Published information identifies gramineous crops such as corn or oats, or *Brassicacae* as crops that will not increase pathogen inoculum density if grown in rotation with beetroot. We tested the susceptibility of 22 different crop types commonly grown in the Lockyer and Fassifern Valleys, to pathogenic *Rhizoctonia* and *Pythium aphanidermatum* isolates collected from local beetroot crops, in the glasshouse. Our objective was to identify non-susceptible crops that may be useful in helping to limit pathogen inoculum build-up when grown in rotation with beetroot.

#### **Materials and Methods**

Seeds of 22 types of crop species were planted in pots of UC mix in the glasshouse. Sowing dates were staggered so that all the plant types were at a similar stage of development when they were inoculated with either *Rhizoctonia* or *Pythium aphanidermatum* on 7 April 2003. Crop and cultivar information and sowing dates are provided in Table 4.

**Table 4:** Sowing dates for crops tested as alternate hosts for beet pathogens

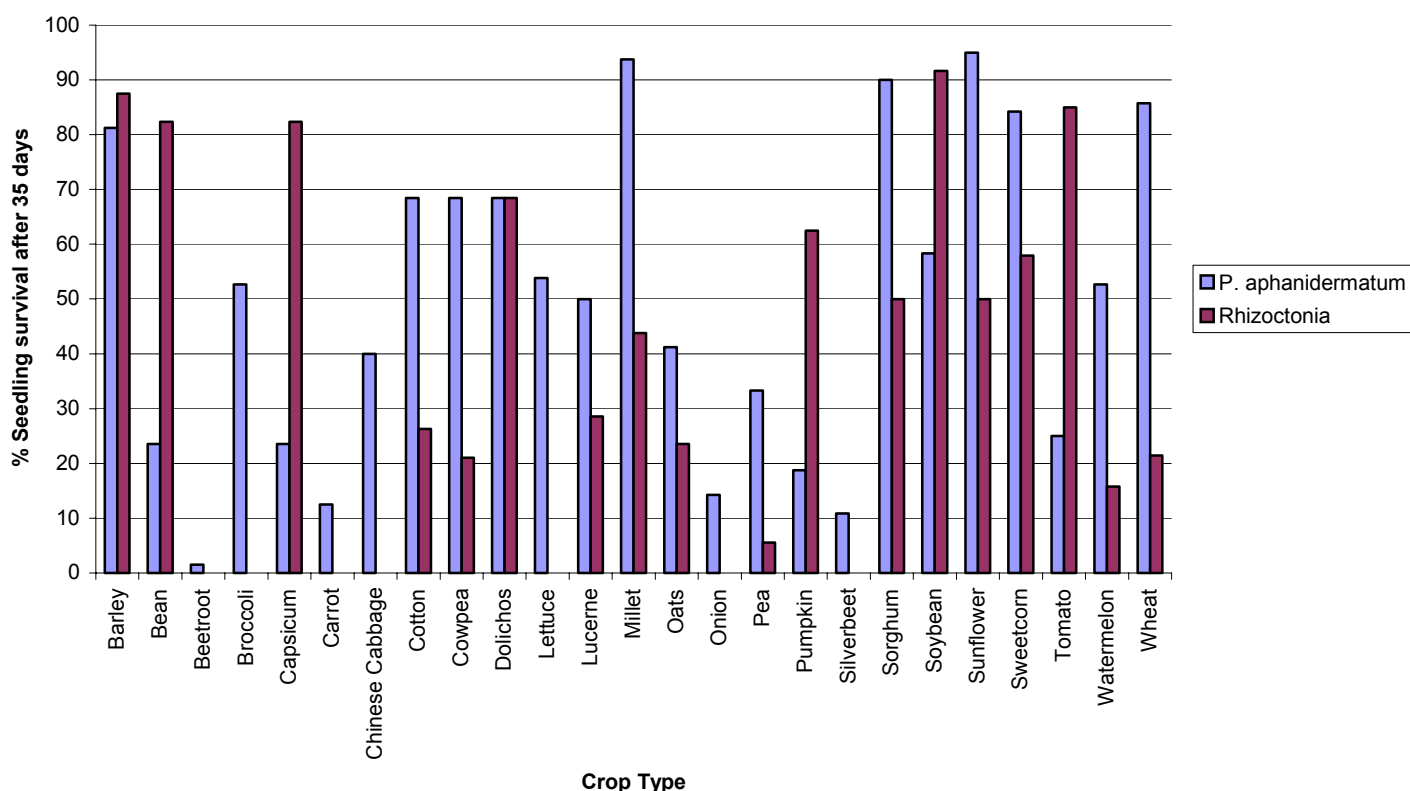
<b>Crop Type</b>	<b>Cultivar</b>	<b>Sowing Date</b>
lettuce	Greenway	14 March 2003
capsicum	Giant Bell	14 March 2003
onion	Gladalan Brown	14 March 2003
beetroot	Detroit Dark Red	17 March 2003
carrot	Royal Chantenay	17 March 2003
silverbeet	Fordhook Giant	17 March 2003
watermelon	Country Sweet	17 March 2003
cotton	Sicala 40	21 March 2003
pea	Early Crop Massey	21 March 2003
tomato	Grosse Lisse	21 March 2003
oats	Moolah	21 March 2003
broccoli	Summer Green	21 March 2003
soybean	A6785	21 March 2003
pumpkin	Queensland Blue	25 March 2003
chinese cabbage	Wong Bok	25 March 2003
sweet corn	Pacific H3	25 March 2003
wheat	Giles	25 March 2003
French beans	Simba	25 March 2003
sunflower	-	28 March 2003
lucerne	Sequel	28 March 2003
sorghum	Jumbo	28 March 2003
Dolichos	Rongai	28 March 2003

Two pots of each type were planted and seedlings were thinned to 5 per pot before inoculation. We used *Pythium aphanidermatum* isolate #1339 (8) ex. mature wilting beets (Peter Lerch), and *Rhizoctonia* isolate #1669 (4) ex. soil Voight #2. Inoculum was prepared by scraping 7-day-old cultures in sterile de-ionised water (1 plate/200mL water). Each pot was drenched with 50mL of inoculum and the pots were arranged randomly on glasshouse benches. Pots were assessed weekly for 4 weeks. Dead seedlings were counted and removed.

## Results

Barley was the crop that was the least susceptible to infection by either pathogen, followed by Dolichos (Figure 10). These two crop types would therefore, be the most suitable for planting as rotations with beetroot on sites that are known to be infested with both pathogen types (Voight #2, Neumann #3, Hauser). For sites where *Rhizoctonia* is the primary problem, barley, French beans, capsicum, soybean or tomatoes look to be the most prospective rotational crops (Moir #1, G.Lerch #3, Litzow #2, Neumann #1, Neumann #2). For sites where *P. aphanidermatum* is the primary pathogen (Litzow #1, Hauser), barley, millet, sorghum, sunflower, sweetcorn and wheat offer promise as rotational crops.

**Figure 10:** Relative susceptibility of a range of crop types to a *P. aphanidermatum* isolate and a *Rhizoctonia* isolate that are pathogenic to beetroot





## **CHAPTER 3: Beetroot Variety Trials**

### **Introduction**

The Lockyer Valley district of south-east Queensland supplies approximately 90% of Australian processed beetroot. Beets are mechanically harvested and are processed by Golden Circle P/L. In order to ensure that the processed product is of a consistent high quality, Golden Circle imposes quality specifications on the raw material provided at the factory. Slicing beets are required to be globe shaped, 50-110mm in diameter, with a small crown and a small non-tapered taproot. Baby beets must fall within the 25-50mm diameter size range. Beets that are misshapen, cracked, or show evidence of disease lesions or other mechanical damage are rejected at the cannery or require additional manual processing, which substantially increases processing costs.

This industry now depends on only three slicing beet varieties, two open-pollinated varieties (Detroit Dark Red and Garnet) and one hybrid (Pablo), and one baby beet variety (New Globe). In recent years soil-borne diseases (*Pythium*, *Rhizoctonia* and *Aphanomyces*) have been reported to cause substantial yield and quality reductions, particularly in crops grown at the extremities of the growing season (i.e. those planted in February/March and those harvested October-December). These pathogens can result in poor stand establishment and may give rise to poor quality, misshapen beets that do not meet the processing specifications set by Golden Circle. Species of *Pythium* and *Rhizoctonia* are currently particularly problematic for this industry.

### **A) Field Assessments of Beetroot Varieties - 2001**

#### **Materials and Methods**

Thirty-two beetroot varieties were compared in two field trials planted on-farm at Forest Hill at a site with a previous history of disease. The first trial was planted in an early planting window on 6<sup>th</sup> April 2001, and the second was planted in a later planting window on 6<sup>th</sup> June 2001. Seed lots were provided directly by seed companies (Table 5). The seeds provided had typically been treated with either thiram or a thiram/metalaxyl seed dressing combination. Prior to planting, seed-lots that only had a thiram dressing were also treated with metalaxyl (Apron Liquid Formulation 35gai/100kg seed) to ensure that a standard treatment (thiram + metalaxyl) was applied to seed of each variety in the trials.

**Table 5:** Beetroot varieties assessed as alternatives to current industry standard varieties in April and June on-farm trials (2001).

Variety	Seed Company	Type
BT0081 <sup>A</sup>	Syngenta	slice
BT0082	Syngenta	slice
BT0083	Syngenta	slice
BT0085	Syngenta	slice
BT0086	Syngenta	slice
BT0087	Syngenta	slice
BT0088	Syngenta	slice
YBT9100	Yates	slice
YBT9101	Yates	slice
YBT9102	Yates	slice
YBT9103	Yates	slice
Four Aces	Yates	slice
Emerald	Yates	slice
Green Top Bunching	Yates	slice
Detroit Dark Red	Yates	slice
Early Wonder Tall Top	Yates	slice
Sapphire	Hendersons	slice
Rapid Red	Hendersons	slice
Improved Detroit Red	Hendersons	slice
Warrior	LeFroy Valley	slice
BTT1004	LeFroy Valley	slice
BTT1005	LeFroy Valley	slice
BTT1006	LeFroy Valley	slice
SPS#1	SPS	slice
SPS#2	SPS	slice
SPS#3	SPS	slice
<b>Pablo<sup>B</sup></b>	<b>Bejo</b>	<b>slice</b>
<b>Detroit Dark Red</b>	<b>Syngenta</b>	<b>slice</b>
<b>Garnet</b>	<b>SPS</b>	<b>slice</b>
Red Cloud	Bejo	slice
BT0084	Syngenta	baby
<b>New Globe</b>	<b>Syngenta</b>	<b>baby</b>

<sup>A</sup>Varieties provided by Syngenta, Yates, LeFroy Valley and South Pacific Seeds were assigned code names by the seed companies.

<sup>B</sup>Bold type denotes varieties currently grown as standard types by the industry

The April trial was planted as an incomplete block design with 8 plots per block and 4 replications. Plots comprised 6 x 5m row lengths with 6 x 2m unplanted buffer row lengths at the plot ends. Seed of the slicing type varieties was spaced 80mm apart and seed of the baby type varieties were spaced at 30mm.

The June trial was planted as a randomized block design with 3 replications. Plots comprised 4 x 5m row lengths with 4 x 2m unplanted buffer row lengths at the plot ends. Seed of the slicing type varieties was spaced 70mm apart and seed for the baby type varieties were spaced at 25mm.

For both trials, seed was threaded into a cellulose tape at the desired spacing (Livyn Pty Ltd) and was rolled onto a spool. Planting was done using a hand-driven tape planter. As the seedlings emerged, percentages of healthy plants in each plot were calculated and used as an indicator of the relative susceptibility of the beetroot varieties to soil-borne fungal pathogens present at the trial sites. Assessments were made at 3-4 day intervals for three weeks after the start of emergence. At each assessment time, data were analysed using REML (restricted maximum likelihood) in Genstat for Windows 5.0, fitting autoregressive process over the rows and columns and other spatial trends as necessary.

Harvest times were staggered to reflect the relative maturities of the specific varieties. For the April trial, plots were harvested over a 3 week period, commencing 17 August 2001 and for the June planting, the slicing varieties were harvested over a 10 day period, commencing 9 November 2001. The baby varieties from the April planting were harvested on the 5 July and those from the June planting were harvested on the 9 October 2001.

At harvest, beets from the centre rows of each plot were removed manually and the tops were cut from the plants with knives. The roots of the slicing types were manually graded into 7 categories according to size and quality criteria suggested by Golden Circle P/L (Table 6) and the baby types were graded according to the quality and size criteria in Table 7.

**Table 6:** Grading categories used in mature beet assessment

<b>Category</b>	<b>Criteria*</b>
oversize	Any root with a diameter > 110mm
slicing	Globe shaped root without disease, cavities or cracking, with a 50-110mm diameter
undersized	Any root with a diameter <50mm
misshapen	Roots within the 50-110mm diameter range that are non-globe shaped with no other apparent evidence of disease, cracking or cavities
cracked	Roots within the 50-110mm diameter size range with cracks severe enough not to be removed during peeling
diseased	Roots within the 50-110mm diameter size range showing disease lesions
cavities	Roots within the 50-110mm diameter size range with cracks/hollow areas under the crown

\* beets meeting the criteria of more than one category (cracked, diseased or cavities) were assigned to the category that accounted for the majority of the symptoms.

**Table 7:** Grading categories used in baby beet assessment

<b>Category</b>	<b>Criteria*</b>
oversize	Any root with a diameter > 50mm
baby	Globe shaped root without disease, cavities or cracking, with a 25-50mm diameter
undersize	Any root with a diameter < 25mm
diseased	Roots within the 25-50mm size range showing disease lesions
misshapen	Roots within the 25-50mm diameter range that are non-globe shaped with no other apparent evidence of disease, cracking or cavities

\* beets meeting the criteria of more than one category (diseased or misshapen) were assigned to the category that accounted for the majority of the symptoms.

For each plot, the number of beets and the total weight of beets in each category was determined and the number of beets from each plot with forked taproots was recorded.

Harvest data were analysed using SAM, an S+ function used for spatially designed experiments (Butler *et al.*, 2001).

## Results

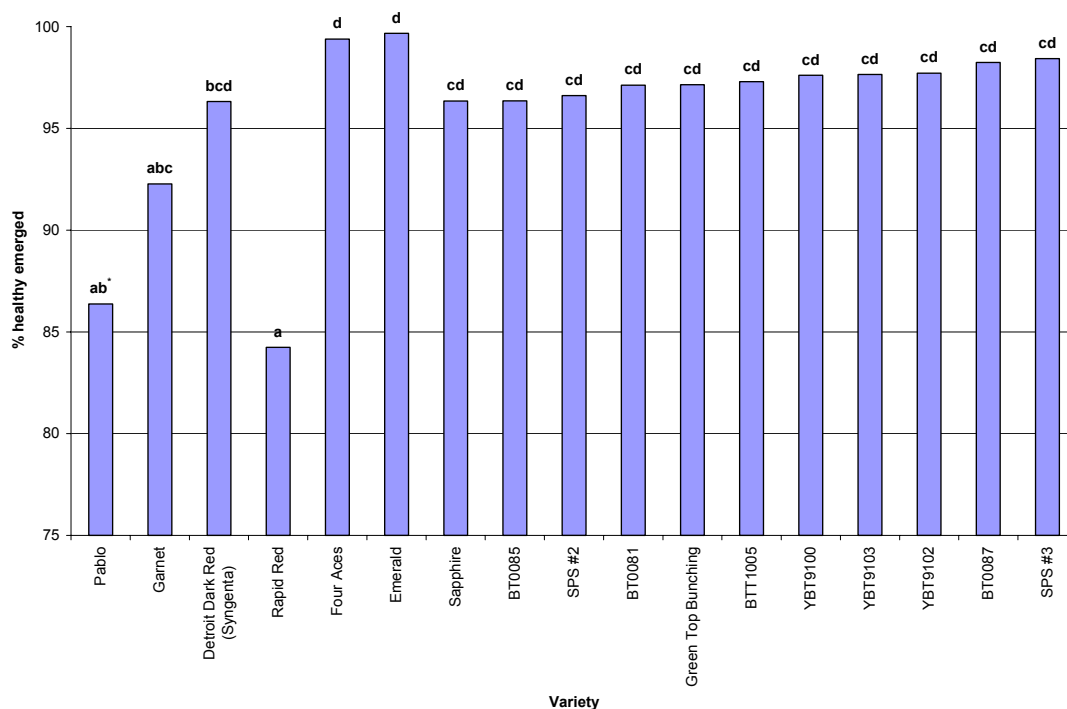
### *April Planting Emergence Data:*

At the final assessment time (11 May 2001), plots of the 3 commercial standard slicing lines (Pablo, Detroit Dark Red (Syngenta), Garnet) contained comparable percentages of healthy plants. Of these three, there was a tendency for Pablo plots to contain lower percentages of healthy plants compared to Detroit Dark Red and Garnet, however this was not a significant difference ( $P=0.05$ ). Plots of thirteen varieties (Sapphire, BT0085, SPS#2, BT0081, Green Top Bunching, BTT1005, YBT9100, YBT9103, YBT9102, BT0087, SPS#3, Four Aces, Emerald) did however, contain significantly ( $P<0.05$ ) higher proportions of healthy plants than plots sown to Pablo (Figure 11).

None of the varieties assessed had significantly ( $P=0.05$ ) higher proportions of healthy plants in the plots than the current commercial standard Detroit Dark Red line (Syngenta). One variety, Rapid Red was inferior to Detroit Dark Red at the final assessment time ( $P<0.05$ ).

Plots of the two varieties grown as baby types in the trial (New Globe and BT0084), contained comparable percentages of healthy seedlings at the final emergence assessment time.

**Figure 11:** Rapid Red was the only variety that was more susceptible than the standard Detroit Dark Red to seedling diseases, but thirteen varieties were less susceptible than the standard Pablo type



\* Bars labeled with the same letters are not significantly different at the 5% level

*April Planting Harvest Data:*

A summary of the harvest data is given in Table 8. At harvest, the standard commercial Detroit Dark Red line (Syngenta) was the poorest performer of the three current standard types included in this trial. The total quantity of material harvested from the plots sown to Detroit Dark Red was comparable to the amount from plots sown to Pablo. However, the percentage and weight of Detroit Dark Red beets that were sliceable was significantly less ( $P<0.05$ ) than the sliceable quantities harvested from plots of the other commercial standard types (Pablo and Garnet). The performance of Detroit Dark Red (Syngenta) was equivalent to the poorest varieties in the trial.

A beetroot variety grown as a processing slicing type is required to yield a large quantity and percentage of sliceable material. Percentage sliceable yield, total sliceable yield and total yield information for each variety is presented in Figures 12 and 13. In this trial BTT1006 produced the best result in terms of both sliceable yield (56.71 kg/plot) and percentage (64.76%). The results for this variety were significantly ( $P<0.05$ ) better than for any other variety in the trial.

This variety was difficult to assess using the criteria set by Golden Circle P/L however, due to its cylindrical shape. Consequently, beets of this variety were assigned to the misshapen category if they were substantially kinked or bent. During processing however, if the appropriate equipment was available, bent beets could be cut into several straight sections, reducing the quantity that would be rejected due to inferior shape, further increasing the quantity of sliceable material.

On the basis of sliceable yield and percentage, Warrior was significantly ( $P<0.05$ ) superior to any other globe shaped variety in the trial. It yielded the highest quantity of sliceable product (25.59 kg/plot) and the percentage of sliceable material (35.97%) harvested from Warrior plots was significantly better ( $P<0.05$ ) than any of the commercial standards. The percentage of sliceable product harvested from Green Top Bunching plots was comparable to the percentage of sliceable Warrior, however Green Top Bunching was inferior to Warrior ( $P<0.05$ ) on the basis of total sliceable yield (kg).

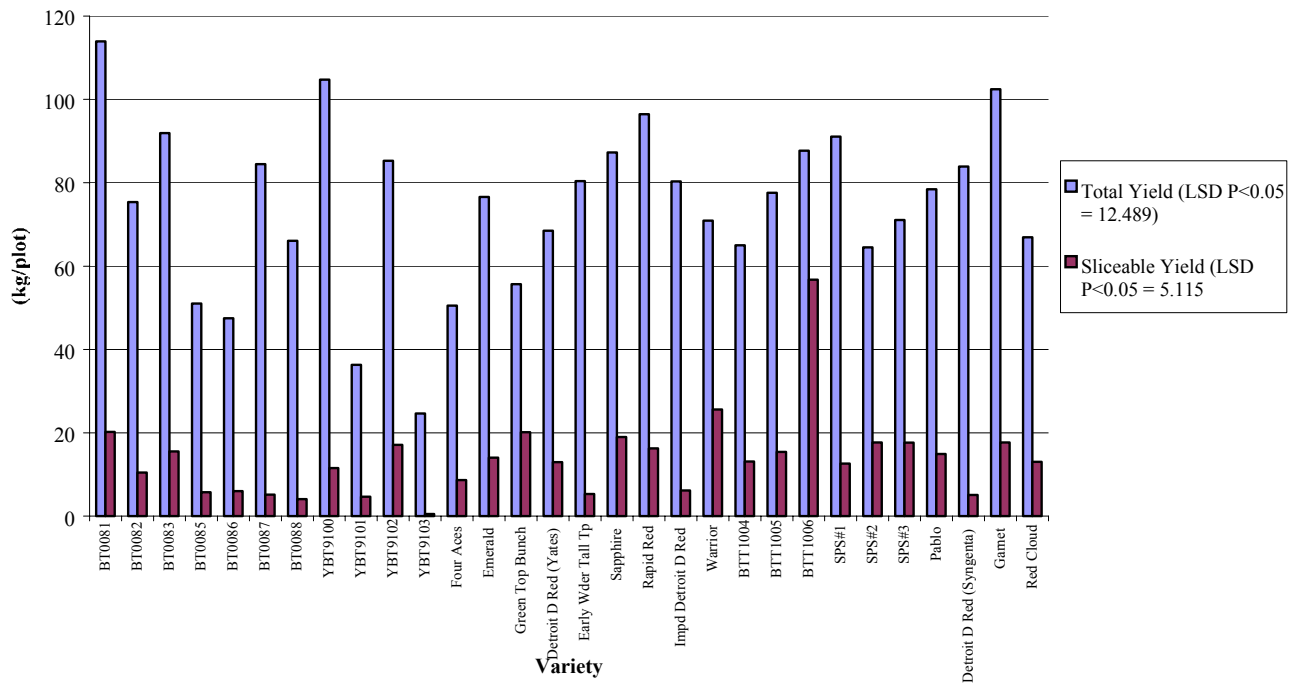
Plots of SPS#2 also yielded a significantly ( $P<0.05$ ) higher percentage weight of sliceable beets than any of the current standards, however the total sliceable weight harvested wasn't significantly greater than that of either Pablo or Garnet ( $P<0.05$ ).

BT0081 produced the highest total yield of any variety assessed. The percentage weight of sliceable material and the quantity of sliceable BT0081 was however, comparable to the sliceable proportions and quantities for Pablo and Garnet. SPS#3, Sapphire and BTT1005 also yielded sliceable quantities that were not significantly different to Pablo and Garnet. These varieties did however, yield higher proportions of sliceable beets than Pablo, although not to a significant extent ( $P<0.05$ ).

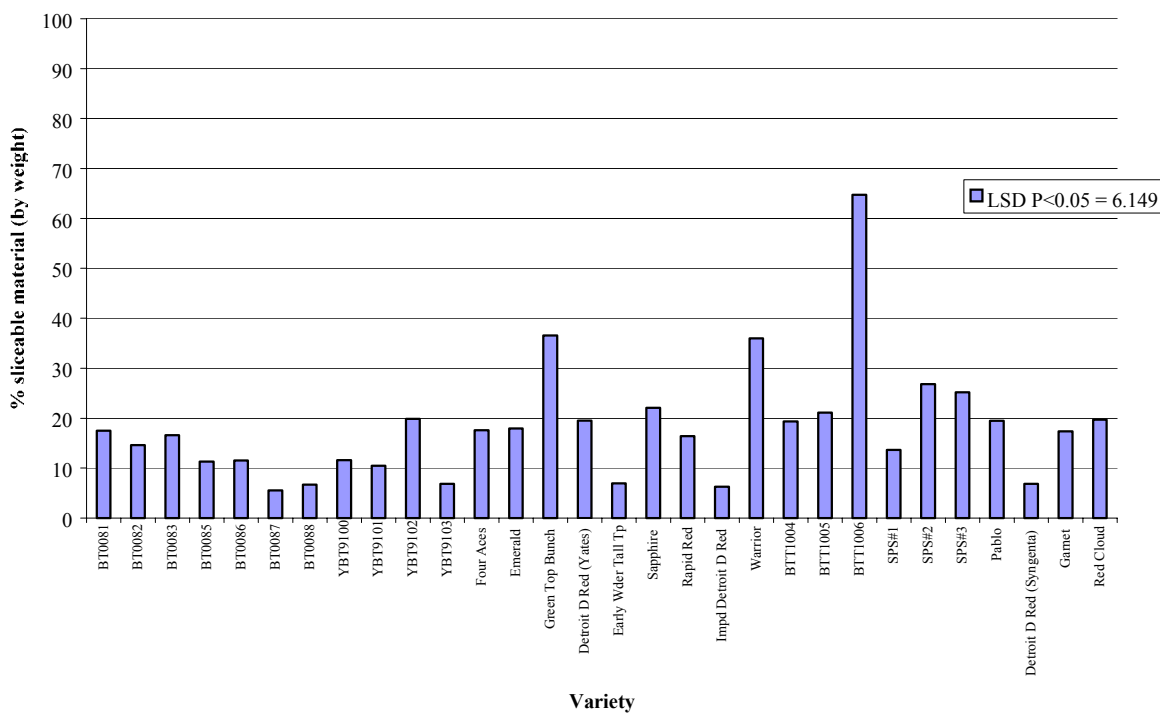
**Table 8:** Summary of harvest data for beetroot variety trial sown 6 April 2001

	<i>Total</i>	<i>Slicing beets as a percentage of total:</i>		<i>Yield of</i>	<i>Slicing beets</i>	<i>Total yield (t/ha)</i>
	<i>Yield from 4 plots (kg)</i>	<i>Weight</i>	<i>Number</i>	<i>sliceable beets per plot (kg)</i>	<i>(t/ha)</i>	
BT0081	452.75	18.40	21.73	20.83	15.63	84.91
BT0082	305.15	14.28	16.31	10.90	8.17	57.23
BT0083	371.33	15.87	19.58	14.74	11.05	69.64
BT0085	204.29	11.69	11.69	5.97	4.48	38.31
BT0086	183.94	11.79	14.32	5.42	4.07	34.50
BT0087	338.17	4.71	5.72	3.98	2.99	63.42
BT0088	282.26	7.42	9.92	5.23	3.93	52.94
YBT 9100	418.87	11.02	12.76	11.54	8.65	78.56
YBT 9101	154.36	9.11	10.10	3.51	2.64	28.95
YBT 9102	348.24	20.38	22.82	17.74	13.31	65.31
YBT 9103	102.55	6.88	10.72	1.76	1.32	19.23
Four Aces	198.64	18.42	25.05	9.15	6.86	37.26
Emerald	301.91	17.57	20.95	13.26	9.95	56.62
Green Top Bunching	226.65	38.29	43.44	21.70	16.28	42.51
Detroit Dark Red (Yates)	271.85	20.40	19.94	13.86	10.40	50.99
Early Wonder Tall Top	322.49	7.68	10.47	6.19	4.65	60.48
Sapphire	339.70	20.41	22.04	17.33	13.00	63.71
Rapid Red	400.07	17.61	18.15	17.62	13.22	75.03
Improved Detroit Red	308.35	6.52	6.99	5.03	3.77	57.83
Warrior	273.90	36.39	36.65	24.92	18.70	51.37
BTT 1004	253.92	19.36	22.14	12.29	9.22	47.62
BTT 1005	303.09	21.56	25.41	16.34	12.26	56.84
BTT 1006	351.33	64.26	54.30	56.45	42.34	65.89
SPS #1	356.66	13.90	17.61	12.40	9.30	66.89
SPS #2	252.62	27.18	39.41	17.16	12.88	47.38
SPS #3	280.68	27.00	32.41	18.95	14.21	52.64
Pablo	292.83	18.73	21.66	13.72	10.29	54.92
Detroit Dark Red (Syngenta)	332.76	5.96	6.82	4.96	3.72	62.41
Garnet	400.90	16.71	20.49	16.75	12.56	75.19
Red Cloud	269.67	19.82	23.27	13.36	10.02	50.58

**Figure 12:** Total yields and sliceable yields of slicing type beetroot (planted April 2001)

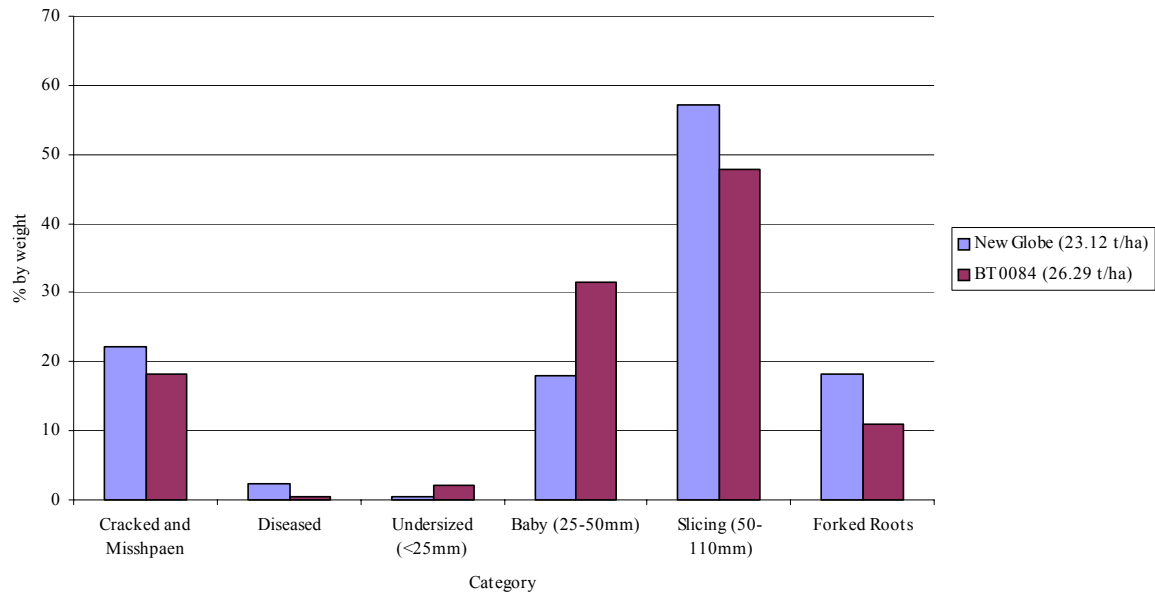


**Figure 13:** Percentage of sliceable material of beetroot varieties at harvest (planted April 2001)



Harvest information for the two baby beetroot types (New Globe and BT0084) is presented in Figure 14.

**Figure 14:** Percentage of baby beets in each grading category



#### *June Planting Emergence Data:*

Isolations from diseased seedlings collected from the trial indicated that *Pythium* was the primary pathogen responsible for disease in the newly emerged seedlings.

No variety had significantly higher proportions of healthy plants than either of the two current standard commercial lines Pablo or Detroit Dark Red (Syngenta), at any of the assessment times. At the final assessment time (12/7/01), the percentages of healthy seedlings were similar for all varieties i.e. there were no significant differences in the percentages of healthy emerged plants between any of the varieties.

At the fourth assessment time (3/7/01), 4 weeks after sowing, plots of BT0085 contained a significantly ( $P<0.05$ ) higher percentage of healthy seedlings compared to the commercial standard Garnet.

Plots of the two varieties grown as baby types (New Globe and BT0084) contained comparable proportions of healthy seedlings at all five assessment times ( $P=0.05$ ).

#### *June Planting Harvest Data:*

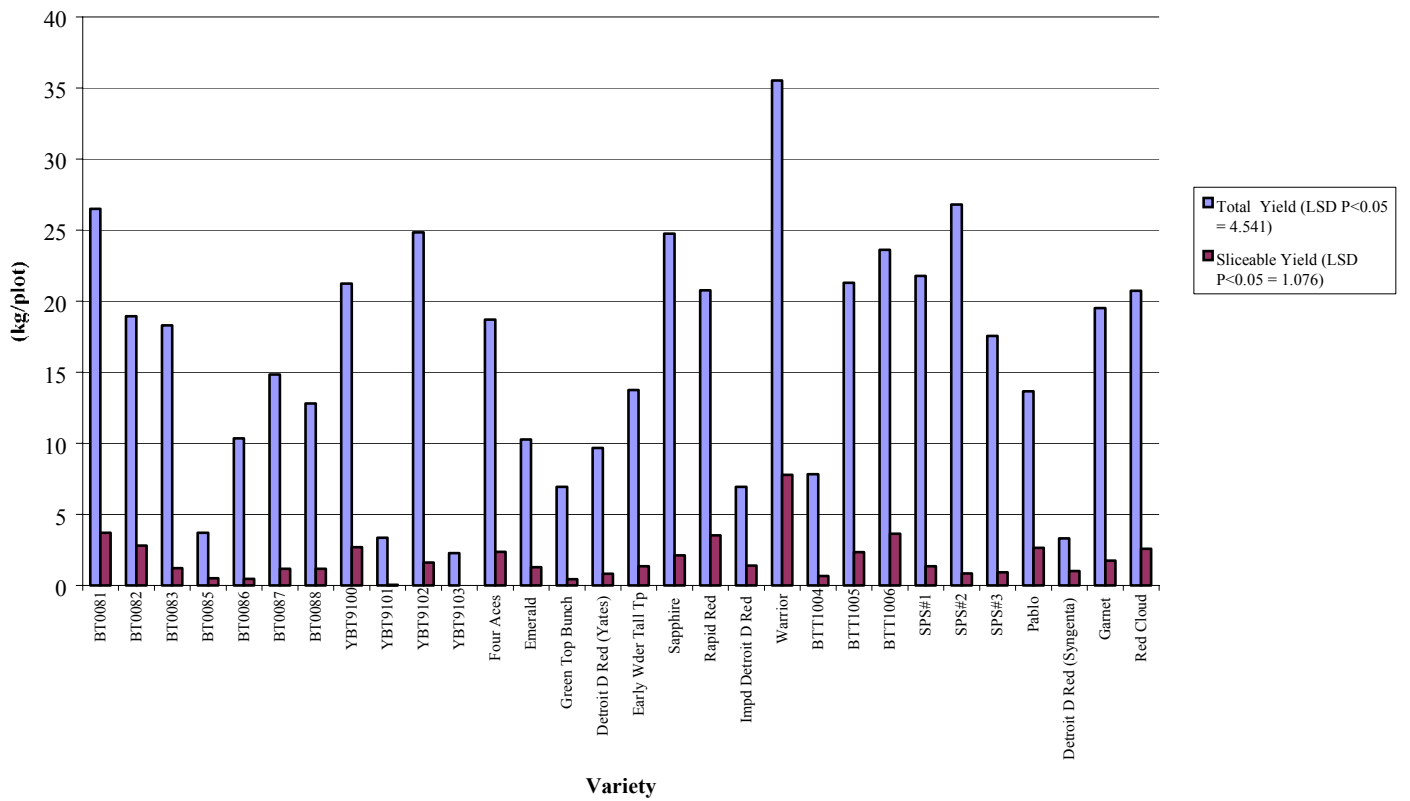
A summary of the harvest data is given in Table 9. A beetroot variety grown as a processing slicing type is required to yield both a large quantity and percentage of sliceable material. Total yield, percentage sliceable yield and total sliceable yield information for each variety is presented in Figures 15 and 16.



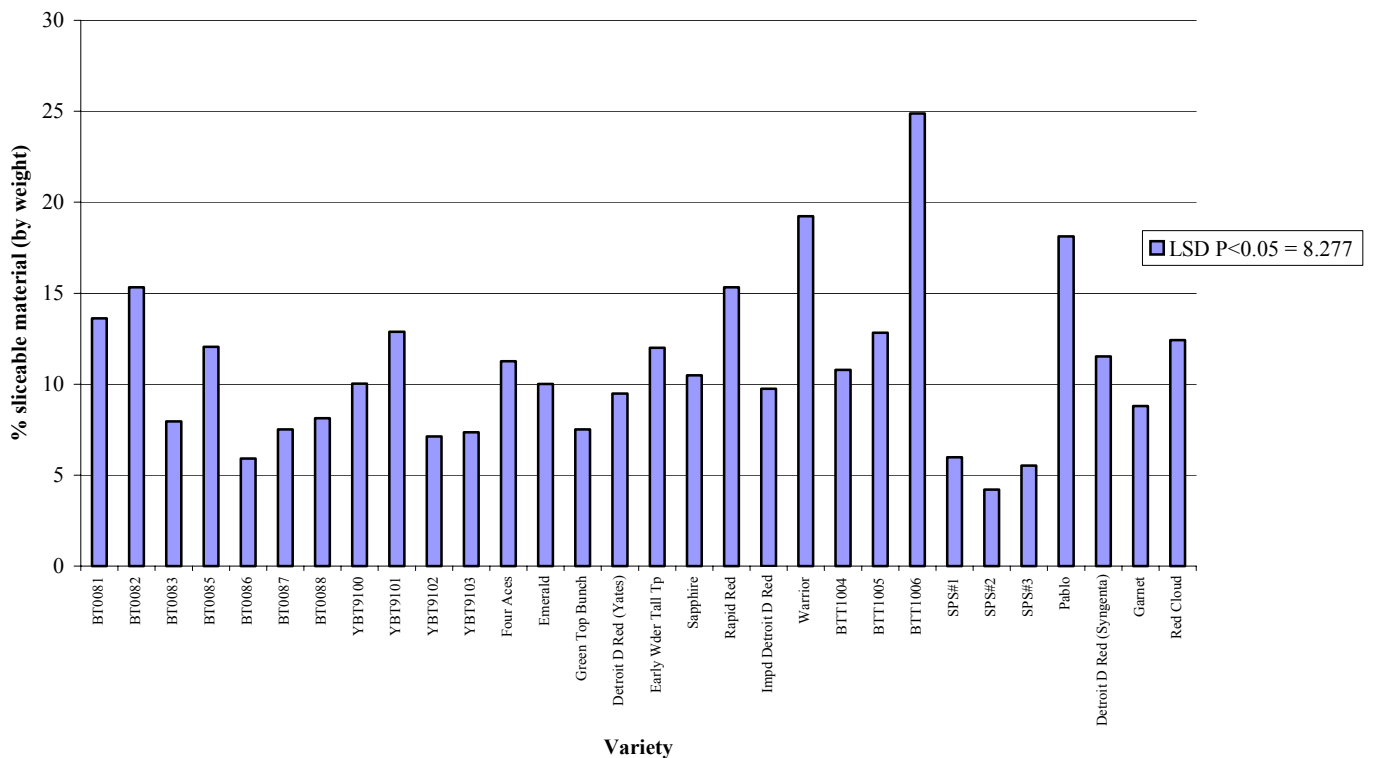
**Table 9:** Summary of harvest data for beetroot variety trial sown 6 June 2001

	<i>Total</i>	<i>Slicing beets as a percentage of total:</i>		<i>Yield of sliceable beets per plot (kg)</i>	<i>Slicing beets (t/ha)</i>	<i>Total yield (t/ha)</i>
	<i>Yield from 3 plots (kg)</i>	<i>Weight</i>	<i>Number</i>			
BT0081	75.68	13.33	8.82	3.36	5.02	37.65
BT0082	60.25	15.09	10.96	3.03	4.52	29.98
BT0083	55.36	7.68	5.10	1.42	2.11	27.54
BT0085	12.04	12.54	5.29	0.50	0.75	5.99
BT0086	33.62	5.65	4.13	0.63	0.95	16.73
BT0087	46.70	8.33	7.41	1.30	1.94	23.23
BT0088	37.46	9.56	7.04	1.19	1.78	18.64
YBT 9100	75.40	9.63	8.49	2.42	3.61	37.51
YBT 9101	12.10	14.71	8.65	0.59	0.89	6.02
YBT 9102	68.23	6.84	5.66	1.56	2.32	33.95
YBT 9103	2.64	10.98	5.71	0.10	0.14	1.31
Four Aces	54.57	10.65	12.05	1.94	2.89	27.15
Emerald	33.45	10.79	8.25	1.20	1.80	16.64
Green Top Bunching	23.00	6.04	4.61	0.46	0.69	11.44
Detroit Dark Red (Yates)	20.78	9.48	5.00	0.66	0.98	10.34
Early Wonder Tall Top	35.92	11.66	8.91	1.40	2.08	17.87
Sapphire	68.73	9.81	7.83	2.25	3.35	34.19
Rapid Red	69.71	15.31	10.30	3.56	5.31	34.68
Improved Detroit Red	28.73	10.09	6.09	0.97	1.44	14.29
Warrior	102.57	18.11	17.02	6.19	9.24	51.03
BTT 1004	21.11	11.37	9.41	0.80	1.19	10.50
BTT 1005	63.42	13.23	13.58	2.80	4.17	31.55
BTT 1006	61.19	25.18	16.92	5.14	7.67	30.44
SPS #1	65.98	5.93	6.09	1.30	1.95	32.83
SPS #2	56.38	5.94	7.77	1.12	1.67	28.05
SPS #3	59.64	5.28	6.38	1.05	1.57	29.67
Pablo	41.84	18.59	12.71	2.59	3.87	20.82
Detroit Dark Red (Syngenta)	18.98	12.33	5.63	0.78	1.16	9.44
Garnet	55.35	8.82	7.62	1.63	2.43	27.54
Red Cloud	68.04	11.26	12.25	2.55	3.81	33.85

**Figure 15:** Mean total yields and sliceable yields of slicing type beetroot



**Figure 16:** Mean percentage sliceable material of beetroot varieties at harvest



On the basis of yield data alone, Warrior was the most promising variety in this trial. Plots sown to Warrior produced total yields and sliceable yields that were significantly higher ( $P < 0.05$ ) than those of any other variety screened. In addition, the percentage of sliceable Warrior beets was equivalent to BTT1006, which yielded the highest percentage of sliceable material of any variety included in the trial.

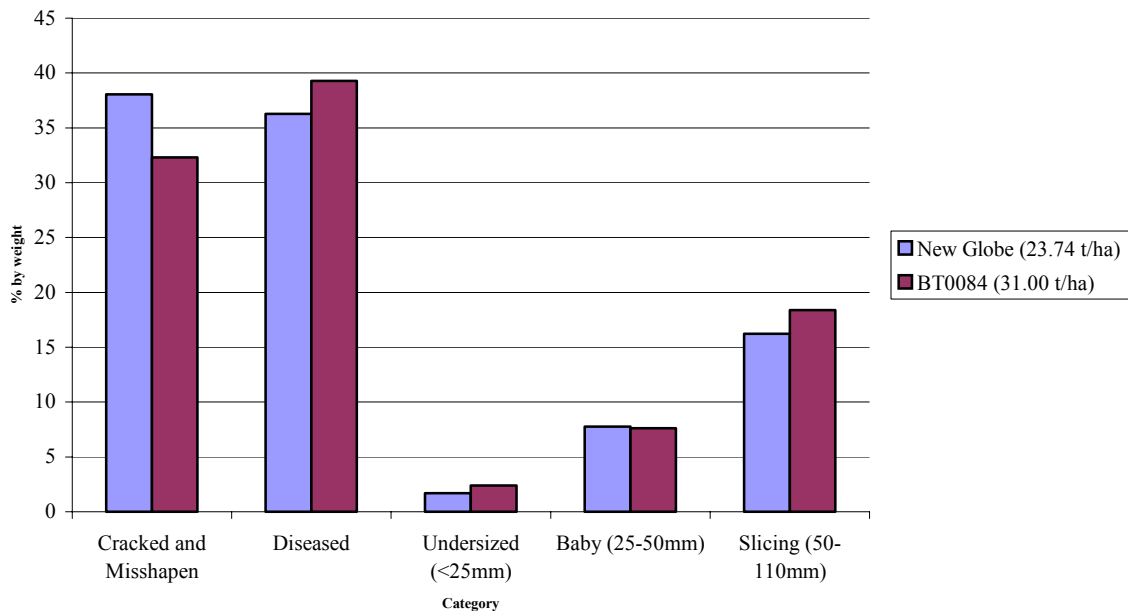
The Detroit Dark Red line (Syngenta) was the poorest of the three standard commercial types assessed. The total yields, sliceable yields and percentage of sliceable beets harvested from plots of this variety were all equivalent to the poorest varieties in the trial ( $P = 0.05$ ).

Pablo was the best of the current standard lines. Fifteen of the lines screened (Warrior, SPS#2, BT0081, YBT9102, Sapphire, BTT1006, SPS#1, BTT1005, YBT9100, Rapid Red, Garnet, BT0082, Four Aces, BT0083, SPS#3, BT0087 and Early Wonder Tall Top) produced significantly greater total yields than Pablo ( $P < 0.05$ ), however in terms of sliceable quantity and percentage of material, Pablo was surpassed only by Warrior ( $P < 0.05$ ).

Nine varieties (BT0081, BTT1006, Rapid Red, BT0082, YBT9100, Red Cloud, Four Aces, BTT1005 and Sapphire) produced equivalent yields and proportions of sliceable beets to Pablo ( $P = 0.05$ ).

Harvest information for the two baby beetroot types (New Globe and BT0084) is presented in Figure 17.

**Figure 17:** Percentage of baby beets in each grading category



## Summary

- Warrior performed better than any other globe-shaped slicing type in both the April and June planting windows.
- Detroit Dark Red was the poorest of the commercial lines in both trials, and was equivalent to the worst varieties assessed in terms of the total sliceable yield and the proportion of sliceable material harvested from each plot.
- In both trials, BTT1006 produced the highest percentage of sliceable material of any variety. BTT1006 was a cylindrical type however, and therefore it did not fit the assessment criteria of Golden Circle. Consequently it was excluded from further assessments. The high recovery of sliceable material from BTT1006 highlights the efficiency of cylindrical lines for this type of processed product. If the processing line at Golden Circle could be modified to allow cylindrical types to be sliced, this would undoubtedly improve efficiency and reduce the quantity of rejected material.
- Nine varieties (Warrior, BT0081, Rapid Red, SPS#2, SPS#3, BTT1005, Green Top Bunching, Sapphire and Pablo) were selected for further assessment based on these two trials (Figure 18).

**Figure 18:** Prospective alternative varieties to industry standard slicing types



Warrior (LeFroy Valley)



BT00081 (Syngenta)



Rapid Red (Henderson)



BTT1005 (LeFroy Valley)



SPS#2 (South Pacific Seeds)



SPS#3 (South Pacific Seeds)



Green Top Bunching (Yates)



Sapphire (Henderson)

## **B) Field Assessments of Beetroot Varieties – 2002**

### **Introduction**

From initial beetroot varietal assessments conducted in 2001, 8 prospective alternative slicing varieties to the current commercial standards were identified. Two of the experiments we report here were completed to assess these prospective types on a commercial scale. The other experiment was completed to assess new genetic material and previous prospective types for suitability as both slicing and baby varieties.

### ***Small-Scale Varietal Assessment (Earl Litzow and Rick Reddacliffe)***

### **Materials and Methods**

Eighteen beetroot varieties were compared as slicing types and five varieties were compared as baby types in a field trial planted on-farm at Forest Hill on 23<sup>rd</sup> May 2002. Seed lots were provided by seed companies (Table 2). The seeds provided had typically been treated with either thiram or a thiram/metalaxyl fungicide seed dressing combination. Prior to planting, seed lots that had only a thiram dressing were also treated with metalaxyl (Apron Liquid Formulation 35 g.a.i./100 kg seed) to ensure that a standard treatment (thiram + metalaxyl) was applied to seed of each variety in the trial.

A germination test was completed for each seed lot planted in the trial following the standard protocol for beetroot seed (International Society of Seed Technologists, International rules for seed testing (1996)).

The trial was planted as a randomised complete block design with 3 replications for slicing types and 4 replications for baby types. Plots comprised 5 x 5m row lengths, with 5 x 2m unplanted buffer lengths at the plot ends. Seed of the slicing type varieties was spaced 80mm apart, and seed of the baby varieties was spaced at 30mm. Seed was threaded into a cellulose tape at the desired spacing (Livyn, Pty Ltd) and was rolled onto a spool. Planting was done using a hand-driven tape planter. The farmer maintained the trial using standard production practices.

Seedling emergence was monitored at 7-day intervals for 4 weeks after sowing, and plants were assessed as either healthy or diseased. At each sampling time the percentage of healthy seedlings was determined for each plot. Data were analysed using ANOVA in Genstat for Windows 5.0.

Plots sown to baby types were harvested in the week commencing 2 September 2002. Slicing types were harvested over a two-week period, concluding 5 November 2002. Harvest times were staggered to reflect the relative maturities of the specific varieties.

**Table 10:** Beetroot varieties assessed in small-scale variety trial (Litzow & Reddacliffe, 2002)

Variety	Seed Company	Type
YBT9105	Yates	slice
YBT9104	Yates	slice
Green Top Bunching	Yates	slice
BT0081	Syngenta	slice
BT0084	Syngenta	slice
Detroit Dark Red	Syngenta	slice
Sapphire	Henderson	slice
Rapid Red	Henderson	slice
Warrior	LeFroy Valley	slice
BTT1005	LeFroy Valley	slice
BTT1006	LeFroy Valley	slice
SPS#2	South Pacific Seeds	slice
SPS#3	South Pacific Seeds	slice
Garnet (carry-over seed 2001)	South Pacific Seeds	slice
Garnet (old, Feb 99 use by date)	PetroSeeds	slice
Pablo (carry-over seed 2001)	Bejo	slice
Pablo (new 2002)	Bejo	slice
New Globe	Syngenta	slice
New Globe	Syngenta	baby
BT0084	Syngenta	baby
Pablo (carry-over seed 2001)	Bejo	baby
SPS#2	South Pacific Seeds	baby
Warrior	LeFroy Valley	baby

At harvest, beets from the centre 2 rows of each plot were removed manually and the tops were cut from the plants with knives. The roots of the slicing types were manually graded into 7 categories (Table 6) and the baby types were graded into 5 categories (Table 7). For each plot, the number of beets and the total weight of beets in each category were determined. Harvest data were analysed using the Analysis of Variance function (ANOVA) in Genstat 5.0 for Windows.

An additional internal assessment was made for the baby types. A selection of 50 beets was made from the material graded as baby beets from each plot. Each beet was cut open and the extent of white zoning and discolouration was measured using a qualitative visual rating scale (0=nil, 1=slight, 2=moderate, 3=severe).

## Results

Seed germination results for all varieties in the trial are presented in Table 11.

**Table 11:** Percentage of germinated seeds from seed lots planted in small-scale variety trial 2002 (Litzow and Reddacliffe)

Variety	Day 3	Day 7	Day 10	Day 14	Total
BT0081 - Syngenta	11	84	1	2	<b>98</b>
BT0084 - Syngenta	13	71	7	1	<b>92</b>
YBT 9104 - Yates	0	88	7	0	<b>95</b>
YBT 9105 - Yates	34	60	2	0	<b>96</b>
Green Top Bunching - Yates	0	71	8	0	<b>79</b>
Rapid Red - Hendersons	91	8	0	1	<b>100</b>
Sapphire - Hendersons	89	7	2	0	<b>98</b>
Warrior – LeFroy Valley	28	63	5	0	<b>96</b>
BTT1005 - LeFroy Valley	23	32	12	9	<b>76</b>
BTT1006 - LeFroy Valley	41	21	8	7	<b>77</b>
SPS #2	6	24	32	7	<b>69</b>
SPS #3	67	22	3	1	<b>93</b>
Detroit Dark Red (Untreated)	77	17	3	0	<b>97</b>
Detroit Dark Red (provided by Golden Circle)	60	15	7	4	<b>86</b>
New Globe (provided by Golden Circle)	79	6	2	3	<b>90</b>
Pablo 2001 - Bejo	43	47	1	0	<b>91</b>
Pablo 2002 - Bejo	3	32	9	29	<b>73</b>
Garnet (expiry date 1999 - Merv Neumann)	28	44	3	4	<b>79</b>
Garnet 2001	0	8	48	22	<b>78</b>

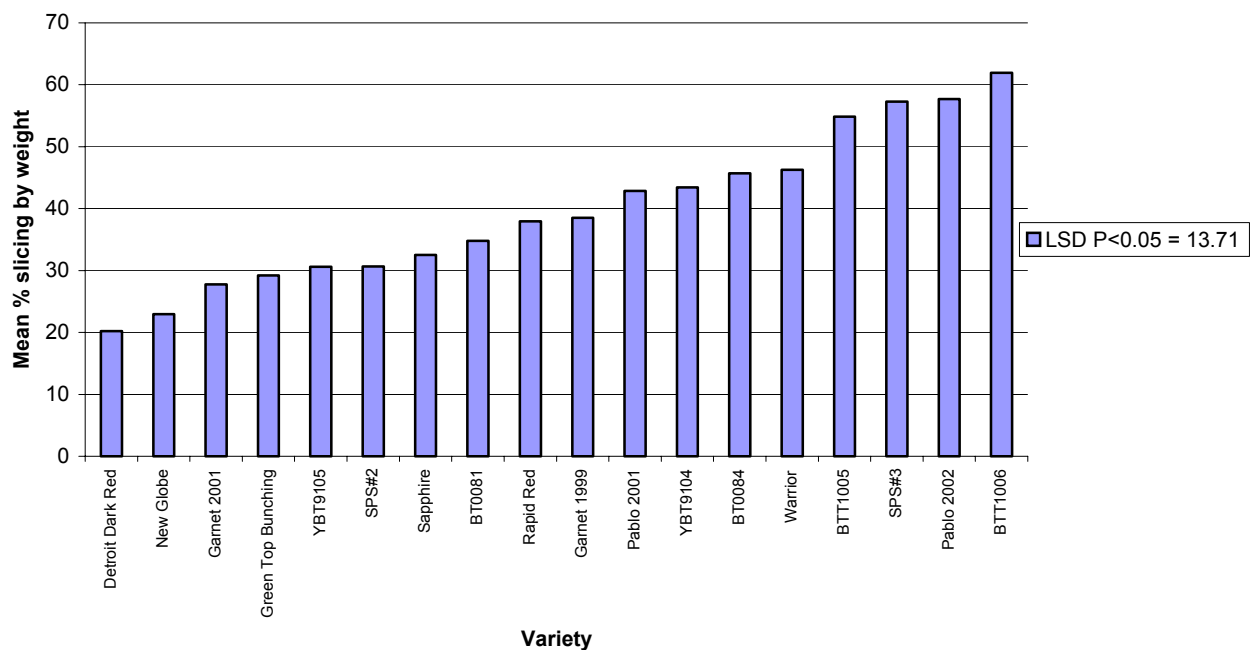


## Slicing Types

Despite large variability in the germination percentages of the different seed lots, all 18 slicing type varieties assessed in this trial emerged at comparable rates after sowing. On the basis of data collected at harvest, the standard commercial Detroit Dark Red line (Syngenta) was the poorest performer of the three current standard commercial types included in this trial. Although it produced an overall yield equivalent to the highest yielding varieties in the trial, the percentage of Detroit Dark Red material that was sliceable was only 20.19% - the lowest for any variety. Percentage sliceable yield, total sliceable yield and total yield information for each variety is presented in Figures 19 and 20.

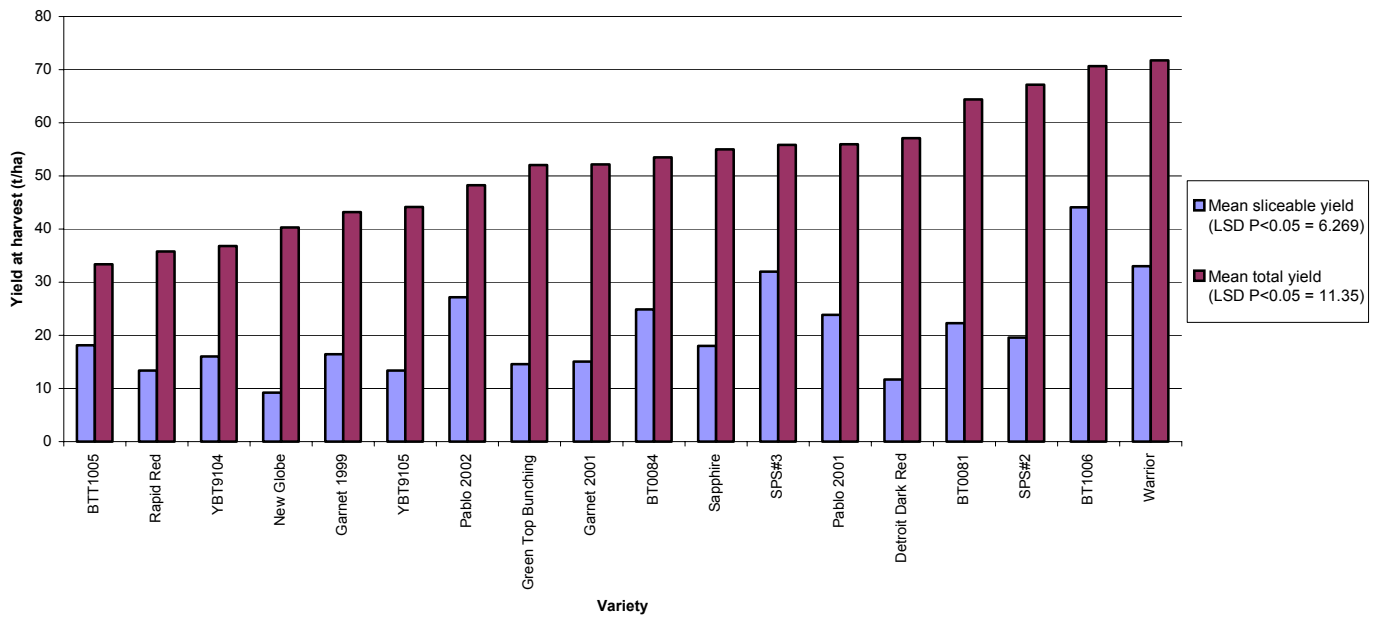
A significantly ( $P < 0.05$ ) higher proportion of sliceable material was recovered for Pablo 2002 (57.69%) than Pablo seed from season 2001 (42.85%) (Figure 19). BTT1006, Pablo 2002, SPS#3, BTT1005 and Warrior were the varieties that produced the highest proportions of sliceable beets. Of these, Warrior, SPS#3 and BTT1006 appeared to be the most prospective varieties because they were both high yielding and produced high proportions of sliceable beets (Figure 20). It seems likely that had harvest been delayed for BTT1006 and SPS#3, the proportion of sliceable beets may have been higher still for these varieties, since both of these yielded significantly greater quantities of undersized material than all other lines in the trial. This result indicated that BTT1006 and SPS#3 are slow-maturing varieties. SPS#2, another variety with a high total yield, had a significantly higher tendency than other varieties to crack, which consequently reduced the proportion of sliceable beets for this variety (data not presented). The proportion of oversized beets or beets containing cavities was comparable for all the varieties tested (data not presented).

**Figure 19:** Sliceable beet yields from small-scale variety trial (Litzow & Reddacliffe, 2002)



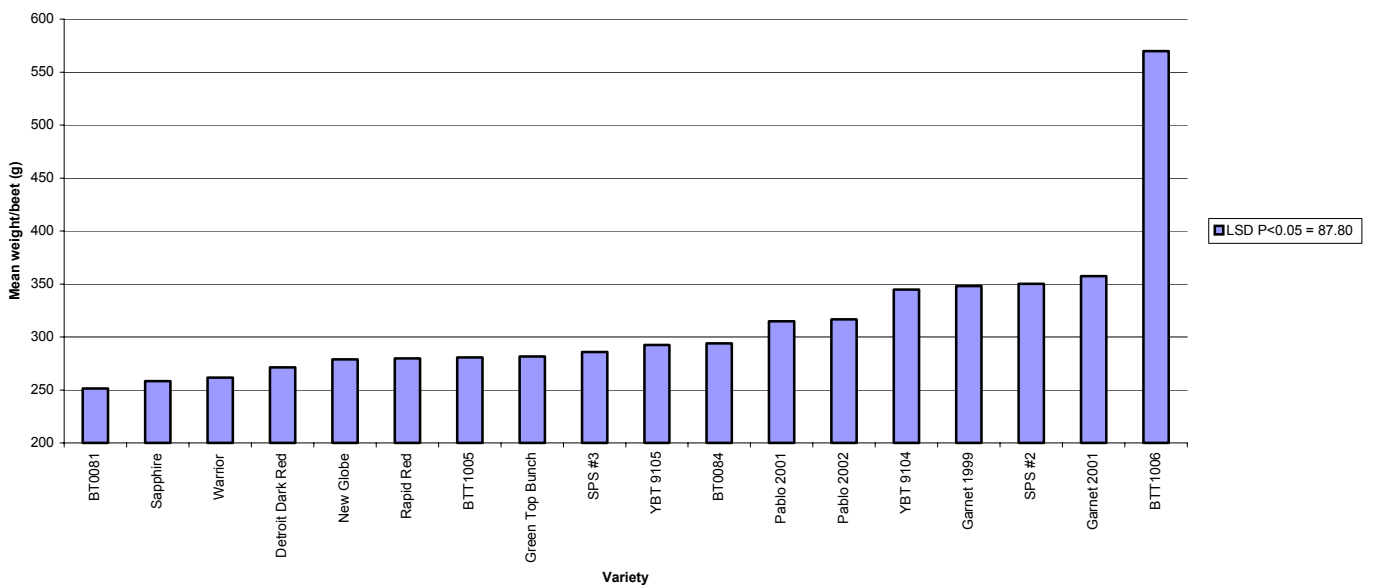


**Figure 20:** Total yields and sliceable yields from small-scale variety trial, (Litzow & Reddacliffe, planted 25/5/02)



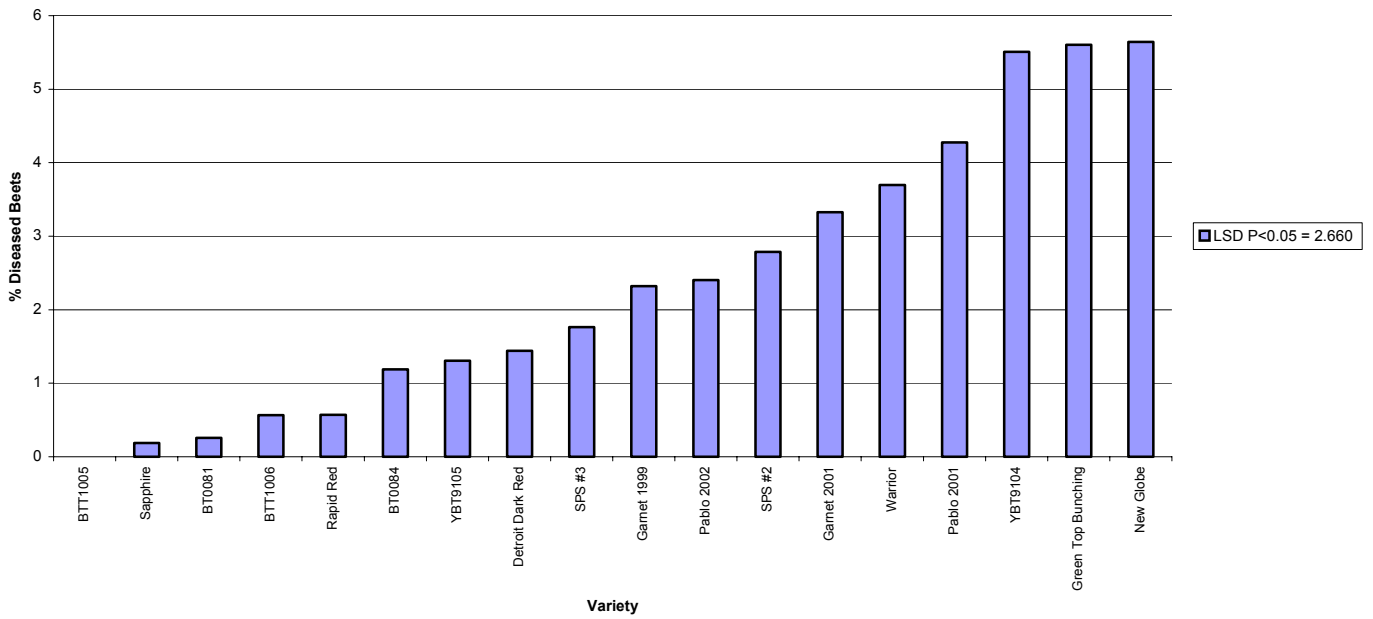
BTT1006 also produced individual beets of the greatest average weight (569.8g) (Figure 21).

**Figure 21:** Mean weight of sliceable beets from small-scale variety trial (Litzow & Reddacliffe, planted 23/5/02)



Disease incidence was very low in this trial. BTT1005 yielded no beets with disease symptoms. New Globe, Green Top Bunching and YBT9104 were the varieties most affected by disease. Despite this, all three varieties contained less than 6% diseased beets (Figure 22).

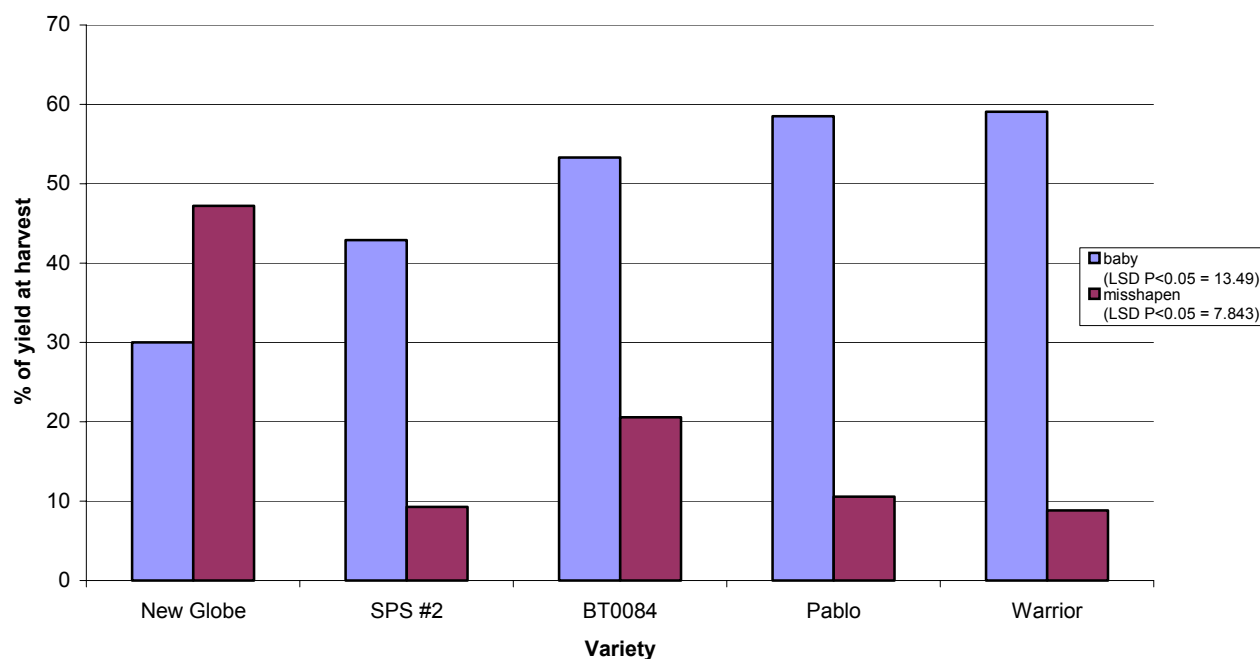
**Figure 22:** Percentage of diseased beets by weight from small-scale variety trial, (Litzow and Reddacliffe, planted 23/5/02)



### Baby Types

In this trial, SPS#2 was significantly slower to emerge than the other varieties. In terms of total yield, all five varieties performed equally well, however there were substantial differences in the proportions of suitable baby sized material recovered from each variety (Figure 23).

**Figure 23:** Percentage acceptable baby and misshapen types from small-scale variety trial (Litzow & Reddacliffe, planted 23/5/02)



The current industry standard type, New Globe, was the poorest variety in the trial in terms of the percentage of baby material recovered (30.01%). New Globe produced a significantly greater quantity of misshapen beets than any other variety (47.19%) (Figure 2). Warrior was the most prospective variety in terms of the percentage yield of baby beets and Pablo and BT0084 yielded comparable proportions of baby beets to Warrior.

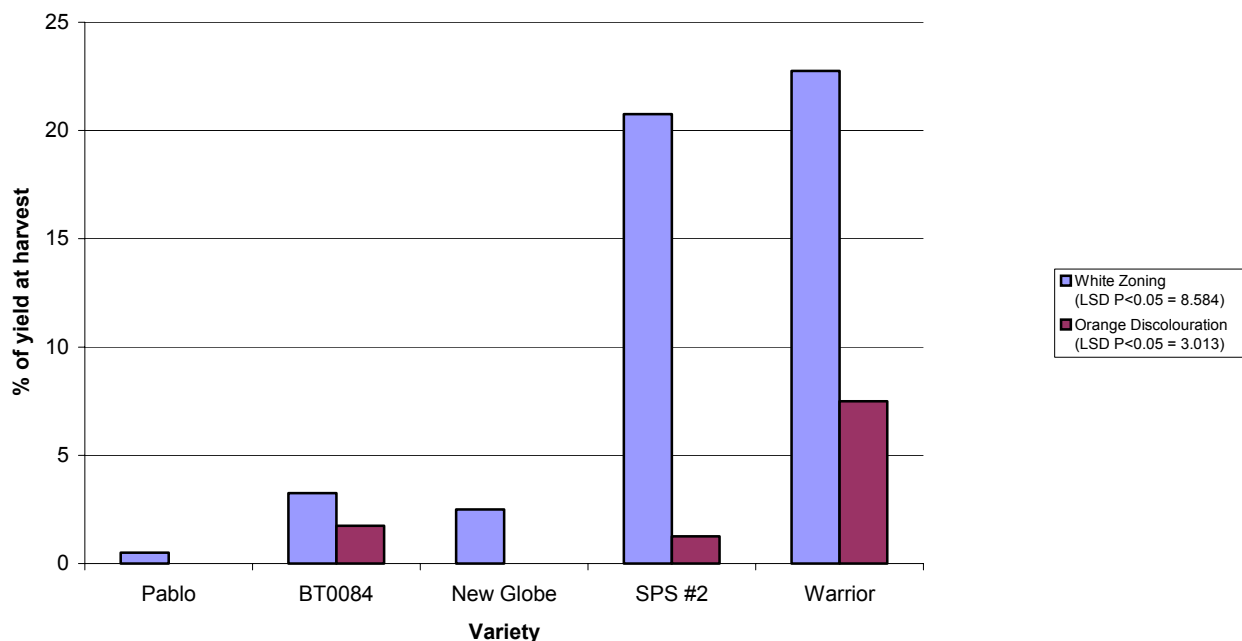
**Figure 24:** New Globe yielded a high proportion of misshapen baby beets



SPS#2 yielded a lower percentage of baby material, however, this variety produced significantly more oversized material than the other varieties, which is likely to have impacted negatively on the proportion of baby material recovered from this variety. SPS#2 may therefore represent a promising variety, which was quicker to mature than the other varieties assessed in this trial. Pablo, Warrior and SPS#2 contained the lowest proportions of misshapen beets of the varieties in the trial. There were no differences between any of the varieties in terms of the proportion of diseased or cracked beets or the percentage of beets containing cavities (data not presented).

Percentage recovery figures for baby beets with internal defects are presented for each variety in Figure 25.

**Figure 25:** Percentage of baby beets with internal defects from small-scale variety trial (Litzow & Reddacliffe, planted 23/5/02)



Both SPS#2 and Warrior contained a significantly higher proportion of beets with internal “white zoning” and orange discolouration than either Pablo or New Globe. Warrior was particularly prone to the “orange discolouration” defect.

## **Summary**

- Detroit Dark Red was the poorest of the three commercial slicing types. It had the lowest proportion of sliceable material of any variety in the trial.
- SPS#3, Warrior and BTT1005 were the most prospective alternatives to the current commercial standard types based on their total yields and percentages of sliceable product.
- SPS#3 and BTT1006 were both slower to reach optimal size than the other slicing types, and SPS#2 had a greater tendency to crack than the other lines.
- The current standard baby type (cv. New Globe) was the poorest of the baby varieties, its high rejection rates being due predominantly to misshapen material. In comparison, Warrior, Pablo, BT00084 and SPS#2 were all promising alternative baby types in terms of size and shape. SPS#2 matured more rapidly than the other lines.
- Warrior and SPS#2 had a greater propensity for internal defects than the other types.

## ***Commercial Scale Variety Trials (Ashley Zelinski and Moira Farms)***

### **Introduction**

Ten beetroot varieties (BT0081, BTT1005, Green Top Bunching, Pablo, Rapid Red, Sapphire, SPS #2, SPS #3, Warrior and Detroit Dark Red) were compared in a field trial planted on-farm at Mt Tarampa . The same varieties, except for Detroit Dark Red, were assessed at a second site on a farm at Forest Hill. The trials were planted on the 11<sup>th</sup> and 5<sup>th</sup> April 2002. Seed of all varieties was sourced directly from seed companies. All seed was treated with thiram/metalaxyl fungicide dressing combinations.

Both trials were planted as randomised complete block designs with 4 replications. Blocks comprised 10 rows (planted on flat ground), 400m long at the Mt Tarampa site and 9 rows (planted on individual beds), 75m long at the Forest Hill location. Immediately prior to harvest, beets were removed manually from 4 x 2m row lengths within each row. The tops were cut from the plants with knives and the roots were manually graded into 7 categories according to size and quality criteria suggested by Golden Circle P/L (Table 6)

For each sample plot, the number of beets and the total weight of beets in each category were determined. Harvest data were analysed using the Analysis of Variance function (ANOVA) in Genstat 5 for Windows. In addition, 50 beets were randomly selected from each plot, cut at harvest, and visually rated for internal defects.

Following the removal of the 2m sample lengths, the remaining beets in each plot were mechanically harvested and sent to Golden Circle P/L for processing. Five of the varieties (Warrior, SPS #2, Sapphire, BT0081 and BTT1005) were canned and assessed by Golden Circle representatives for processing characteristics.

## **Results**

### *Commercial Scale Variety Trial (Ashley Zelinski)*

At harvest, in terms of the quantity and percentage of sliceable material, the standard commercial Detroit Dark Red line was the poorest variety in this trial.

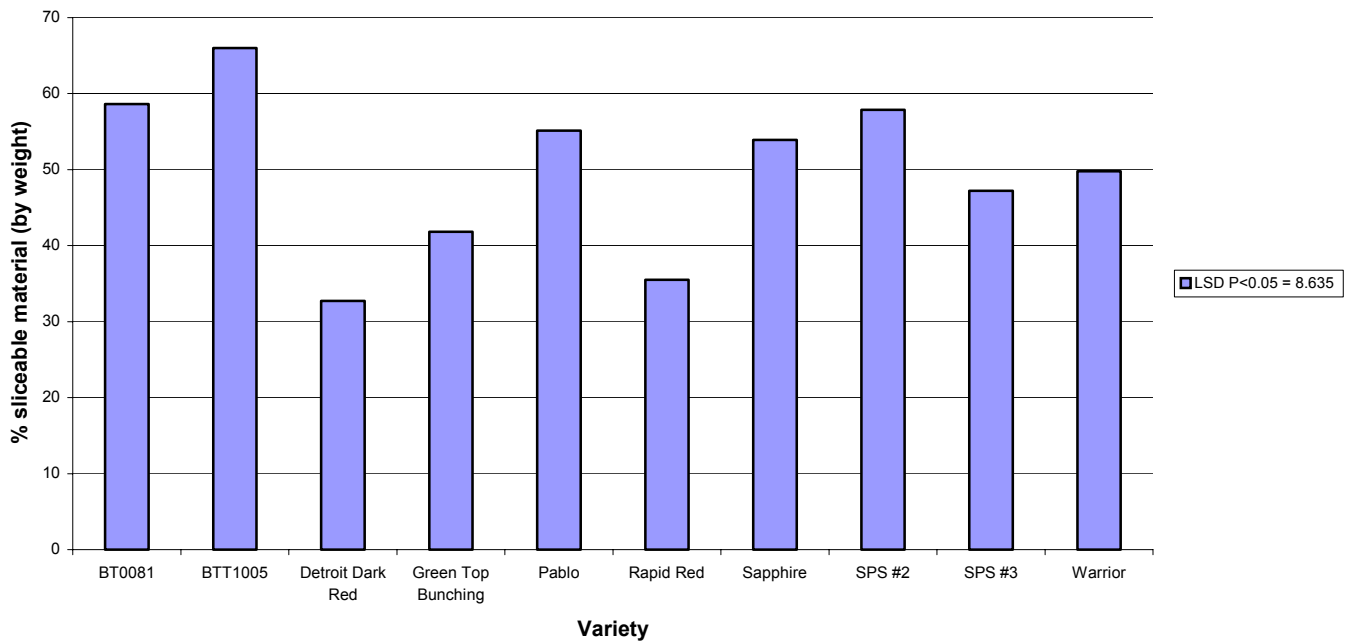
A beetroot variety grown as a processing slicing type is required to yield a large quantity and percentage of sliceable material. Percentage sliceable yield and total yield information for each variety is presented in Figures 26 and 27.

In this trial the three varieties BTT1005, BT0081 and SPS#2 produced the best result in terms of both the quantity and percentage of sliceable material. BTT1005 had significantly less misshapen beets than any other variety and Detroit Dark Red had significantly more.

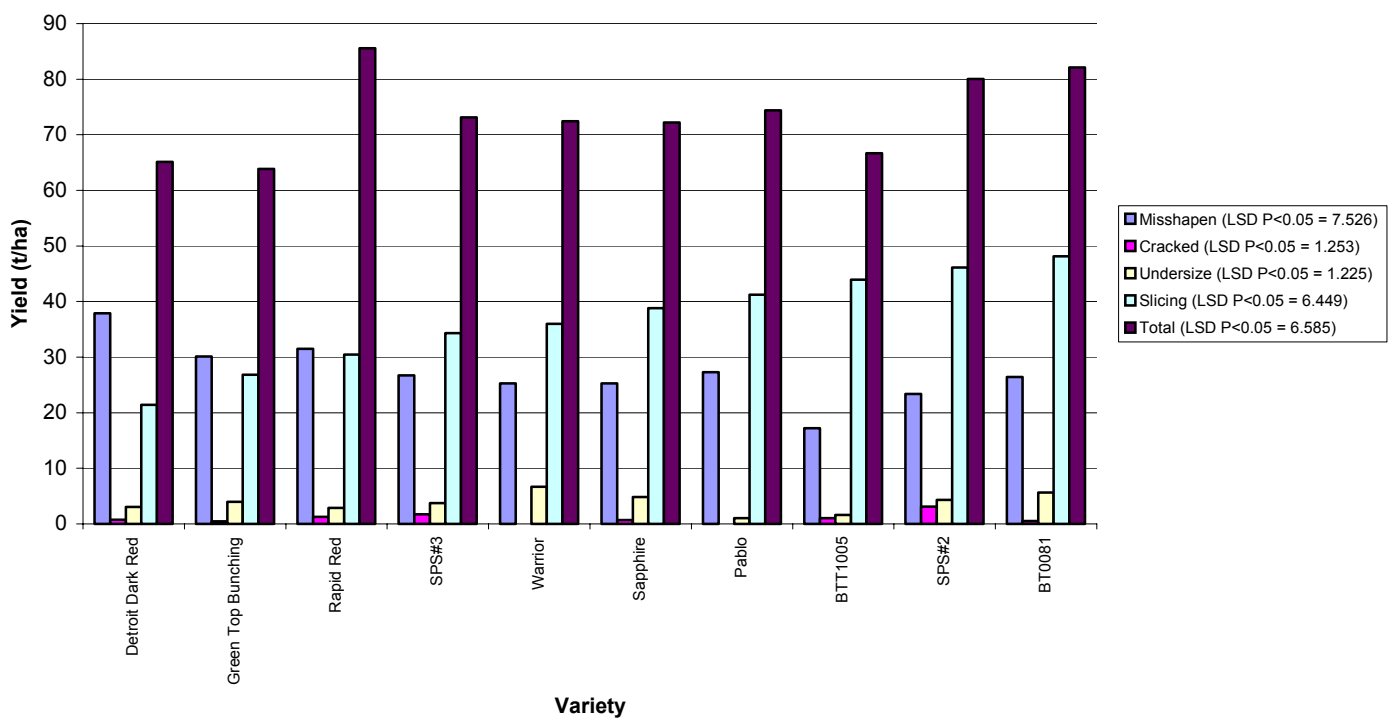
SPS #2 and SPS#3 had significantly more cracked material than all other varieties, but there were no significant differences between varieties in terms of susceptibility to disease, on the basis of a visual assessment at harvest.

Detroit Dark Red, Green Top Bunching and Rapid Red were the poorest performers in the trial in terms of the total quantity and percentage of sliceable material.

**Figure 26:** Percentage of sliceable beetroot (by weight) at harvest (Zelinski, 2002)

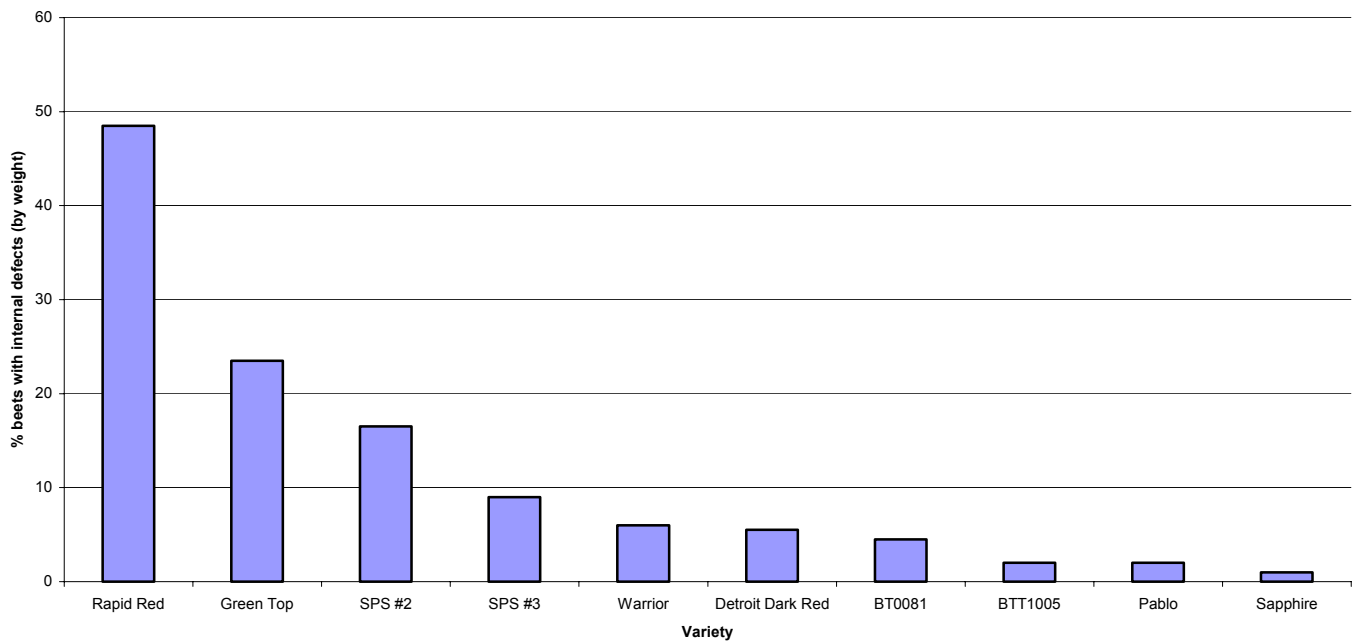


**Figure 27:** Yield data for slicing type beetroot (Zelinski 2002)



Data from internal assessments is presented in Figure 28. White zoning, orange discolouration and hollowness were categorised as defects. Rapid Red fared significantly ( $P<0.05$ ) worse than any of the other varieties tested in terms of internal defects (Figure 28). Green Top Bunching and SPS #2 also had significantly more internal defects than the other varieties. The severity of internal defects was equivalent in all other varieties.

**Figure 28:** Percentage of beetroot with internal defects (Zelinski, 2002)



**Figure 29:** “White zoning” of vascular cambium tissue of cv. Rapid Red



*Commercial Scale Variety Trial (MoirasFarms)*

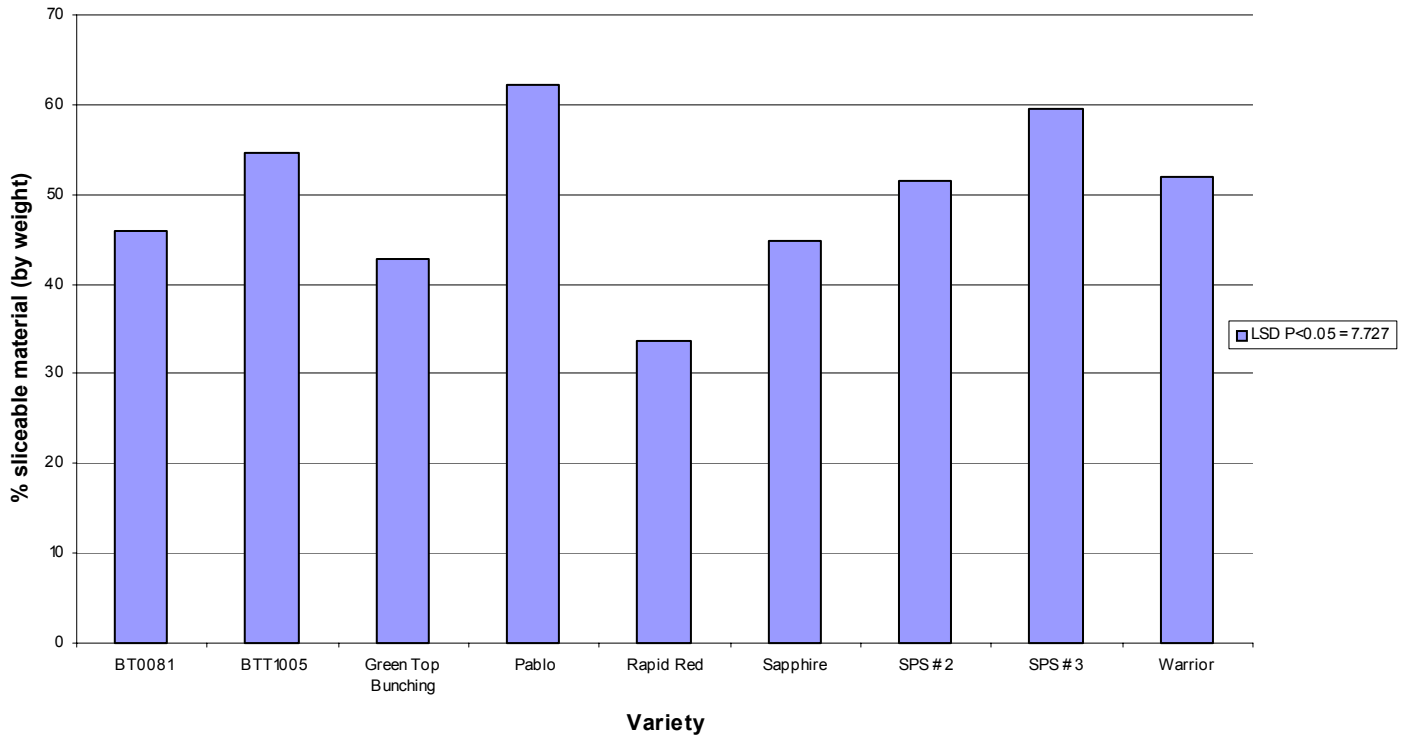
Percentage sliceable yield and total yield information for each variety is presented in Figures 30 and 31. In this trial, the largest proportions of sliceable material were recovered from BTT1005, SPS #3 and Pablo (the standard industry line). Rapid Red was the poorest variety in the trial in terms of the quantity of sliceable material and the sliceable material expressed as a percentage of the total yield. Green Top Bunching, BT0081 and Sapphire also yielded relatively low proportions of sliceable material.

Rapid Red produced a significantly ( $P < 0.05$ ) greater quantity of misshapen material than any other variety, closely followed by Sapphire and BT0081, which had greater quantities of misshapen material than Pablo – the standard industry type.

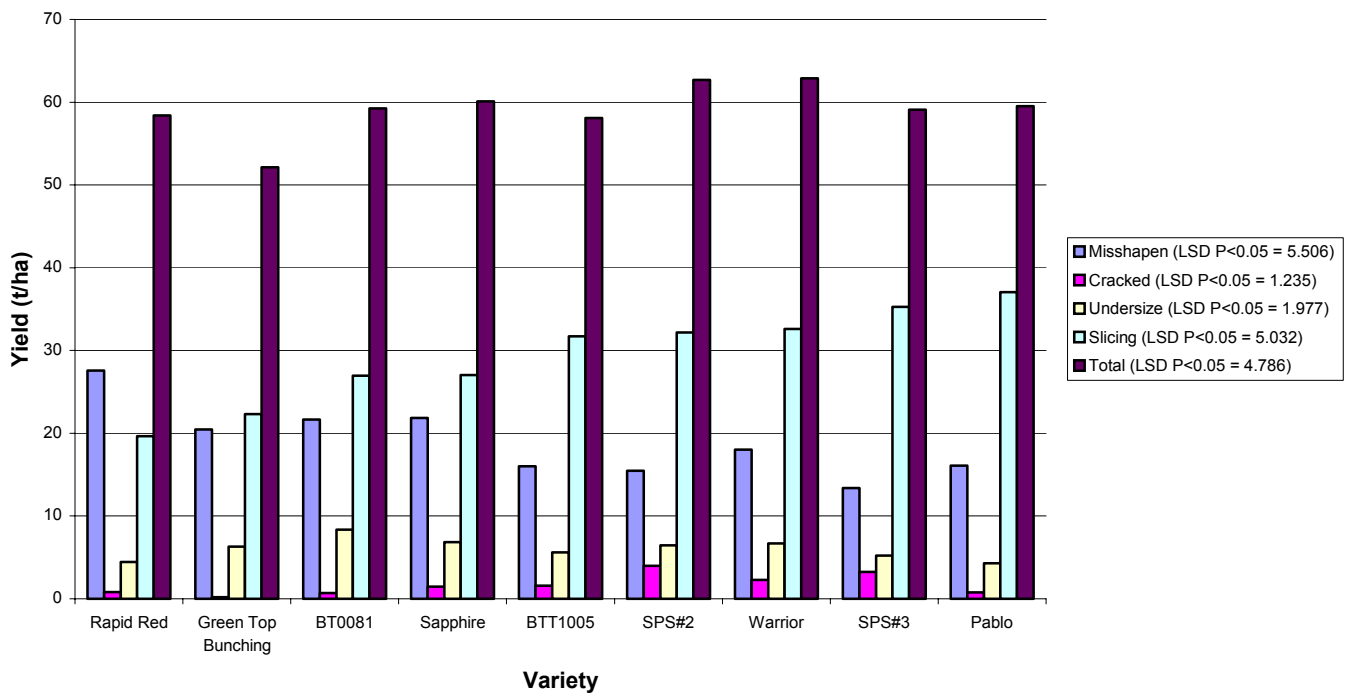


SPS#2 and SPS#3 contained significantly ( $P<0.05$ ) more cracked roots than all the other varieties, but there was no significant difference between the varieties in terms of susceptibility to disease, on the basis of a visual assessment at harvest.

**Figure 30:** Percentage sliceable beetroot (by weight) at harvest (Moira Farms, 2002)



**Figure 31:** Yield data for slicing type beetroot (Moira Farms, 2002)



*Assessment of Varieties by Golden Circle P/L*

Five of the varieties grown in the commercial scale varietal assessments by Ashley Zelinski and Moira Farms (Warrior, SPS#2, Sapphire, BT0081 and BTT1005), were processed by Golden Circle and assessed as alternate production varieties to current slicing types. A summary of Golden Circle’s assessments are presented (Tables 12 and 13)

**Table 12:** Visual, texture and flavour characteristics of alternate slicing type beet varieties grown in commercial-scale field assessments

<b>Variety</b>	<b>Visual Assessment (Pre-Cooking)</b>	<b>Taste and Appearance (Post-Cooking)</b>
Warrior	<ul style="list-style-type: none"> <li>- spherical consistent shape</li> <li>- good for producing circular slices</li> <li>- no holes, minimal disfigurement</li> <li>- low requirement for trimming</li> <li>- potentially increased production time</li> <li>- reduced cost of labour associated with processing</li> </ul>	<ul style="list-style-type: none"> <li>- typical taste of canned beetroot</li> <li>- texture slightly “rubbery”</li> </ul>
SPS#2	<ul style="list-style-type: none"> <li>- spherical consistent shape</li> <li>- good for producing circular slices</li> <li>- some holes, but beets containing holes were easily recognized because they were malformed</li> <li>- low requirement for trimming</li> </ul>	<ul style="list-style-type: none"> <li>- typical taste of canned beetroot</li> <li>- slightly fibrous, particularly in the larger slices</li> </ul>
Sapphire	<ul style="list-style-type: none"> <li>- spherical consistent shape</li> <li>- good for producing circular slices</li> <li>- very smooth, shiny exterior</li> <li>- some holes, but far fewer than SPS#2</li> <li>- stalks and roots easily removed</li> <li>- finished product (pre-cook) presented second behind Warrior</li> </ul>	<ul style="list-style-type: none"> <li>- typical taste of canned beetroot</li> <li>- slices have a good texture, shape and size</li> </ul>
BTT1005	<ul style="list-style-type: none"> <li>- product from Zelinski differed in appearance to that from Moira Farms</li> <li>-Zelinski product: odd shaped, contained white rings when sliced and a white non-concentric pattern typical of a beetroot that contains hollows. Numerous hollows.</li> <li>-Moira product: no problem with shape, internal discolouration or hollows</li> </ul>	<ul style="list-style-type: none"> <li>- slight to apparent “earthy” flavour</li> <li>- slight rubbery texture (but not offensively so)</li> </ul>
BT0081	<ul style="list-style-type: none"> <li>- odd shaped</li> <li>- some hollows</li> <li>- very light flesh colour (not evident when canned)</li> </ul>	<ul style="list-style-type: none"> <li>- very sweet, clean taste</li> <li>- flawless flavour</li> <li>- texture a little hard</li> </ul>

**Table 13:** Processing characteristics of alternate slicing type beet varieties grown in commercial-scale field assessments

Date	Variety	Load Wt. (kg)	Odenburg Wt. (kg)	Post-trim Wt. Approx. (kg)	Final Drained Wt. (kg)	% of Load Used	% Recovery (post-trim)	% Recovery (final)
30/9/02	Warrior	4698.6	4586.7	4120	3413.6	97.6	85.5	72.65
30/9/02	SPS#2	7861.4	7559.4	6580	5477.8	96.2	83.7	69.68
30/9/02	Sapphire	7695.2	7391.9	7030	6033.8	96.1	91.4	78.41
3/10/02	BTT1005	5182.8	5063.2	4590	3479.4	97.7	88.6	67.13
3/10/02	BT0081	5479.7	5413.8	4265	3854.9	98.8	77.8	70.35

Due to the small size of the trials, wastage played a major role in reducing recovery. The level of wastage indicated should not be extrapolated as an indicator of what a full load would produce, since the level of wastage in running out the line is equivalent for any production amount.

Golden Circle P/L considered three of the varieties to be prospective alternatives to current slicing standards. Sapphire was considered the best performer, followed by Warrior and BT0081. SPS#2 and BTT1005 are to be considered for generic brands. Warrior had the best circular shape and was considered to be most ideal for burger beetroot.

### *Plant Spacing Assessment for Slicing and Baby Types (Ashley Zelinski)*

#### **Introduction**

The density at which beetroot seed is sown is a variable that is manipulated by growers depending on the type of product (baby vs slice), the time of year and the variety being grown. Not only does the sowing rate influence the total yield of raw product per unit of land area, but it is likely that it may also have an impact on the quality of the harvested material. The quantity of misshapen material seems particularly likely to be influenced by the spacing distance. As a complicating factor to this argument however, all beetroot varieties currently grown by the Australian industry have multigerm seeds, with between 1 and 4 plants arising from each seed. Since the seeds are multigerm, it seems reasonable to speculate that plant crowding will necessarily occur because multiple shoots all arise from the one point, and that spacing seed further apart will hence do little to negate plant crowding. We wanted to test whether changing the distance between the plants within the row alters the quality and quantity of harvested material in baby and slicing beet crops.

#### **Materials and Methods**

The optimal planting densities for cv. Detroit Dark Red as a slicing type beet and cv. New Globe as a baby variety were determined in two field trials conducted on-farm at Mt Tarampa. The Detroit Dark Red was sown on 10 July 2002 and the New Globe on 15 June 2002. All seed was sown on flat ground in single rows spaced 21" apart. Three weeks after sowing, seedlings in plots of New Globe each comprising 5 rows, 2m long were thinned to the desired spacing. Six plant spacings (20, 25, 30, 40, 50 and 60mm) were evaluated. Similarly, plots of seedlings (5 rows x 2m long) of

Detroit Dark Red in the slicing trial were thinned. The six spacings in the Detroit Dark Red trial were 60, 70, 80, 90, 100 and 110mm. Both trials were completed as randomised complete block designs with 4 replications.

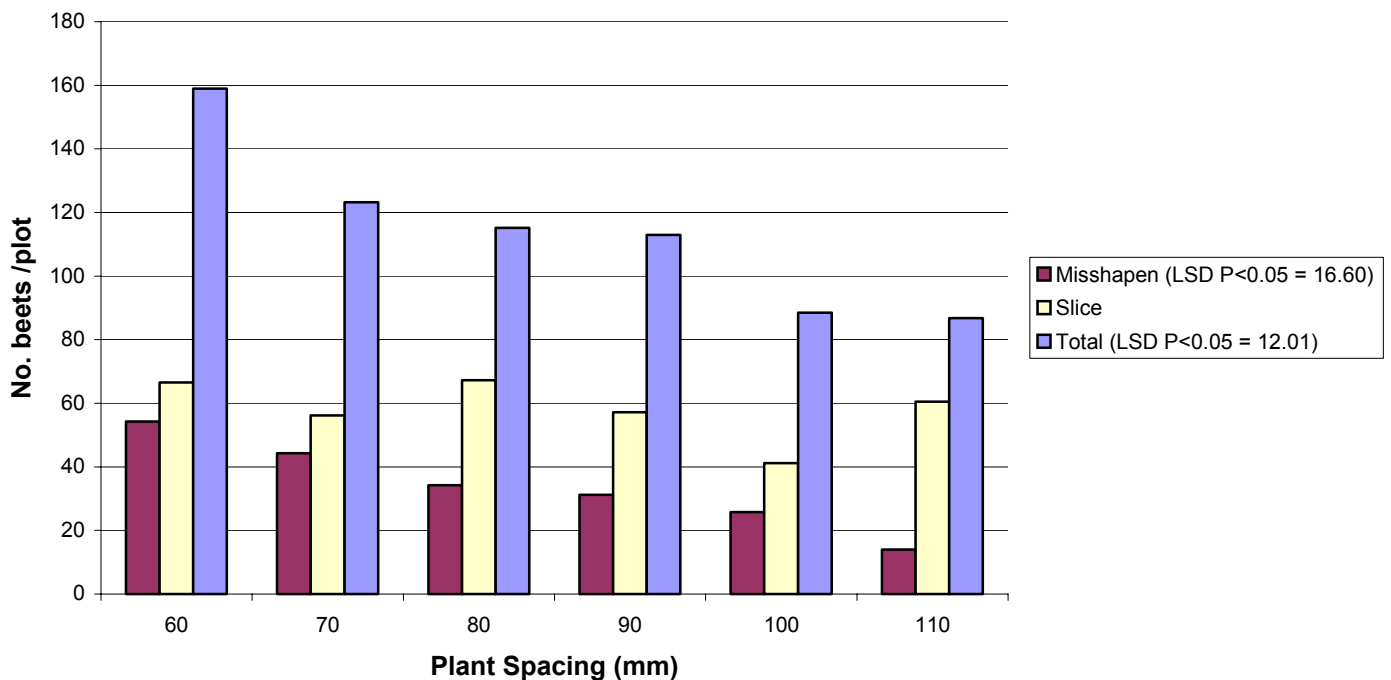
At harvest, beets from the centre 3 rows of each plot were removed manually and the tops were cut from the plants. The roots were graded into 7 categories previously given (Table 6). For each plot, the number of beets and the total weight of beets in each category were determined. Harvest data were analysed using the Analysis of Variance function in Genstat 5.0 for Windows.

## Results

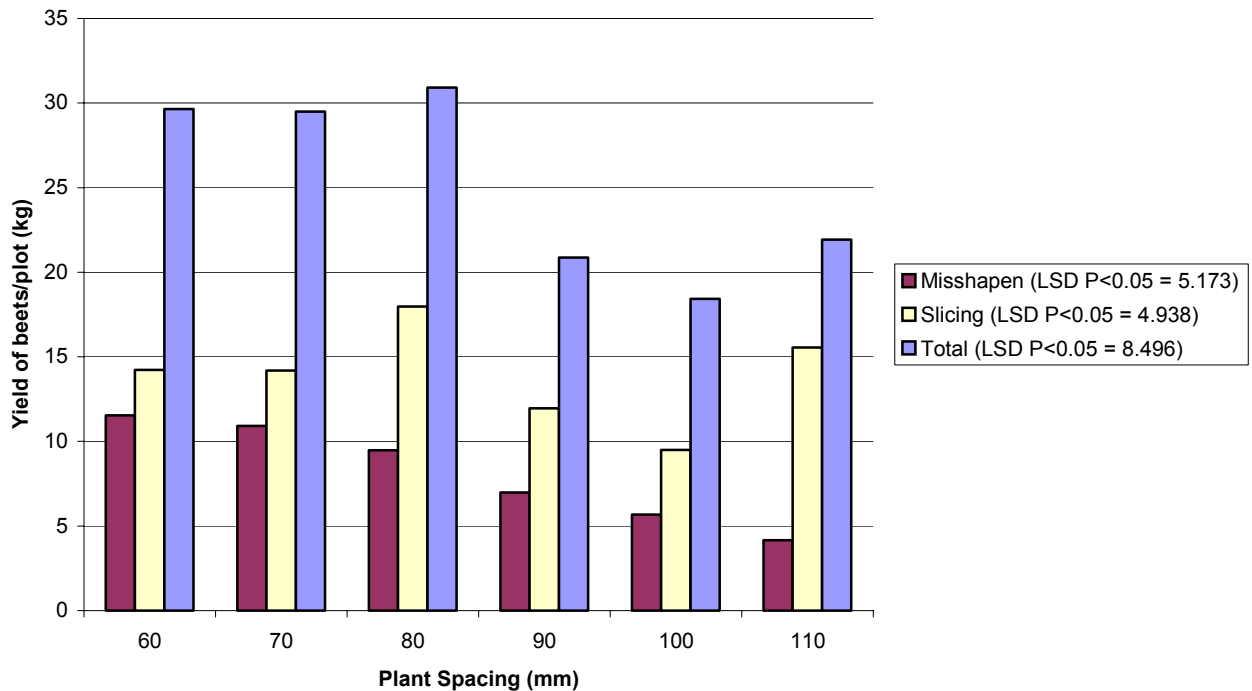
### *Slicing Types*

Data for the slicing beetroot plant spacing assessment is presented in Figures 32 and 33. On the basis of total yields and sliceable yields, 80mm was the optimal spacing for the plants in this trial. The total yield (kg) of beets from plots with an 80mm plant spacing was greater than plots in which plants was spaced further apart. As well as a high total yield, plots with plants spaced at 80mm yielded quantities of sliceable material equivalent to the highest in the trial (Figure 33). Plots with plants spaced at 60 and 70mm yielded greater numbers of misshapen beets than plots where plants were more widely spaced. As plant spacing decreased, the number of misshapen beets increased (Figure 32).

**Figure 32:** Numbers of harvested beetroot (Detroit Dark Red) from plant spacing assessment graded into different categories (Ashley Zelinski) (planted 15 June 2002)



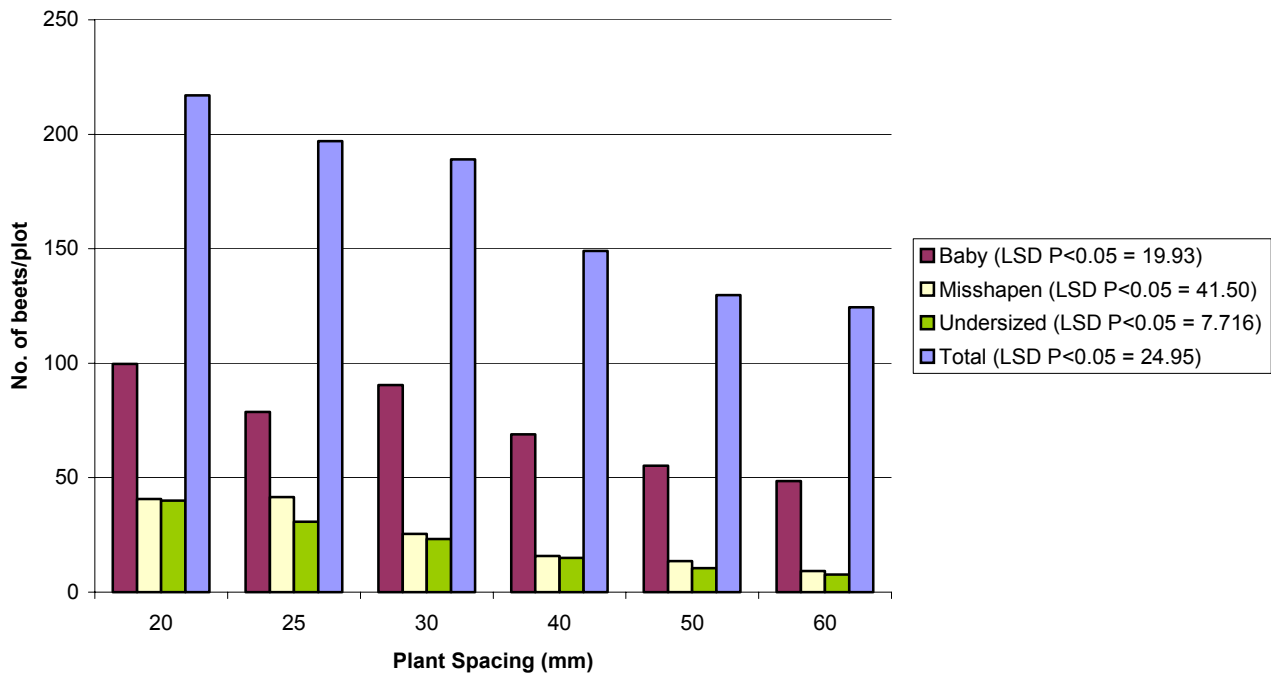
**Figure 33:** Total weights of harvested beets (Detroit Dark Red) from plots in plant spacing assessment (Ashley Zelinski) (planted 15 June 2002)



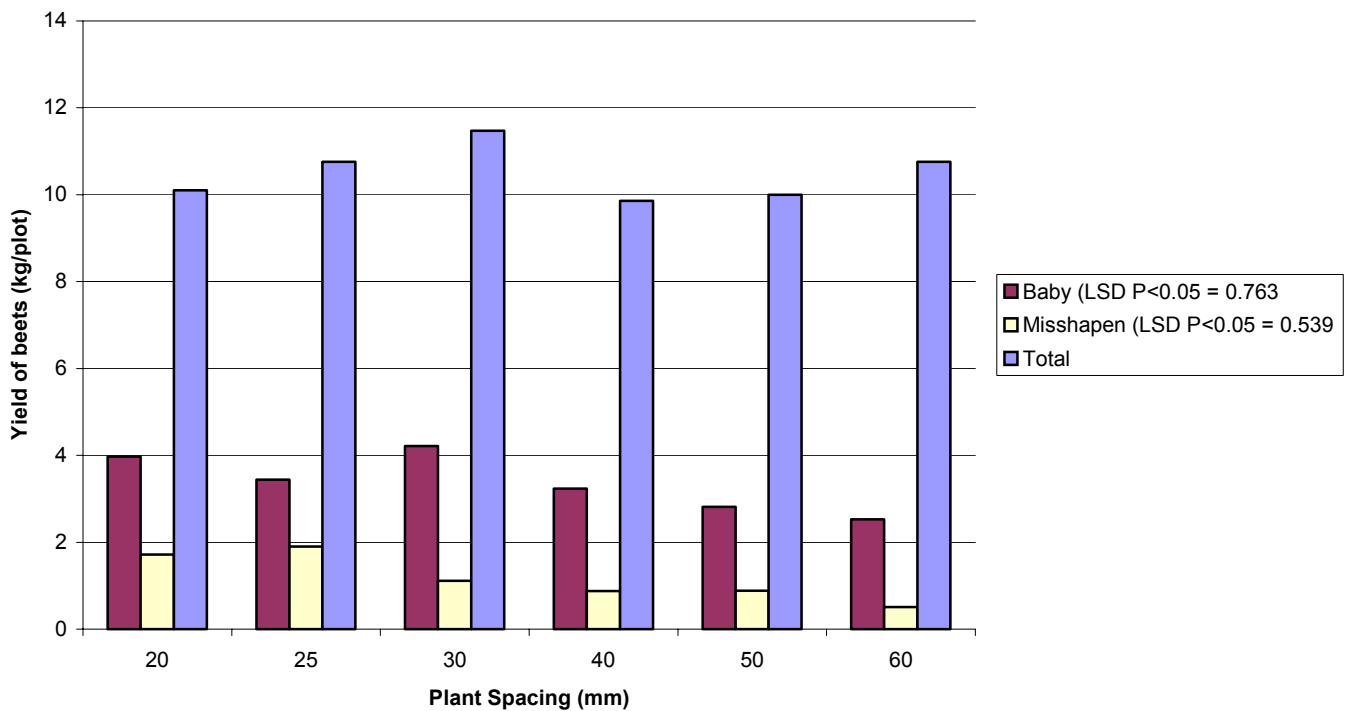
*Baby Types*

Data for the baby beetroot plant spacing assessment is presented in Figures 34 and 35. The optimal spacing for cv. New Globe plants in this trial was 30mm. The number of baby beets recovered was greatest from plots in which plants was spaced at 20 or 30mm and the weight of baby material was also greatest from the 30mm plots. There were no significant differences between the total yields (kg) obtained from any of the spacings. Plots with plants spaced at 40mm or less did, however, yield a higher proportion of baby beets. When plants were spaced at 50-60mm, plots contained significantly greater proportions of oversized beets. At spacings of 20-25mm, proportions of the total yield that were misshapen or undersized were significantly greater ( $P<0.05$ ).

**Figure 34:** Numbers of harvested beetroot (New Globe) from baby beet plant spacing assessment, graded into different categories (Ashley Zelinski) (planted 15 June 2002)



**Figure 35:** Total yields of harvested baby beetroot (New Globe) from plant spacing assessment (Ashley Zelinski) (planted 15 June 2002)



For both the slicing and baby beet trials we established that substantial improvements in processable yield and quality can be realised by altering plant spacing. In particular, our data shows a clear inverse relationship between the quantity of misshapen beets and the distance between the plants, in both trials. It is highly probable therefore, that by planting multigerm beet varieties the Australian industry is reducing the quality and quantity of sliceable product that it produces. For multigerm varieties, because multiple plants arise from the one seed, plants encroach on each other as they grow. The results from our trials clearly indicate that if plants impinge on each other's growth because they are spaced close together, higher proportions of misshapen and undersized material will result. Furthermore, we have demonstrated that by thinning plants (to remove the "multigerm effect"), plant spacing can be optimized so that a favourable compromise is obtained between total yield and beet quality. It seems therefore, that the use of multigerm lines is reducing the efficiency of the industry to produce the high quality product it desires. For this reason, it is the author's recommendation that monogerm beet varieties be sought by this industry. The seed of monogerm lines will have a greater upfront cost to growers than seed of the current standard varieties, however it would be surprising if this additional cost was not offset by the gains in quality that result. A cost/benefit analysis for different varieties should be completed by Golden Circle P/L to test this theory.

## Summary

- As in previous trials, Detroit Dark Red was again the poorest commercial standard, and was equivalent to the worst varieties in the trial.
- BTT1005, BT0081, Warrior, SPS#2 and SPS#3 were the most prospective alternative slicing types.
- Rapid Red, Green Top Bunching and SPS#2 had more beets with internal defects. Rapid Red was particularly prone to white zoning in the parenchyma tissue. SPS#2 and SPS#3 were also more susceptible to cracking than the other varieties.
- All varieties were equally susceptible to disease and disease levels were low in both trials.
- The total number of beets in plots of SPS#5 was significantly less than in plots of either SPS#4 or Detroit Dark Red. This was presumably because SPS#5 was a monogerm variety. All other varieties in this trial were multigerm.
- Sapphire, Warrior and BT0081 were assessed by Golden Circle P/L to be suitable alternatives to current standard lines for canning. SPS#2 and BTT1005 are to be considered for generic brands. Warrior was judged to have the best circular shape and was considered to be most ideal for burger beetroot.
- A spacing distance between plants of 80mm was optimal for slicing beets cv. Detroit Dark Red, and a distance of 30mm was best for baby beets cv. New Globe. A clear inverse relationship between plant spacing and the quantity of misshapen material, was demonstrated in both trials. Since plant spacing

strongly influences harvest quality and quantity, monogerm beet varieties should be sought by the industry.

## **C) Field Assessments of Beetroot Varieties – 2003**

### **Introduction**

Additional varieties to those sourced for the 2001-2002 field trials were obtained from seed companies in 2003. These were assessed against the current industry slicing types in small-scale field trials in 2003.

The poor performance of Detroit Dark Red in the 2001-2002 trials, and in particular its high rejection rates due to misshapen material, led us to speculate that the parent seed company may no longer be maintaining the genetic integrity of the variety through a regular selection program, and that consequent genetic drift has resulted in poor uniformity in physical characteristics. With the view of seeking to fix this genetic drift problem by commencing a seed production program for Detroit Dark Red and possibly other open pollinated types in Australia, we sourced germplasm of globe shaped red beet lines from the National Germplasm System from the United States Department of Agriculture, Agriculture Research Division ([www.ars-grin.gov/npgs/serachgrin.html](http://www.ars-grin.gov/npgs/serachgrin.html)). It was hoped that this old material would be more “true to type” than current seed lots that had undergone genetic drift. The lines were compared to the standard commercial types in a small on-farm trial.

### ***Small-scale Varietal Trial (Ashley Zelinski)***

#### **Materials and Methods**

Two beetroot varieties (SPS#4 and SPS#5) were compared to the standard commercial slicing types (Pablo, Detroit Dark Red and Garnet) in a field trial planted on-farm at Mt Tarampa on 21 May 2002. The seed lots were provided by South Pacific Seeds. All seeds were treated with a thiram + metalaxyl fungicide dressing prior to planting.

The trial was planted as a randomised complete block design with 5 replications. Plots comprised 4 x 5m row lengths, with 5 x 2m unplanted buffer lengths at the plot ends. Seed was spaced at 70mm. The farmer maintained the trial using standard production practices. Plots were harvested 16 October 2003.

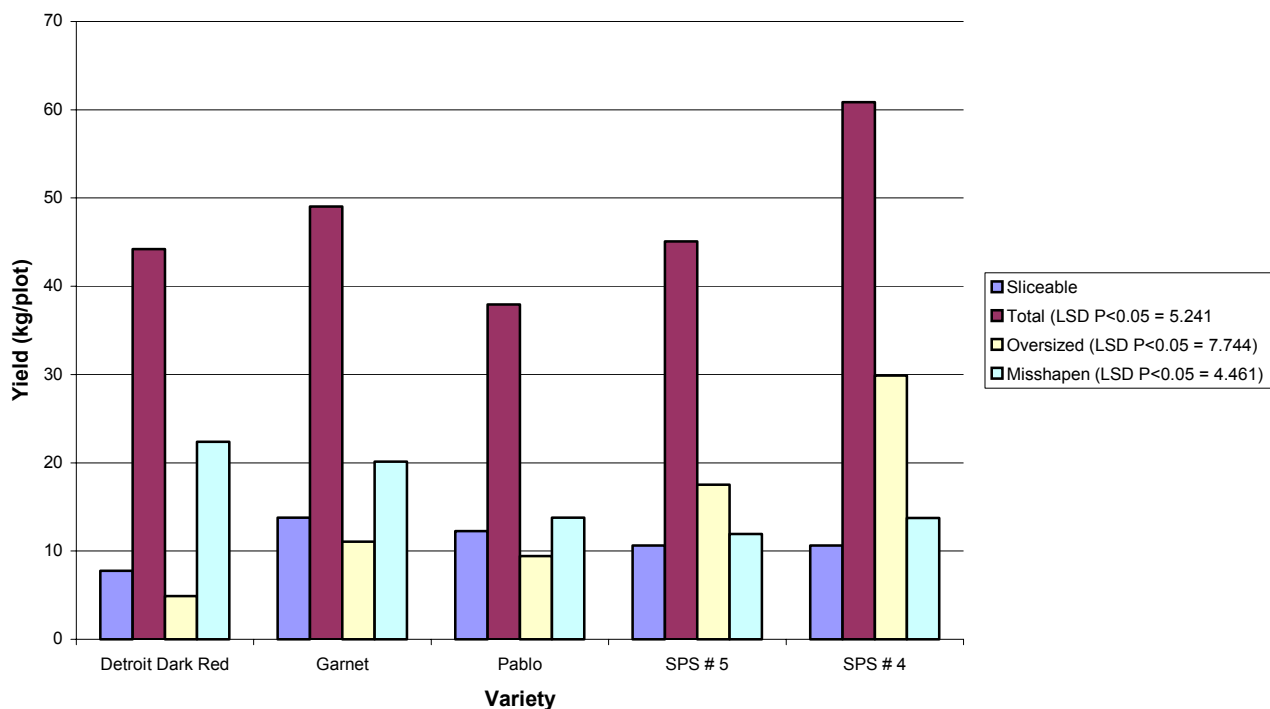
At harvest, beets from the centre 2 rows of each plot were pulled and the tops were cut from the plants with knives. The roots were manually graded into 7 categories (Table 6). For each plot, the number of beets and the total weight of beets in each category were determined. Harvest data were analysed using the Analysis of Variance function (ANOVA) in Genstat 6.0 for Windows.



## Results

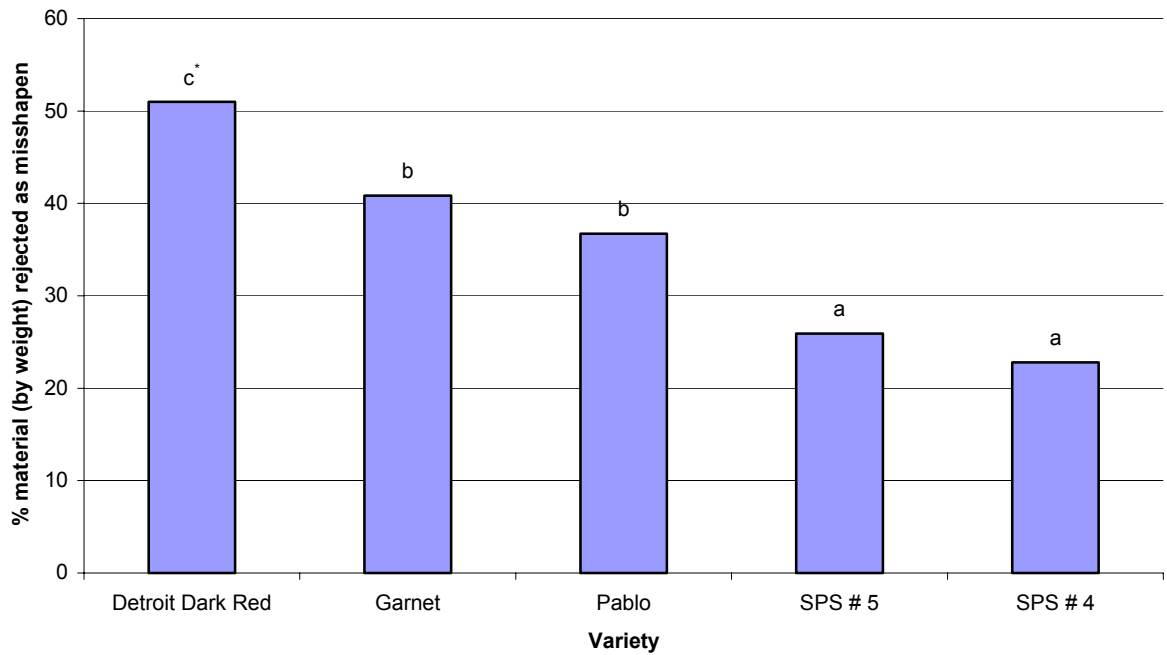
All the varieties were comparable in terms of quantity of sliceable material and sliceable material expressed as a percentage of the total yield. The amount of disease was also equivalent in all varieties (disease levels were low in the trial). SPS#4 and SPS#5 seemed to be quicker to mature than the other types. Both of these varieties, particularly SPS#4, produced significantly ( $P < 0.05$ ) greater quantities of oversized material than the standard commercial lines (Figure 36). It may have been the case, therefore, that if SPS#4 and SPS#5 were harvested earlier, a substantial portion of the material rejected as oversized may have been graded into the sliceable category.

**Figure 36:** Yield break-down for slicing type beetroot varietal trial (Zelinski, 2003)



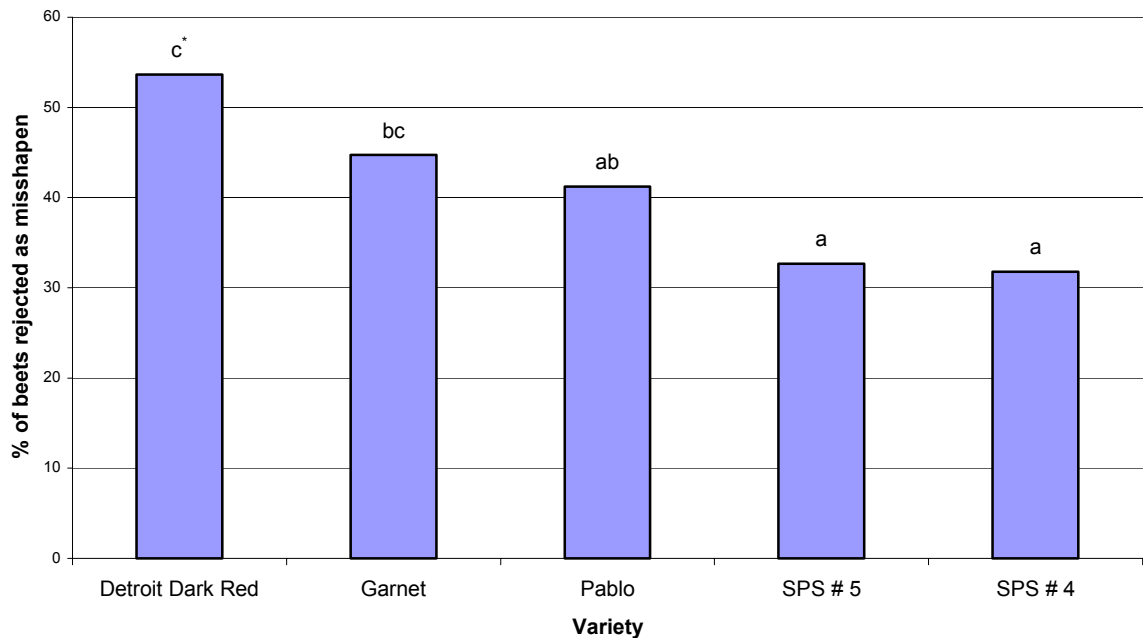
In contrast, rejections from both Detroit Dark Red and Garnet were most frequently due to misshapen material. Detroit Dark Red had a greater number of misshapen beets than any other variety. SPS#4 and SPS#5 had significantly ( $P < 0.05$ ) fewer misshapen beets than Garnet or Detroit Dark Red, and the weight of material that was rejected because it was misshapen was lowest for SPS#4 and SPS#5 (Figures 37 and 38).

**Figure 37:** Percentage of misshapen rejected beets (by weight) (Zelinski, 2003)



\* Bars with the same letters are not significantly different at the 5% level

**Figure 38:** Percentage of beets rejected as misshapen (by number) (Zelinski, 2003)



\* Bars with the same letters are not significantly different at the 5% level

### **USDA Germplasm Screening Trial (Ashley Zelinski)**

Forty-four germplasm accessions of red globe-shaped *Beta vulgaris* subsp. *vulgaris* types, were obtained from the Western Regional Plant Introduction Station, Washington, USA (Table 14).

**Table 14:** *Beta vulgaris* germplasm accessions obtained from USDA

<b>PI Accession Number</b>	<b>Species</b>	<b>Variety/Cultivar</b>
285589	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Epipski Freege
285591	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Okragly Cienmnoczerwony
357351	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Polsko
357354	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Kocansko
357356	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Okruglo
357357	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Okrugla
531260	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Bordo
531261	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Detroit
535846	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Czerwona Kula
590590	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Smooth Leaf Crosby
590591	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Seneca Detroit
590592	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Improved Early Blood
590593	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Improved Early Egyptian
590594	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Crosby Green Top
590595	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Eastern Wonder
590597	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Early Wonder Improved
590598	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Green Top Early Wonder
590600	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Detroit Perfected
590601	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Detroit Dark Red Short Top
590602	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Detroit Dark Red Morses Strain
590603	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Detroit Dark Red Ferrys Strain
590604	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Detroit Dark Red Medium Top
590605	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Detroit Dark Red
590608	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Asgrow Wonder
590609	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Early Flat Red Egyptian
590610	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Edmands Early Blood Turnip
590611	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Detroit Dark Red Canners
590617	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Crosbys Egyptian
590618	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Dewings Early Blood Turnip
590619	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Early Flat Egyptian
590623	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Perfected Canner
590627	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Special Crosby
590630	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Detroit Short Top 36
590631	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Perfected Detroit 6
590632	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Hastings Improved Blood Turnip
590635	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Burpees Improved Blood Turnip
590636	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Early Wonder/Boston Crosby
590637	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Detroit No. 12
590639	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Early Wonder Smooth Leaf
590640	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Detroit Dark Red Garnet Strain
590700	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Detroit Short Top
592989	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Red Baron
612331	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Detroit Vuurbal
612338	<i>Beta vulgaris</i> subsp. <i>vulgaris</i>	Detroit Type

The trial was planted at Mt. Tarampa on 21 May 2003 as a randomised complete block design with 2 replications. All seeds were treated with a thiram + metalaxyl fungicide dressing prior to planting. Plots comprised 1 x 3m row lengths, with 1 x 2m unplanted buffer lengths at the plot ends. Seed was planted by hand and was spaced at 70mm. The farmer maintained the trial using standard production practices. Plots were harvested during the week beginning the 13 October 2003.

At harvest, 10 plant top heights were measured from each plot before the plants were pulled, and an average top height was determined for each variety. Also, the crown diameters of 10 plants from each plot were qualitatively assessed as small, medium or large. All the beets were then pulled from each plot and the tops were cut from the plants. The roots were manually graded into 7 categories (Table 6). Since there was only such a small quantity of material of each variety in this trial, no statistical analysis was completed after grading because the sample sizes were small. Rather, the grading process was used in a more qualitative way here to help distinguish varieties with desirable phenotypes.

## Results

A summary of harvest information is presented in Table 15.

**Table 15:** Characteristics of beet accessions from USDA at harvest

Variety/Cultivar	% of sliceable yield (by weight)	Top Height (cm)	Crown Diameter*
Asgrow Wonder	5.6	50-55	S-M
Bordo	-	-	-
Burpees Improved Blood Turnip	6.8	40	S-M
Crosby Green Top	41.7	25-30	S-M
Crosbys Egyptian	7.7	40	S-M
Czerwona Kula	15.6	70	M
Detroit	-	-	-
Detroit Dark Red	12.0	45-50	S-M
Detroit Dark Red Canners	22.5	35	S-M
Detroit Dark Red Ferrys Strain	39.2	45-50	S-M
Detroit Dark Red Garnet Strain	33.2	35-40	S-M
Detroit Dark Red Medium Top	28.1	40	S-M
Detroit Dark Red Morses Strain	22.5	35-40	S-M
Detroit Dark Red Short Top	49.5	40-50	S-M
Detroit No. 12	19.4	40	S-M
Detroit Perfected	11.7	45	S-M
Detroit Short Top	9.5	30-35	S-M
Detroit Short Top 36	37.3	20-25	M
Detroit Type	1.1	65-70	M
Detroit Vuurbal	18.9	45	M
Dewings Early Blood Turnip	7.0	60	M
Early Flat Egyptian	0.0	55	L
Early Flat Red Egyptian	0.0	40-45	M-L
Early Wonder Improved	4.5	45-50	M-L
Early Wonder Smooth Leaf	8.2	50	M
Early Wonder/Boston Crosby	3.0	50	M
Eastern Wonder	13.2	25-30	S-M
Edmands Early Blood Turnip	3.5	60	M-L
Epipski Freege	0.1	50	L
Green Top Early Wonder	23.3	35	S-M
Hastings Improved Blood Turnip	4.7	60	M
Improved Early Blood	-	-	-
Improved Early Egyptian	0.0	40-45	M
Kocansko	0.0	65	M-L
Okragly Cienmnoczerwony	11.8	45	S-M
Okrugla	1.0	55	M-L
Okruglo	0.0	60	L
Perfected Canner	22.8	50	S-M
Perfected Detroit 6	22.4	30-35	S-M
Polsko	3.5	50	S-M
Red Baron	46.1	20	S
Seneca Detroit	23.7	50	M
Smooth Leaf Crosby	5.6	35	M
Special Crosby	10.6	45-50	S-M

\*Crown Diameter Ratings: S = small, M = medium, L = large  
 - = did not germinate

Desirable characteristics for processing include a high percentage of globe-shaped sliceable material, a small – medium crown diameter and a strong top. Most of the varieties were inappropriate because of their shape characteristics. However, six varieties: Detroit Dark Red Short Top, Red Baron, Crosby Green Top, Detroit Dark Red Ferry's Strain, Detroit Short Top 36 and Detroit Dark Red Garnet Strain produced high proportions of globe-shaped beets, and small-medium crown diameters and therefore may be useful in an open-pollinated selection or breeding program (Figure 39). One of these varieties, Red Baron, although promising in terms of shape, had only a very short top (20cm), which may limit its usefulness because current harvest equipment requires a large, strong top so that the beets can be pulled.

**Figure 39:** Beet varieties from USDA assessment with desirable agronomic traits for processing



Detroit Dark Red Short Top



Red Baron



Crosby Green Top



Detroit Dark Red Ferry's Strain



Detroit Short Top 36



Detroit Dark Red Garnet Strain

## *Commercial Scale Varietal Trial (Ashley Zelinski)*

### **Materials and Methods**

Seed of fifteen beetroot varieties were obtained from commercial seed companies and planted in a late planting window at Mt. Tarampa on 21 August 2003 (Table 16). The trial design was a randomised complete block with 2 replications. The standard slicing types, Detroit Dark Red, Pablo and Garnet, and the baby line, New Globe were also included in the trial. All seeds were treated with a thiram + metalaxyl fungicide dressing prior to planting. Plots comprised 1 x 90m row lengths, with 1 x 5m unplanted buffer lengths at the plot ends. Seed was spaced at 70mm. The farmer maintained the trial using standard production practices.

**Table 16:** Beetroot varieties included in commercial scale variety trial (Zelinski, 2003)

<b>Variety</b>	<b>Seed Company</b>
Action F1	Bejo
Wodan F1	Bejo
Cornell F1	Bejo
Alto F1	Bejo
Redondo F1	Bejo
1947 F1	Bejo
Pronto	Bejo
Detroit 243	Daehnfeldt
Lola	Daehnfeldt
Modana	Daehnfeldt
Big Red	Chris Seeds/Syngenta
Pacemaker III	Chris Seeds/Syngenta
Solo	Chris Seeds/Syngenta
Mona Lisa	Rijk Zwaan
Akela	Rijk Zwaan

### **Results**

Extremely hot weather and a series of hailstorms severely damaged the beets in this trial. The trial was abandoned prior to harvest.

## **D) Field Assessments of Beetroot Varieties – 2004**

### *Variety Trial 2004 (Ashley Zelinski)*

#### **Materials and Methods**

Seed of fourteen beetroot varieties were obtained from commercial seed companies and planted at Mt. Tarampa on 26 April 2004 (Table 17). In addition, three additional lots of cv. Garnet seed were also included in the trial (Garnet, 1992; Garnet, 1999 and Garnet DPI (produced at Stanthorpe in 2003)), as were the standard slicing types,

Detroit Dark Red, Pablo and Garnet. The trial design was a randomised complete block with 4 replications. All seeds were treated with a thiram + metalaxyl fungicide dressing prior to planting. Seed was spaced at 70mm. The farmer maintained the trial using standard production practices. Harvest dates were staggered depending on the maturity of the varieties. The first varieties were harvested on 20 September 2004 and harvesting was completed on 4 October 2004.

At harvest, all beets from the plots were removed manually and the tops were cut from the plants with knives. The roots were manually graded into 7 categories (Table 6). For each plot, the number of beets and the total weight of beets in each category were determined. Harvest data were analysed using the Analysis of Variance function (ANOVA) in Genstat 6.0 for Windows.

An additional internal assessment was also made. A selection of 20 beets was made from the material graded as slicing beets from each plot. Each beet was cut open and the extent of white zoning and discolouration was measured using a qualitative visual rating scale (0=nil, 1=slight, 2=moderate, 3=severe).

**Table 17:** Varieties planted on-farm at Mt. Tarampa 26 April 2004 (Zelinski)

Variety	Seed Company
Pablo	Bejo
Wodan F1	Bejo
Redondo F1	Bejo
Pronto	Bejo
SPS 247-4	South Pacific Seeds
SPS 246-4	South Pacific Seeds
Lola	Daehnfeldt
Big Red	Chris Seeds/Syngenta
Pacemaker III	Chris Seeds/Syngenta
Solo	Chris Seeds/Syngenta
Mona Lisa	Rijk Zwaan
Akela RZ	Rijk Zwaan
Detroit Dark Red	Chris Seeds/Syngenta
Garnet	Chris Seeds/Syngenta

## Results

The most promising varieties in the trial in terms of total yield and % sliceable yield (by weight) were Mona Lisa, Solo, Big Red and Pablo. Solo and Big Red both produced total yields and sliceable percentages equivalent to Pablo (Figures 40 and 42). Mona Lisa produced a low total yield, however this was probably because it was a monogerm type (Figure 40). The % recovery of sliceable material from Mona Lisa was equivalent to the highest in the trial. Mona Lisa did however, have a very small top, which may make it difficult to harvest with existing harvest machinery. Big Red also had a fairly small top.

SPS 247-4, Redondo, Wodan, Lola, Pronto and SPS 246-4 all yielded total quantities of material equivalent to or greater than Pablo, but the proportion of material that was suitable for slicing for these varieties was low. For example, Redondo produced



significantly higher yields than any other variety (Figure 40), but it was equivalent to the poorest varieties in the trial in terms of the proportion of the material that was suitable for slicing. A large proportion of Redondo was rejected because it was oversized, indicating that this may be a fast maturing variety (data not presented). This variety warrants further investigation, since it also yielded the lowest proportion of misshapen material (by weight) of any variety.

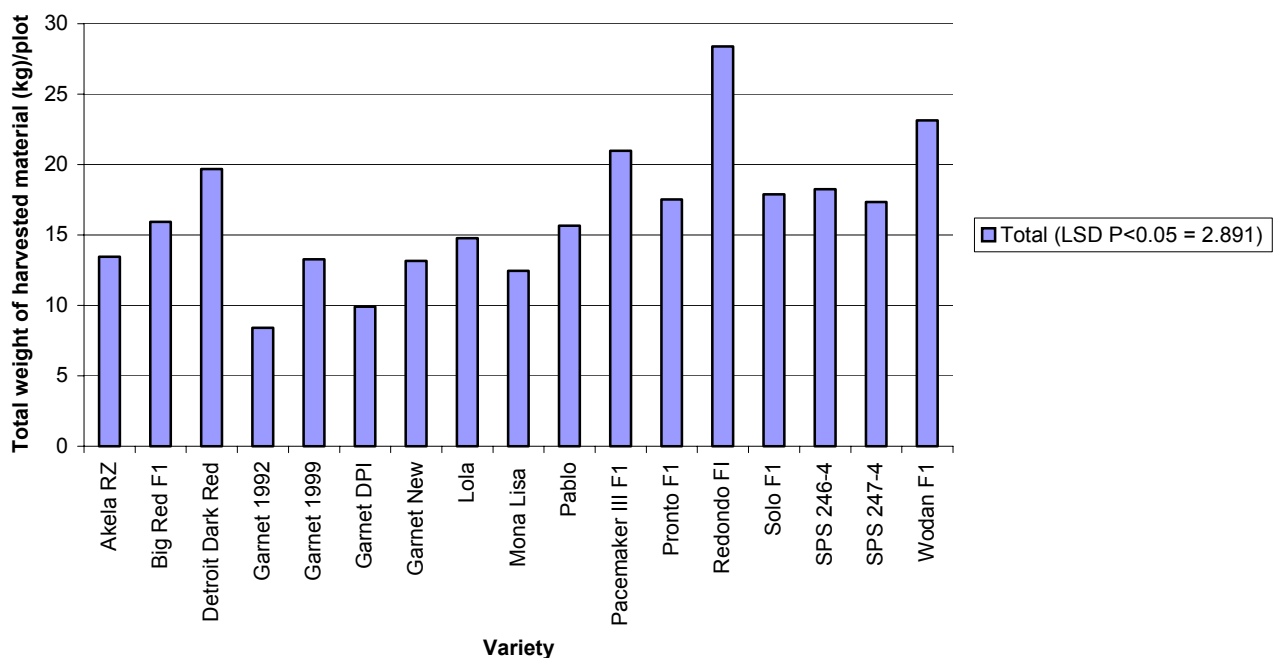
Wodan was also exceptionally high yielding, but poor in terms of sliceable yield. In this case, however, the high rejection rate was due mainly to large quantities of misshapen material (Figure 41).

Redondo, Solo, Lola, Garnet 1999, Pablo and Pacemaker yielded the lowest proportions of misshapen material. Detroit Dark Red, one of the standard industry types, was equivalent to the worst varieties in the trial in terms of the proportion of sliceable material recovered and the proportion of its yield that was misshapen.

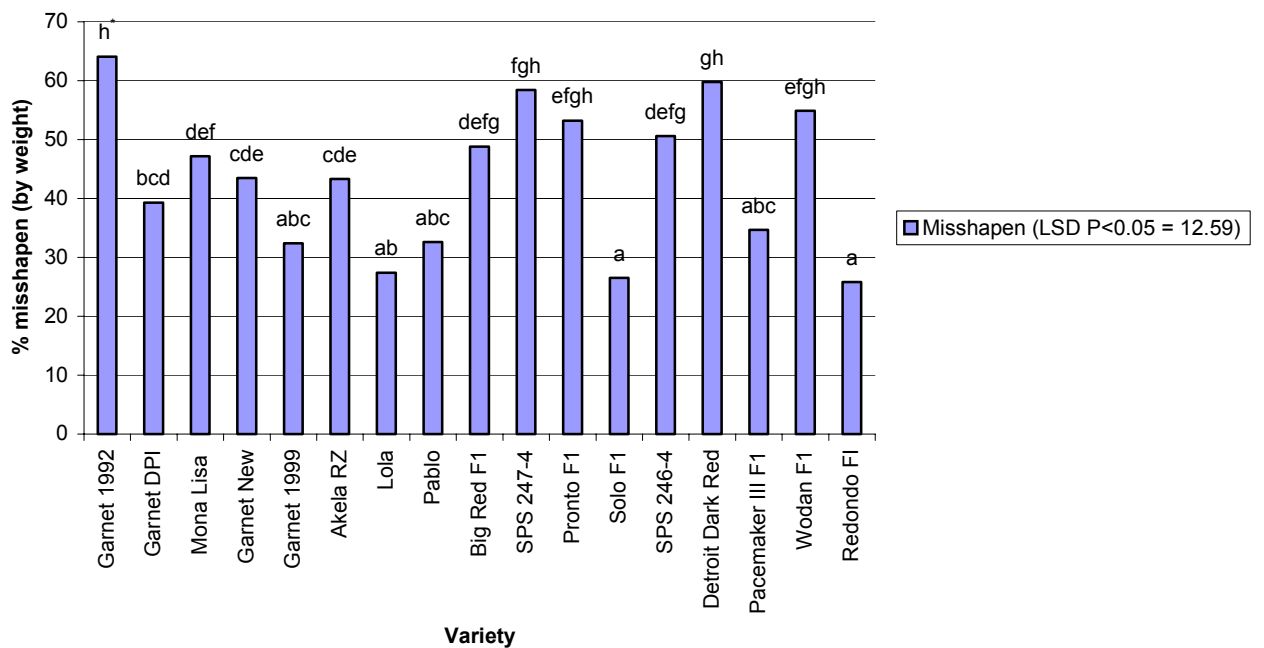
Pacemaker and SPS 247-4 yielded significantly higher proportions of undersized material than any of the other varieties (data not presented), indicating that these two varieties may be slower to mature than the other types tested.

The incidence of internal defects was very low in beets of all varieties. The Garnet that was produced by DPI did have a higher tendency for white zoning in the parenchyma tissue than the other types assessed in the trial. Disease pressure was low at this trial site, and all varieties produced equivalent quantities of diseased material.

**Figure 40:** Mean weight of material harvested from each plot (Zelinski, 2004 )

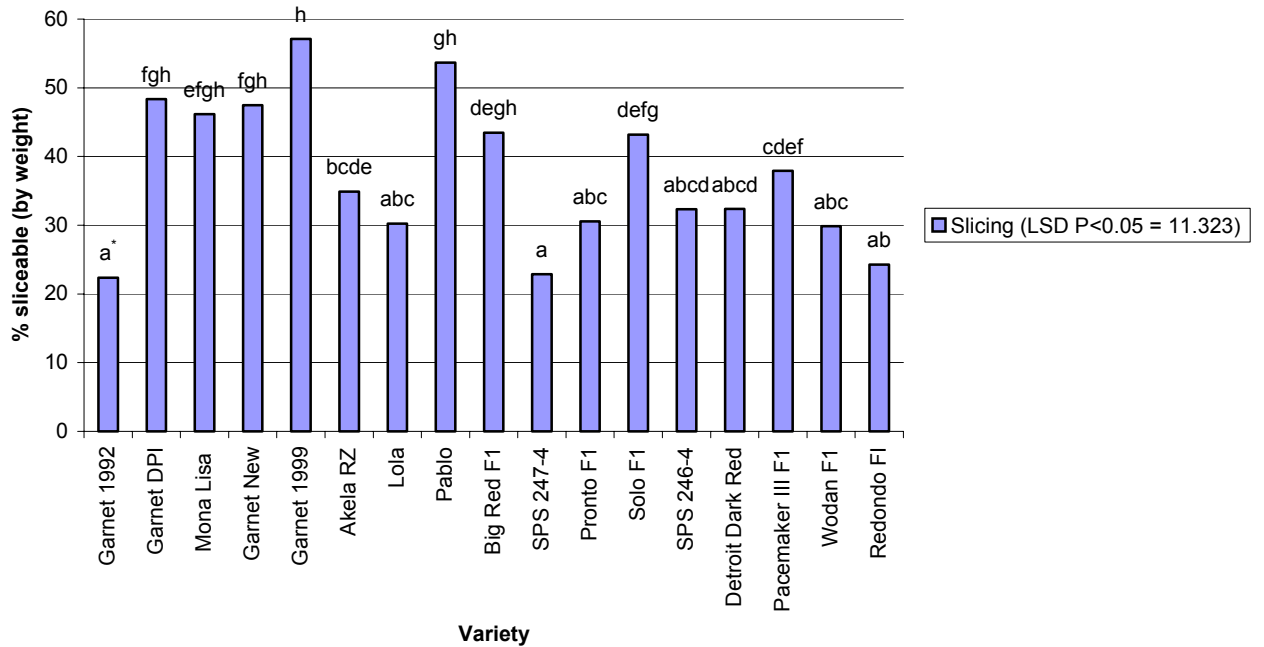


**Figure 41:** Percentage of misshapen material (by weight) (Zelinski, 2004)



\* Varieties with the same letters are not significantly different at the 5% level

**Figure 42:** Percentage of slicing material (by weight)(Zelinski, 2004)



\* Varieties with the same letters are not significantly different at the 5% level

## *Variety Trial 2004 (Glenn Lerch)*

### **Materials and Methods**

Seed of 13 beetroot varieties were obtained from commercial seed companies and planted at Forest Hill on 4 May 2004 (Table 18). The standard slicing types (Detroit Dark Red, Pablo and Garnet) were included in the trial and in addition, two extra lots of cv. Garnet seed were also assessed (Garnet, 1992; Garnet, 1999). The trial design was a randomised complete block with 4 replications. All seeds were treated with a thiram + metalaxyl fungicide dressing prior to planting. Seed was spaced at 70mm and plots comprised 5m single row lengths. The farmer maintained the trial using standard production practices. Harvest dates were staggered depending on the maturity of the varieties. The first varieties were harvested on 30 September 2004 and harvesting was completed on 5 October 2004.

At harvest, all beets from the plots were removed manually and the tops were cut from the plants with knives. The roots were manually graded into 7 categories (Table 2). For each plot, the number of beets and the total weight of beets in each category were determined. Harvest data were analysed using the Analysis of Variance function (ANOVA) in Genstat 6.0 for Windows.

An additional internal assessment was also made. A selection of 10 beets was made from the material graded as slicing beets from each plot. Each beet was cut open and the extent of white zoning and discolouration was measured using a qualitative visual rating scale (0=nil, 1=slight, 2=moderate, 3=severe).

**Table 18:** Varieties planted on-farm at Forest Hill 4 May 2004 (Lerch)

<b>Variety</b>	<b>Seed Company</b>
Pablo	Bejo
Wodan F1	Bejo
Action	Bejo
Warrior	LeFroy Valley Seed Co.
SPS 247-4	South Pacific Seeds
SPS 246-4	South Pacific Seeds
Big Red	Chris Seeds/Syngenta
Pacemaker III	Chris Seeds/Syngenta
Solo	Chris Seeds/Syngenta
Mona Lisa	Rijk Zwaan
Akela RZ	Rijk Zwaan
Detroit Dark Red	Chris Seeds/Syngenta
Garnet	Chris Seeds/Syngenta

### **Results**

The most promising varieties in the trial in terms of both total yield and % sliceable yield were Pablo, Garnet 1999, Pacemaker III, Warrior and Wodan. Pacemaker III, Warrior and Wodan all produced total yields and sliceable percentages equivalent to Pablo (Figures 44 and 46).

The proportion of Mona Lisa, Big Red and Akela beets that were suitable for slicing was also very high and equivalent to the highest of any of the varieties in the trial, however the total yields for these three varieties were significantly lower than the highest yielding lines. Big Red also produced the lowest proportion of misshapen beets of any variety (Figure 43).

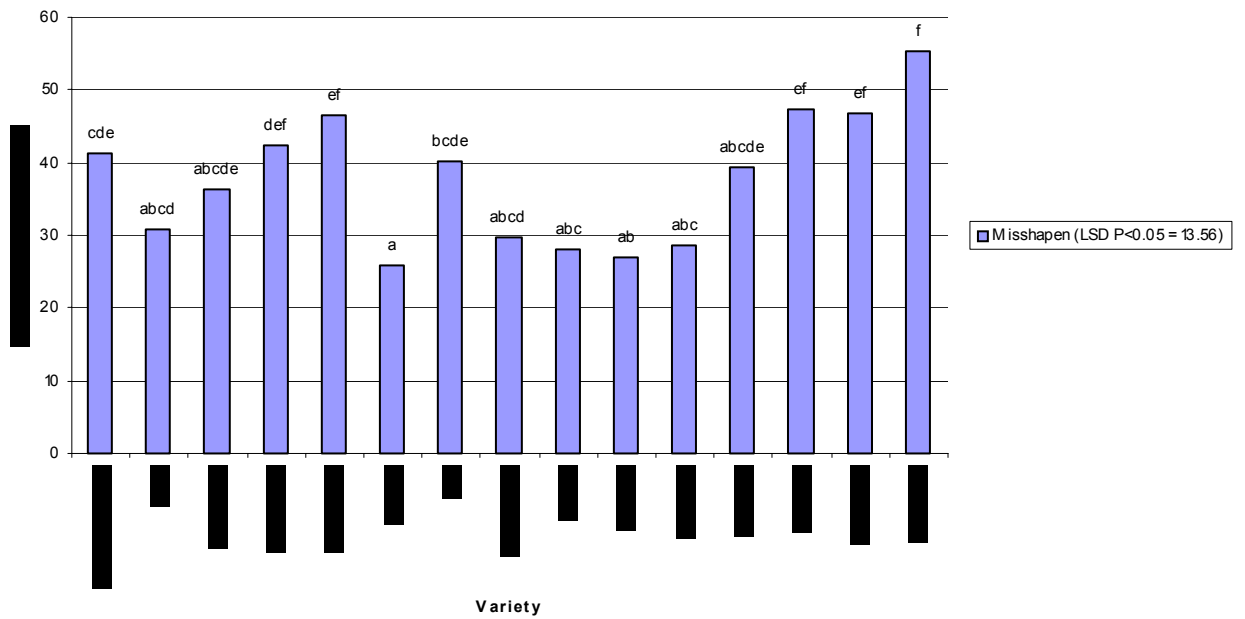
In the case of Mona Lisa, its low total yield was probably due in part to it being a monogerm type. Both Mona Lisa and Big Red also produced substantial quantities of undersized beets (Figure 45), which would have also contributed to their lower total yields, ie. both varieties tended to mature more slowly than the other lines. The failure of these two varieties to reach slicing size seemed to be linked to very high temperatures close to harvest. Both lines seemed to be intolerant to high temperatures, so we harvested them prematurely rather than trying to keep them growing into the hotter months. As in the variety trial at Ashley Zelinski's, Mona Lisa and Big Red both had smaller tops than the other varieties, which may make them difficult to harvest with existing harvest machinery.

Action and SPS 246-4 were both high yielding varieties (equivalent to the best yielding varieties in the trial) however both had high rejection rates due to misshapen material. SPS 247-4 also performed poorly, producing high quantities of misshapen product. Rates of rejection due to misshapen product were so high for this variety that the proportion of total yield that was retained for slicing was equivalent to the lowest retention level for any variety (Figure 43). In addition to high quantities of misshapen material, SPS 247-4 also yielded large quantities of undersized beets, indicating that this line may have been slower to mature than the other lines assessed (Figure 45).

Surprisingly, Detroit Dark Red performed comparatively well in this trial, producing total yields and proportions of sliceable product equivalent to Pablo.

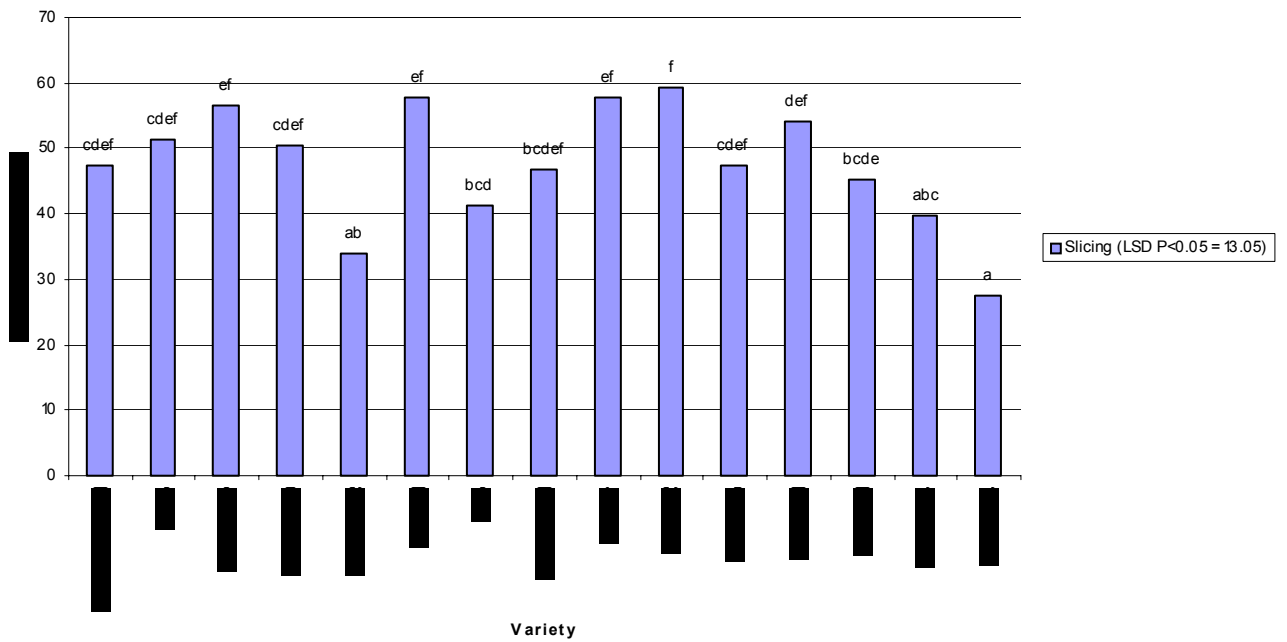
The incidence of internal defects was very low in beets of all varieties. Solo had a tendency for more white zoning in the cambium tissue than any of the standard lines (Pablo, Detroit Dark Red, Garnet (New)).

**Figure 43:** Proportion of total yield rejected as misshapen. Variety trial Glenn Lerch (2004)



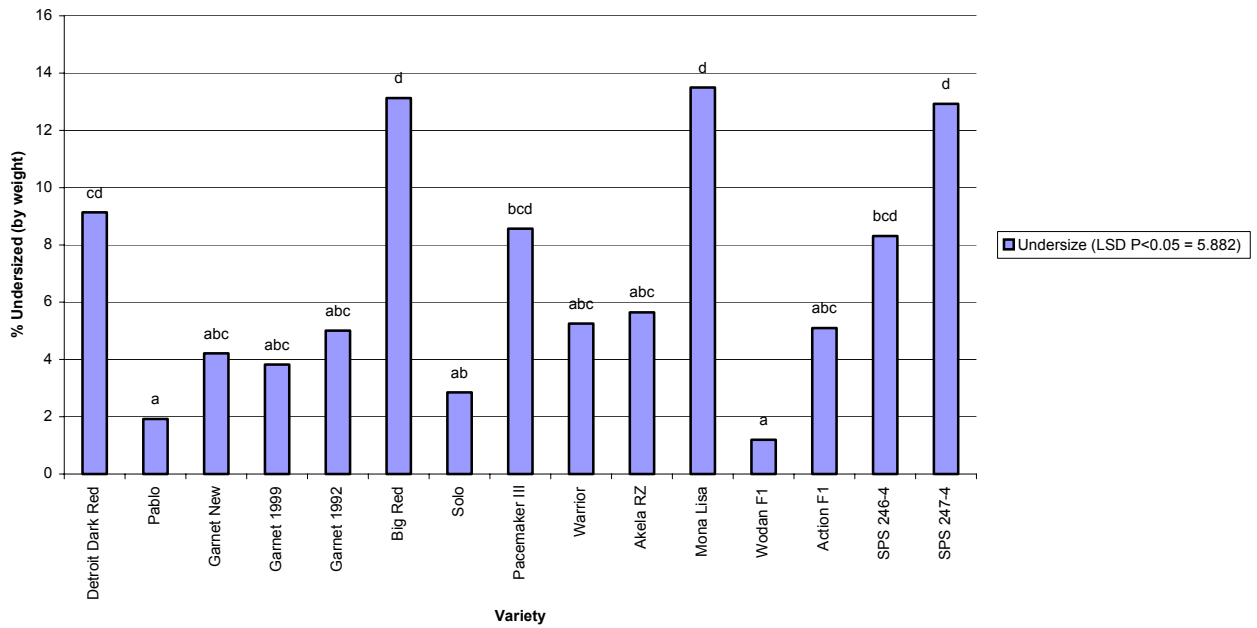
\* Varieties with the same letters are not significantly different at the 5% level

**Figure 44:** Proportion of total yield retained as sliceable product. Variety trial 2004 (Lerch)



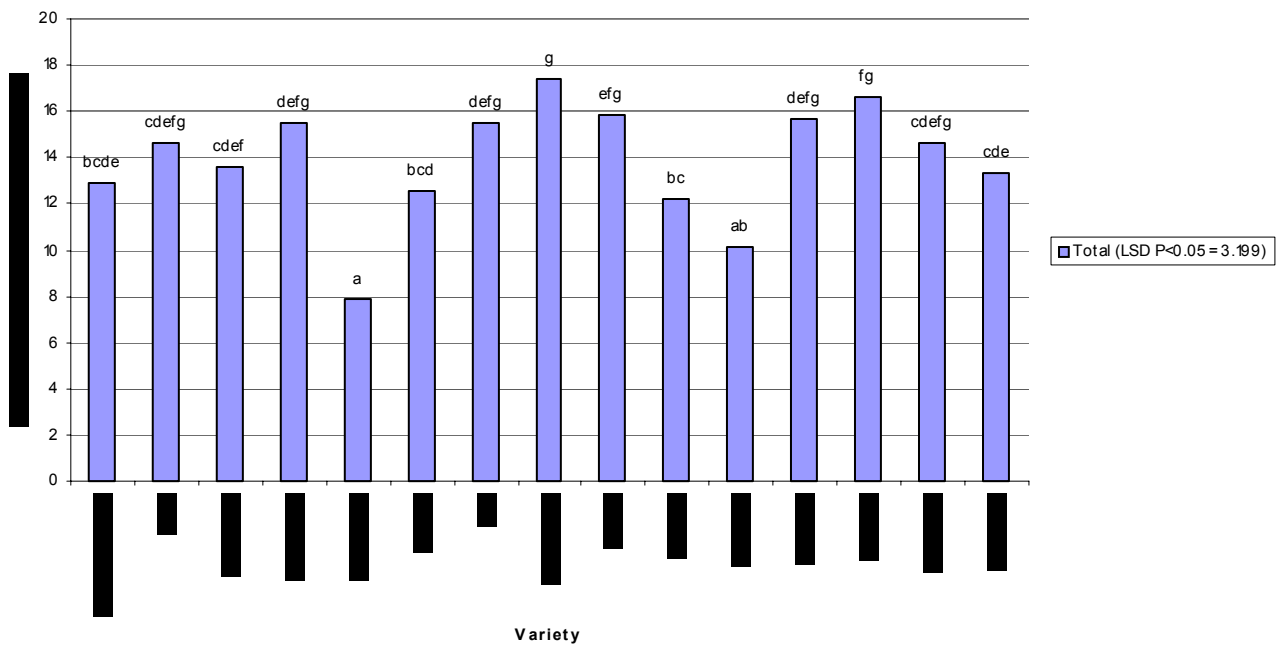
\* Varieties with the same letters are not significantly different at the 5% level

**Figure 45:** Proportion of total yield rejected as undersized. Variety trial Glenn Lerch (2004)



\* Varieties with the same letters are not significantly different at the 5% level

**Figure 46:** Total yields of varieties. Variety trial Glenn Lerch (2004)



\* Varieties with the same letters are not significantly different at the 5% level

## CHAPTER 4: Fungicide Assessments

### Introduction

A complex of soil-borne fungal pathogens, principally *Pythium* spp. and *Rhizoctonia solani* threaten the viability of the Australian beetroot industry. Infections of young plants reduce crop stands, and later infections attack developing beets, reducing quality and increasing processing costs. Beetroot seed planted in Australia is routinely treated with dressings of thiram or metalaxyl (Apron<sup>®</sup>), or a combination of the two. These treatments alone do not provide adequate protection against the soil-borne pathogens when disease pressure is high. Furthermore, neither fungicide is particularly effective against *Rhizoctonia solani*. No fungicide is currently registered for use as an in-furrow or pre-plant soil or post-plant application. We completed a series of experiments to identify which fungicides or fungicide combinations give the most comprehensive disease control and how best to apply them to the crop to minimise disease.

### A) Initial Field Assessments of Fungicides – 2001

#### *Fungicide Trial, Home Farm (Voight, 2001)*

#### Materials and Methods

Thirty-six treatments were compared in a field trial planted at Lowood on 12th April 2001, on a site with a previous history of disease. Twenty-two fungicides were applied to beetroot seed cv. Detroit Dark Red as either slurries or liquid applications. Selected fungicides were also applied to seed that was primed in a 0.34M NaCl solution prior to fungicide application following the method of Osburn and Schroth (1986). In addition, immediately before the first irrigation six fungicides were applied as single soil spray applications to plots sown with seed dressed with thiram + metalaxyl (Table 19).

The trial was planted as a 12 row x 12 column block design with 4 replications. Plots comprised 5 x 5m row lengths with 5 x 2m blank row lengths at the plot ends. Seed was spaced 56mm apart.

A regular irrigation program for the trial was initiated 6 days after sowing using overhead irrigation. Seedling emergence was monitored at 3-4 day intervals for 3 weeks after sowing, and plants were assessed as either healthy or diseased. At each assessment the percentage of healthy seedlings was determined for each plot. Data were analysed using REML (restricted maximum likelihood) in Genstat for Windows 5.0, fitting autoregressive process over the rows and columns and fitting other spatial trends as necessary.

**Table 19:** Fungicide treatments assessed (Lowood, April 2001 Peter Voights)

<b>Treatment</b>			
	<b>Active</b>	<b>Registered Trademark</b>	<b>Rate</b>
<b>Seed Dressings</b>	Tebuconazole	Raxil C Dry	2.5 g.a.i./100kg seed
	Triadimenol	Baytan C DSD	22.5 g.a.i./100kg seed
	Chlorothaonil	Bravo 720 SC	0.552L/100kg seed
	Thiram	Thiram	400 g.a.i./100kg seed
	Metalaxyl	Apron Liquid Formulation	35 g.a.i./100kg seed
	Propamocarb	Previcur	0.36L/100kg seed
	Acibenzolar-S-methyl	Bion 500WG	2.4g/100kg seed
	PCNB	Quintozene WP	180 g.a.i./100kg seed
	Tolclophos methyl	Rizolex WP	0.288kg/100 kg seed
	Pencycuron	Monceren 250 FS	15 g.a.i./100kg seed
	Phosphonate	Phospot 400	1.44L/100 kg seed
	Benomyl	Benlate WP	100 g.a.i./100 kg seed
	Iprodione	Rovral Aquaflow	20 g.a.i./100kg seed
	Flutolanil	Moncut	0.15mL/100kg seed
	Difenconazole	Score	24 g.a.i./100kg seed
	Trifloxystrobin	Tega 075 EC	200mL/100kg seed
	Azoxystrobin	Amistar 500 WG	1.2 kg/100kg seed
	Krezoxim methyl	Stroby	24 g/100kg seed
	Carboxin	Vitaflow	250 mL/100kg seed
	Fludioxinil	Maxim 100 FS	20 g.a.i./100kg seed
Procymidone	Sumiscelex	200mL/100kg seed	
Hymexazol	Tachigaren 70 WP	700g/100kg seed	
Untreated control	-	-	
<b>Soil Applications + Thiram/Apron Treated Seed</b>	PCNB	Quintozene WP	16.5kg/ha
	Fludioxinil + metalaxyl	Maxim XL 035FS	0.8kg/ha
	Azoxystrobin	Amistar 500WG	0.25kg/ha
	Tolclophos methyl	Rizolex WP	0.12kg/ha
	Procymidone	Sumiscelex	2L/ha
	Metalaxyl-M	Ridomil Gold 25G	20kg/ha
	Hymexazol	Tachigaren 70 WP	12.86kg/ha
Untreated control	-	-	
<b>Seed Dressings + Primed Seed</b>	Metalaxyl	Apron Liquid Formulation	35 g.a.i./100kg seed
	Thiram	Thiram	400 ga.i./100kg seed
	Azoxystrobin	Amistar 500WG	1.2kg/100kg seed
	Tolclophos methyl	Rizolex WP	0.288kg/100kg seed
	Untreated control	-	-



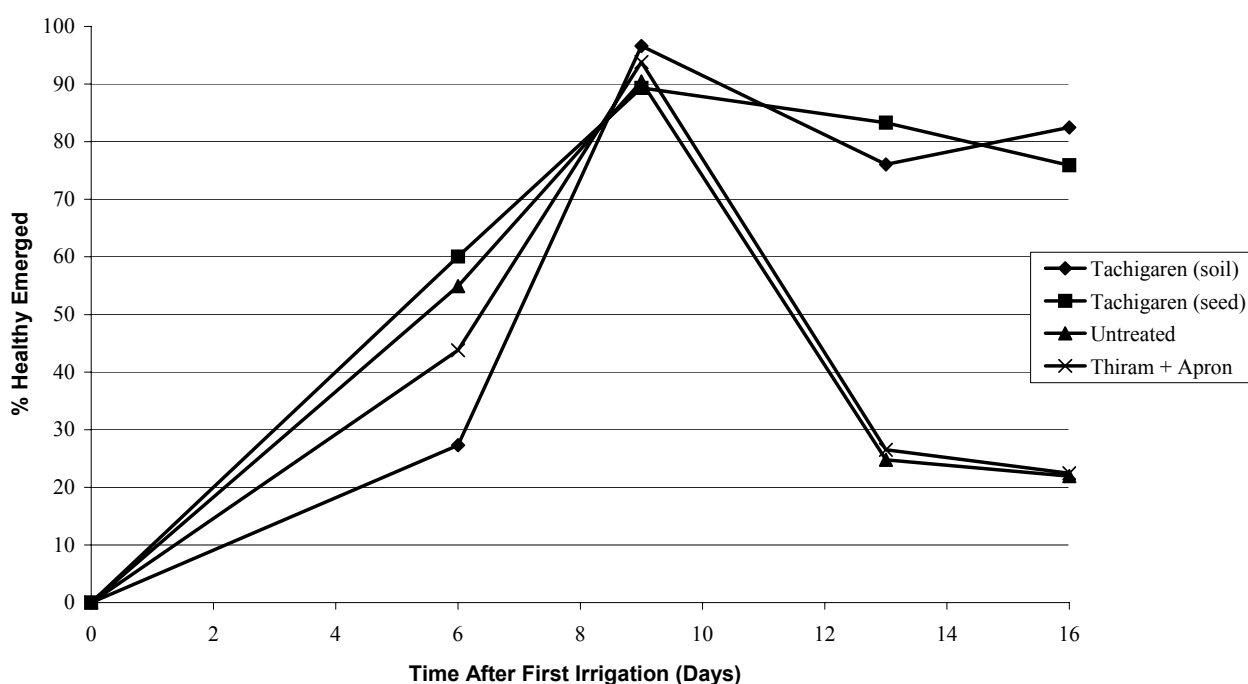
## Results

Disease pressure was extremely high in this trial following heavy rainfall just prior to the first assessment. Substantial losses were apparent at the final two assessment times. Isolations from diseased plants indicated that *Pythium* and *Aphanomyces* were the primary pathogens responsible.

Hymexazol (Tachigaren<sup>®</sup> 70 WP) as a seed dressing and as a soil spray application ( $1.29\text{g/m}^2$ ) were the best treatments in this trial. As a soil application, hymexazol delayed the rate of seedling emergence compared to the untreated seed ( $P<0.05$ ) however the total number of emerged seedlings was not significantly reduced by the second assessment time (9 days after the first irrigation). At the final two assessments (13 and 16 days after the first irrigation), >75% of seedlings in the hymexazol treatments were free of disease, compared to only 20-25% of seedlings in the untreated plots. The industry standard seed dressing combination (metalaxyl + thiram) did not offer any improvement over the untreated seed ( $P<0.05$ ) (Figure 47). The hymexazol treatments were the only two treatments in the trial that provided significant disease control at the final two assessment times, compared to the standard industry practice and the untreated plots.

Priming the seed before sowing significantly increased the rate of seedling emergence ( $P<0.05$ ) however overall emergence levels in primed treatment plots were reduced compared to those in the treatments applied to non-primed seed (data not presented).

**Figure 47:** Effect of fungicide treatment on disease incidence (%)



Hymexazol seed treatments are used commercially to control *Pythium* and *Aphanomyces* infections of sugarbeet in Finland, France, England and The Netherlands. The results reported here indicate that this fungicide may also be useful for disease control in beetroot, particularly in view of the poor control levels being achieved with the current standard industry treatments in Australia.

### ***Fungicide Trial, (Moira Farms, 2001)***

#### **Materials and Methods**

The fungicides assessed at Voight's Home Farm (April 2001) were reassessed in a late planting window with Moira Farms, in a block previously sown to sunflower. Treatments were identical to those in Table 19. The trial was planted on 7 June 2001 with a hand-driven tape planter and the seed (cv. Detroit Dark Red) was spaced 70mm apart. The trial was planted as a 12 row x 12 column block design with 3 replications. Plots comprised 4 x 5m row lengths with 4 x 2m blank row lengths at the plot ends.

A regular irrigation program for the trial was initiated after sowing using overhead irrigation. Seedling emergence was monitored at 3-4 day intervals for 3 weeks after sowing, and plants were assessed as either healthy or diseased. At each assessment the percentage of healthy seedlings was determined for each plot. Data were analysed using REML (restricted maximum likelihood) in Genstat for Windows 5.0, fitting autoregressive process over the rows and columns and fitting other spatial trends as necessary.

At harvest, beets from the centre rows of each plot were removed manually and the tops were cut from the plants with knives. The roots were manually graded into 7 categories according to size and quality criteria suggested by Golden Circle P/L (Table 6).

#### **Results**

The disease pressure in this trial was extremely low and consequently, no significant fungicidal effects were detected ( $P < 0.05$ ).

### ***Glasshouse Assessment of Phytotoxicity of Tachigaren***

#### **Introduction**

Evidence from trialwork conducted outside Australia indicates that when applied as a seed dressing, Tachigaren rates in excess of 20 g.a.i./kg can slow seedling emergence (Asher and Payne, 1989). Tachigaren may also be beneficial in controlling seedling disease when it is applied as a soil application, as demonstrated by our trial results obtained from the fungicide trial on Peter Voight's farm. For this reason, we thought it important to establish the application rate at which Tachigaren produces toxic effects on plants, when it is applied as a soil application.

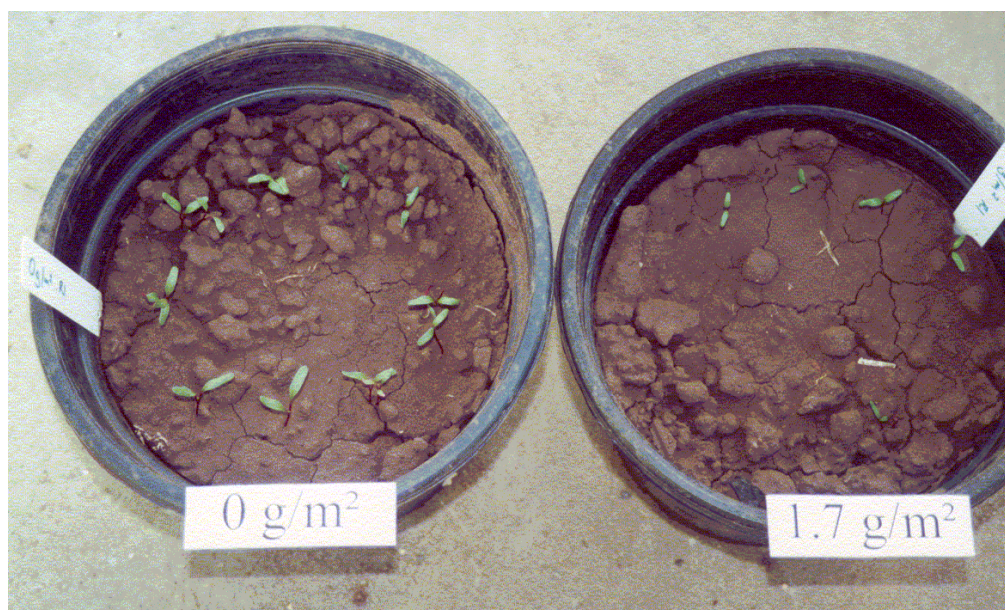
## Materials and Methods

A glasshouse experiment was established in which 10 beetroot cv. Pablo seeds were sown in pots of sterilized soil at 40mm spacings. Tachigaren 70WP was then sprayed onto the soil surface in the pots at different rates (0 (control), 0.3,0.7,1,1.3 and 1.7 g/m<sup>2</sup>). The experimental design was a randomized complete block with 4 pots (replicates) of each Tachigaren application rate. The seedlings started to emerge 7 days after the pots were sown. Emerged seedlings in each pot were counted daily until 20 days after sowing. Seedlings were then thinned so that each pot contained 5 plants. Weekly counts of the number of leaves on each plant were made for a further 4 weeks. The plants were then destructively sampled at the final assessment time, and the leaf area of each plant was measured with a leaf area meter.

## Results

Application of Tachigaren at 0.3g/m<sup>2</sup> and 0.7g/m<sup>2</sup> delayed seedling emergence by 1 day ( $P<0.05$ ). If the Tachigaren concentration was increased to 1.0g/m<sup>2</sup> or greater, a significant proportion of the beetroot seedlings were prevented from emerging (Figure 48). Presumably, the higher concentrations were toxic enough to kill the seeds.

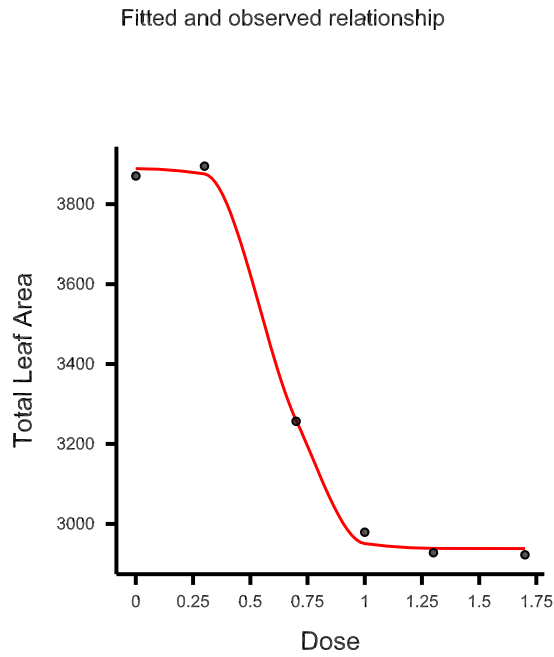
**Figure 48:** Tachigaren 70WP was toxic to beetroot seeds cv. Pablo at concentrations greater than 1.0g/m<sup>2</sup>



The leaf area was significantly reduced ( $P<0.05$ ) by Tachigaren concentrations of 0.7g/m<sup>2</sup> or greater. A logistic regression model best explained the relationship between the dose of Tachigaren and leaf area (adjusted  $R^2 = 99.5\%$ )(Figure 49):

$$\text{Leaf Area} = 2938.5 + 950.9 / (1 + \text{Exp} (12.23 \times (\text{Tachigaren Concentration} - 0.6449)))$$

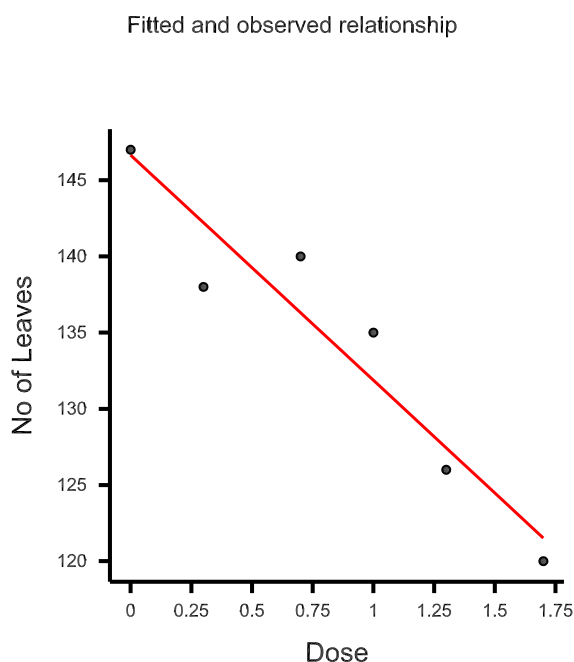
**Figure 49:** The leaf area of beetroot plants treated with a range of Tachigaren concentrations (doses) was best explained by an S-shaped logistic curve



A strong linear relationship existed between the number of leaves on the beetroot plants and the dose of Tachigaren applied (adjusted $R^2=88.1\%$ )(Figure 50):

$$\text{Number of leaves} = -14.78 \text{ Tachigaren dose} + 146.65$$

**Figure 50:** The number of leaves on beetroot plants treated with a range of Tachigaren concentrations (doses) was best explained by a linear regression



## B) Field Assessments of Fungicides – 2002

### Introduction

Tachigaren WP (hymexazol) gave highly effective control of *Pythium* spp. in the on-farm field trial completed at Voight's home farm in 2001. In order to obtain additional efficacy data for this product (which could be submitted as a component of a permit request for minor-use), two additional field trials were completed on-farm in 2002. In these trials, Tachigaren was applied to seed at three different rates and was compared to untreated seed and standard seed dressings (thiram/metalaxyl)

### Materials and Methods

Eight fungicide seed dressings were compared in two on-farm field trials. The first trial was planted on Merv Neumann's home farm on 20 March 2002, and the second on Peter Voight's home farm on 26 March 2002. Untreated seed (cv. Detroit Dark Red) was provided by Syngenta Seeds. Fungicides were applied to the seed as either liquid suspensions or slurries (Table 20).

**Table 20:** Fungicide treatments assessed on-farm (Merv Neumann & Peter Voight, 2002)

<b>Treatment</b>	<b>Application Rate</b>
1. Untreated	-
2. Apron (metalaxyl)	35 g.a.i./100kg seed
3. Apron (metalaxyl) + thiram	35 g.a.i./100kg seed + 400 g.a.i./100kg seed
4. Rizolex WP (tolclophos methyl)	0.8kg/100 kg seed
5. Thiram	400 g.a.i./100kg seed
6. Tachigaren (hymexazol)	1400g/100kg seed
7. Tachigaren (hymexazol)	700g/100kg seed
8. Tachigaren (hymexazol)	350g/100kg seed

Both trials were planted with a hand-driven tape planter, with seed spaced 70mm apart. The trial design was a randomized complete block with 4 replications. Plots comprised 6 x 5m row lengths with 6 x 2m blank row lengths at the plot ends.

A regular irrigation program for the trial was initiated after sowing using overhead irrigation, and the growers maintained the trials using commercial production practices. We monitored seedlings at 3-4 day intervals for 3 weeks after sowing, and assessed plants as either healthy or diseased. At each assessment the percentage of healthy seedlings was determined for each plot. Data were analysed using ANOVA in Genstat 6 for Windows.

At harvest, beets from the centre rows of each plot were removed manually and the tops were cut from the plants with knives. The roots were manually graded into 7 categories according to size and quality criteria suggested by Golden Circle P/L (Table 6).

## **Results**

Disease pressure was extremely low in both trials, presumably because drought conditions prevailed during the production of both crops. Since disease levels were so low, no differences in the emergence of plants, or crop yields or quality were afforded by any of the fungicide treatments ( $P < 0.05$ ).

## C) Field Assessments of Fungicides – 2003

### *Fungicide Trial (Earl Litzow, 2003)*

Nine fungicides and fungicide combinations were compared in a field trial planted on-farm at a site in Forest Hill with a history of *Pythium* root rot. The trial was planted on 24 June 2003. Fungicide treatments were applied to seed as slurries or liquid applications (Table 21).

**Table 21:** Fungicide treatments assessed on-farm as seed dressings (Litzow, 2003)

Treatment	Application Rate
1. Untreated	-
2. Apron (metalaxyl)	35 g.a.i./100kg seed
3. Apron (metalaxyl) + thiram	35 g.a.i./100kg seed + 400 g.a.i./100kg seed
4. Rizolex WP (tolclophos methyl)	0.8kg/100 kg seed
5. Thiram	400 g.a.i./100kg seed
6. Apron (metalaxyl) + Rizolex WP (tolclophos methyl)	35 g.a.i./100kg seed + 0.8kg/100 kg seed
7. Tachigaren (hymexazol)	700g/100kg seed
8. Tachigaren (hymexazol) + Rizolex WP (tolclophos methyl)	700g/100kg seed + 0.8kg/100 kg seed
9. Phosspot (phosphonic acid)	1.44L/100 kg seed

The trial was planted with a hand-driven tape planter, with seed spaced 70mm apart. The trial design was a randomized complete block with 4 replications. Plots comprised 6 x 5m row lengths with 6 x 2m blank row lengths at the plot ends.

A regular irrigation program for the trial was initiated after sowing using overhead irrigation, and the grower maintained the trials using commercial production practices. We monitored seedlings at 3-4 day intervals for 3 weeks after sowing, and assessed plants as either healthy or diseased. At each assessment the percentage of healthy seedlings was determined for each plot. Data were analysed using ANOVA in Genstat 6 for Windows.

At harvest, beets from the centre rows of each plot were removed manually and the tops were cut from the plants with knives. The roots were manually graded into 7 categories according to size and quality criteria suggested by Golden Circle P/L (Table 6).

### **Results**

Disease pressure was extremely low in the trial, presumably because drought conditions prevailed during the production of the crop. Since disease levels were so low, no differences in the emergence of plants, or crop yields or quality were afforded by any of the fungicide treatments ( $P>0.05$ ).

### ***Fungicide Trial (Glenn Lerch, 2003)***

Eleven fungicides and fungicide combinations were compared in a field trial planted on-farm at a site in Forest Hill with a history of *Rhizoctonia* root rot. The trial was planted on 14 April 2003. All fungicide treatments except the drenches, were applied to untreated cv. Detroit Dark Red seed as slurries or liquid applications. The drench applications were applied as soil sprays to the plots, using a motorized back-pack sprayer fitted with a 1m boom and 4 flat fan nozzles, after the seed was sown (Table 22).

**Table 22:** Fungicide treatments assessed on-farm as seed dressings (Lerch, 2003)

<b>Treatment</b>	<b>Application Rate</b>
1. Untreated	-
2. Thiram	400 g.a.i./100kg seed
3. Apron (metalaxyl) + thiram	35 g.a.i./100kg seed + 400 g.a.i./100kg seed
4. Rizolex WP (tolclophos methyl)	0.8kg/100 kg seed
5. Quintozene WP	180 g.a.i./100kg seed
6. Apron (metalaxyl) + Rizolex WP (tolclophos methyl)	35 g.a.i./100kg seed + 0.8kg/100 kg seed
7. Monceren 250 FS	15 g.a.i./100kg seed
8. Tachigaren (hymexazol) + Rizolex WP (tolclophos methyl)	700g/100kg seed + 0.8kg/100 kg seed
9. Moncut	0.15mL/100kg seed
10. Rizolex WP (drench)	120g/ha.
11. Monceren (drench)	1.37L/ha.

The trial was planted with a hand-driven tape planter (Livyn P/L), with seed spaced 70mm apart. The trial design was a randomized complete block with 4 replications. Plots comprised 4 x 4m row lengths with 4 x 2m blank row lengths at the plot ends.

A regular irrigation program for the trial was initiated after sowing using overhead irrigation, and the grower maintained the trials using commercial production practices. We monitored seedlings at 3-4 day intervals for 3 weeks after sowing, and assessed plants as either healthy or diseased. At each assessment the percentage of healthy seedlings was determined for each plot. Data were analysed using ANOVA in Genstat 6 for Windows.

At harvest, beets from the centre rows of each plot were removed manually and the tops were cut from the plants with knives. The roots were manually graded into 7 categories according to size and quality criteria suggested by Golden Circle P/L (Table 6).

### **Results**

Disease pressure was extremely low in the trial, presumably because drought conditions prevailed during the production of the crop. Since disease levels were so low, no differences in the emergence of plants, or crop yields or quality were afforded by any of the fungicide treatments ( $P>0.05$ ).



### ***Fungicide Trial (Moira Farms (Berlins Block), 2003)***

Eleven fungicides and fungicide combinations were compared in a field trial planted on-farm at a site in Forest Hill with a history of *Rhizoctonia* root rot. The trial was planted on 14 April 2003. All fungicide treatments except the drenches, were applied to untreated cv. Detroit Dark Red seed as slurries or liquid applications. The drench applications were applied as soil sprays to the plots, using a motorized back-pack sprayer fitted with a 1m boom and 4 flat fan nozzles, after the seed was sown (Table 23).

**Table 23:** Fungicide treatments assessed on-farm as seed dressings (Lerch, 2003)

<b>Treatment</b>	<b>Application Rate</b>
1. Untreated	-
2. Thiram	400 g.a.i./100kg seed
3. Apron (metalaxyl) + thiram	35 g.a.i./100kg seed + 400 g.a.i./100kg seed
4. Rizolex WP (tolclophos methyl)	0.288kg/100 kg seed
5. Quintozene WP	180 g.a.i./100kg seed
6. Apron (metalaxyl) + Rizolex WP (tolclophos methyl)	35 g.a.i./100kg seed + 0.288kg/100 kg seed
7. Monceren 250 FS	15 g.a.i./100kg seed
8. Tachigaren (hymexazol) + Rizolex WP (tolclophos methyl)	700g/100kg seed + 0.288kg/100 kg seed
9. Moncut	0.15mL/100kg seed
10. Rizolex WP (drench)	120g/ha.
11. Monceren (drench)	1.37L/ha.

The trial was planted with a hand-driven tape planter (Livyn P/L), with seed spaced 70mm apart. The trial design was a randomized complete block with 4 replications. Plots comprised 5 x 5m row lengths with 5 x 2m blank row lengths at the plot ends.

A regular irrigation program for the trial was initiated after sowing using overhead irrigation, and the grower maintained the trials using commercial production practices. We monitored seedlings at 3-4 day intervals for 3 weeks after sowing, and assessed plants as either healthy or diseased. At each assessment the percentage of healthy seedlings was determined for each plot. Data were analysed using ANOVA in Genstat 6 for Windows.

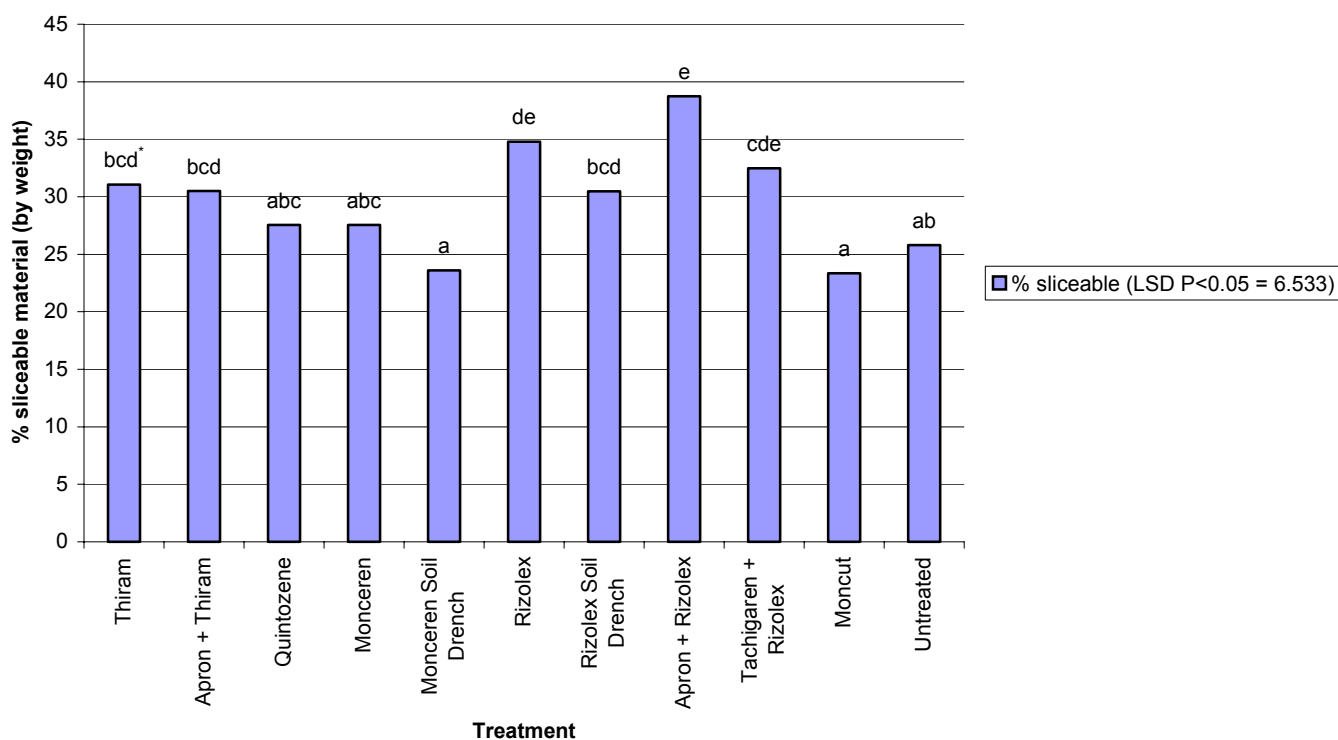
At harvest, beets from the centre rows of each plot were removed manually and the tops were cut from the plants with knives. The roots were manually graded into 7 categories according to size and quality criteria suggested by Golden Circle P/L (Table 6).

### **Results**

Plots of all treatments yielded equivalent weights of material at harvest. The three seed dressing treatments containing Rizolex (Tachigaren + Rizolex, Rizolex and Apron + Rizolex) all produced significantly greater proportions of sliceable material than plots sown with untreated seed (Figure 51). All the other fungicide treatments were ineffective. In addition to a higher proportion of sliceable material, plots sown

with seed treated with the Apron + Rizolex combination produced a significantly greater number of sliceable beets than untreated plots.

**Figure 51:** Fungicides assessed on-farm Berlin's block (Moira Farms, 2003)



\* Treatments with the same letters are not significantly different at the 5% level

This data was submitted to the APVMA as a component of a minor use permit application for Rizolex WP as a seed dressing and in-furrow application for beetroot for control of *Rhizoctonia*. The permit (permit 6543) was issued on 7 January 2004 and will remain current until 31 December 2005.

## D) Field Assessments of Fungicides – 2004

### *Fungicide Trial for control of Pythium and Rhizoctonia (Merv Neumann, 2004)*

The efficacy of Rizolex and Apron for control of *Pythium* and *Rhizoctonia* infections was assessed when the fungicides were applied via different methods: seed dressings, band-sprays and in-furrow applications and combinations of all three. A field trial was established on-farm at a site in Forest Hill with a history of *Rhizoctonia* and *Pythium* root rots. The trial was planted on 15 April 2004. For the seed dressings, Rizolex 500 WP (8g/kg seed) was applied to untreated beetroot seed (cv. Detroit Dark Red) as a slurry, and Apron (1mL/kg seed) was applied as a liquid. In furrow treatments were applied by spraying the fungicide into shallow furrows that were manually dug into the top of the hilled-up rows. Spraying was completed with a motorized backpack sprayer fitted with a wand attachment, and then the furrows were filled with soil by raking over the tops of the rows. Band sprays were applied as soil sprays to the plots, using a motorized back-pack sprayer fitted with a 1m boom and 4 flat fan nozzles, after the seed was sown. The following treatments were assessed:

1. Untreated seed
2. Seed coated with Rizolex 500 WP
3. Seed coated with Apron liquid formulation
4. Seed coated with Apron liquid formulation + Rizolex 500 WP
5. Untreated seed + in-furrow Rizolex 500 WP application
6. Untreated seed + Rizolex 500 WP band spray at planting
7. Untreated seed + in-furrow Apron application
8. Untreated seed + Apron band spray at planting
9. Untreated seed + in-furrow Apron/Rizolex combination
10. Untreated seed + Apron/Rizolex combination band spray at planting
11. Apron coated seed + in-furrow Apron application
12. Apron coated seed + Apron band spray at planting
13. Rizolex coated seed + in-furrow Rizolex application
14. Rizolex coated seed + Rizolex band spray at planting
15. Apron + Rizolex coated seed + in-furrow Apron/Rizolex combination
16. Apron + Rizolex coated seed + Apron/Rizolex combination band spray at planting

Rizolex 500 WP was applied at a rate of 120g/10 000m of row length for in-furrow applications and 0.83kg/ha for band-spray applications. Apron was applied as Ridomil Gold EC at a rate of 0.715L/10000m of row length for in-furrow applications and 1.3L/ha for band spray applications.

The trial design was a randomized complete block with 3 replications. Plots comprised 6 x 5m row lengths with 6 x 2m blank row lengths at the plot ends.

A regular irrigation program for the trial was initiated after sowing using overhead irrigation, and the grower maintained the trials using commercial production practices. We monitored seedling emergence at 3-4 day intervals for 3 weeks after sowing, and assessed plants as either healthy or diseased. At each assessment the percentage of healthy seedlings was determined for each plot. Data were analysed using ANOVA in Genstat 6 for Windows.

At harvest, beets from the centre rows of each plot were removed manually and the tops were cut from the plants with knives. The roots were manually graded into 7 categories according to size and quality criteria suggested by Golden Circle P/L (Table 6).

## Results

Disease pressure was extremely low in the trial. Since disease levels were so low, no differences in the emergence of plants, or crop yields or quality were afforded by any of the fungicide treatments ( $P>0.05$ ).

***Spray Application Trials using Rizolex 500 WP to control Rhizoctonia (Gatton Research Station and Merv Neumann Home Farm, 2004)***

**Introduction**

Rizolex 500 WP can currently only be used as a seed dressing or an in-furrow application in beetroot crops. This means that the fungicide will only help to control infection if it occurs soon after the crop is planted. We wanted to test if additional foliar sprays applied throughout the crop lifecycle would provide extra disease control. In addition, because infested soil thrown onto petioles and crowns of plants during cultivation is a primary source of inoculum for the development of *Rhizoctonia* foliar and crown rot, we wanted to test if disease control might be improved by directing fungicide into beet crowns. For this reason we chose to compare two types of spray rigs, a conventional boom and a boom fitted with droppers.

**Materials and Methods**

This experiment was completed at two locations. The first trial was established on-farm at a site in Forest Hill with a history of *Rhizoctonia* root and crown rot. The second trial was done on DPI Gatton Research Station in the disease isolation area. The DPI site did not have a history of *Rhizoctonia*, so before the trial was established, sterile oat seed inoculated with a pathogenic isolate of *Rhizoctonia* (isolate #1339 (8) ex. mature wilting beetroot, Peter Lerch), was drilled into the soil in rows 0.75m apart. The site was watered to promote the establishment of the fungus in the soil. The trial at DPI was planted on 1 April 2004, and trial at the Forest Hill site was planted on 15 April 2004. Ten treatments were compared as follows:

1. Untreated seed
2. Seed coated with Rizolex 500 WP (8g/kg seed)
3. Untreated seed + In-furrow Rizolex application
4. Seed coated with Rizolex 500 WP (8g/kg seed) + In-furrow Rizolex application
5. Rizolex coated seed + In-furrow Rizolex application + Foliar Rizolex spray (conventional boom) (1 application 5 weeks after sowing)
6. Rizolex coated seed + In-furrow Rizolex application + Foliar Rizolex spray (boom with droppers) (1 application 5 weeks after sowing)
7. Rizolex coated seed + In-furrow Rizolex application + Foliar Rizolex spray (conventional boom) (2 applications, 5 weeks and 9 weeks after sowing)
8. Rizolex coated seed + In-furrow Rizolex application + Foliar Rizolex spray (boom with droppers) (2 applications, 5 weeks and 9 weeks after sowing)
9. Rizolex coated seed + In-furrow Rizolex application + Foliar Rizolex spray (conventional boom) (3 applications, 5 weeks, 9 weeks and 13 weeks after sowing)
10. Rizolex coated seed + In-furrow Rizolex application + Foliar Rizolex spray (boom with droppers) (3 applications, 5 weeks, 9 weeks and 13 weeks after sowing)

For the seed dressings, Rizolex 500 WP (8g/kg seed) was applied to untreated beetroot seed (cv. Detroit Dark Red) as a slurry. For in-furrow applications it was applied at a rate of 120g/10 000m of row length, and a rate of 0.83kg/ha was used for foliar applications. In furrow treatments were applied by spraying the fungicide into shallow furrows that were manually dug into the top of the hilled-up rows. Spraying was completed with a motorized backpack sprayer fitted with a wand attachment, and after they were sprayed, the furrows were filled with soil by raking over the tops of

the rows. Foliar sprays were applied with a motorized back-pack sprayer fitted with a 1m boom and 4 air-induction nozzles (Teejet AI 11003) (conventional boom), or short droppers and air-induction nozzles (boom with droppers).

The trials were randomized complete block designs with 3 replications. Plots at the DPI site comprised 4 x 2.5m row lengths with 4 x 1m blank row lengths at the plot ends. Plots at the Forest Hill site comprised 6 rows x 5m with 6 x 2m blank row lengths at the plot ends.

Regular irrigation programs were initiated for the trials using overhead irrigation. The grower at the Forest Hill site maintained the trial using commercial production practices.

At harvest, beets from the centre rows of each plot were removed manually and the tops were cut from the plants with knives. The roots were manually graded into 7 categories according to size and quality criteria suggested by Golden Circle P/L (Table 6).

## **Results**

Disease pressure was extremely low in both trials. Since disease levels were so low, no differences in crop yields or quality were afforded by any of the fungicide treatments ( $P>0.05$ ).

## **E) Additional Fungicide Assessments**

### ***Assessment of fungicidal activity of a selection of fungicides against *Rhizoctonia* isolates from beetroot soils***

This experiment was conducted to assess the efficacy of a selection of fungicides against pathogenic *Rhizoctonia* isolates cultured from diseased beetroot plants and soils from the Lockyer Valley.

### **Materials and Methods**

Four isolates of *Rhizoctonia* isolated from symptomatic beetroot plants from farms in the Lockyer Valley (1667(2) ex. soil Moira #1, 1668(21) ex. soil Neumann #1, 1670(19) ex. soil Hauser, 1728(4) ex. seedlings, Voight home farm), were used in this experiment. Molten potato dextrose agar was amended with four concentrations of each of four fungicides (Rizolex 500WP, Monceren 250 FS; Moncut, Quintozene WP) as follows:

Rizolex 500 WP (label rate: 8g/kg seed)

Rizolex 500 WP (half label rate: 4g/kg seed)

Rizolex 500 WP (quarter label rate: 2g/kg seed)

Rizolex 500 WP (twice label rate: 16g/kg seed)

Monceren 250 FS (label rate: 0.6mL/kg seed)

Monceren 250 FS (half label rate: 0.3mL/kg seed)

Monceren 250 FS (quarter label rate: 0.15mL/kg seed)

Monceren 250 FS (twice label rate: 1.2mL/kg seed)  
 Moncut (label rate: 50mL/L)  
 Moncut (half label rate: 25mL/L)  
 Moncut (quarter label rate: 12.5mL/L)  
 Moncut (twice label rate: 100mL/L)  
 Quintozene (label rate: 2.4g/kg seed)  
 Quintozene (half label rate: 1.2g/kg seed)  
 Quintozene (quarter label rate: 0.6g/kg seed)  
 Quintozene (twice label rate: 4.8g/kg seed)

Eight petri dishes of each treatment were prepared and two plates of each treatment were inoculated with each of the four *Rhizoctonia* isolates. Plates were inoculated by placing a small section (25mm<sup>2</sup>) of mycelium of each isolate in the centre of each plate. Unamended potato dextrose agar plates were the controls in the experiment. Radial colony growth was measured on each plate, once per day, for four days after the plates were inoculated.

## Results

Average colony growth (mm) after 4 days for plates amended with fungicides at label rates are given in Table 24.

**Table 24:** Average colony diameters of *Rhizoctonia* isolates on potato dextrose agar plates amended with fungicides at label rates after 96 hours

Fungicide	Isolate			
	1667 (2)	1668 (21)	1670 (19)	1728 (4)
Untreated	87	87	87	87
Rizolex	0	0	0	3
Monceren	24.5	0	13.5	38.5
Moncut	0	0	0	0
Quintozene	14.5	10.5	0	11

Rizolex 500 WP and Moncut applied at recommended label rates provided the best control of all 4 isolates tested. In all cases these two fungicides either completely inhibited the radial growth of the fungal colonies or inhibited it to such a great extent that growth was very minor. Both Monceren and Quintozene did not appear to be as effective in reducing colony growth. Both of these fungicides only provided complete inhibition of one of the *Rhizoctonia* isolates tested.

This experiment was conducted as a preliminary investigation of prospective fungicides for control of *Rhizoctonia* diseases of beetroot. The results clearly indicate variability in the fungicidal activities of the chemicals tested, and interestingly, the sensitivity of the four isolates tested to the various fungicides. Isolate 1728 (4) appeared to be the least sensitive isolate, with only Moncut completely inhibiting the growth of this isolate. On the basis of the results, it appears that both Rizolex and Moncut may be particularly useful for control of *Rhizoctonia* in beetroot.

## *Assessment of methods of application of fungicides to beetroot seed for control of *Pythium* species*

### Materials and Methods

Seven fungicides were applied to beetroot seed cv. Detroit Dark Red via 7 application methods as follows:

Fungicides	Application Methods
Thiram (5g/kg seed)	dry dust
Apron liquid formulation (1mL/kg seed) + Thiram (5g/kg seed)	slurry
Tachigaren 70WP (7g/kg seed)	steep in fungicide (room temp, 8hr)
Rizolox 500 WP (8g/kg seed) + Apron (1mL/kg seed)	steep in fungicide (40°C, 8hr)
Apron liquid formulation (1mL/kg seed)	acetone infusion of fungicide (2 min)
Rizolox 500 WP (8g/kg seed) + Tachigaren 70WP (7g/kg seed)	primed in NaCl followed by slurry
Untreated seed	primed in NaCl/fungicide combination

After the seeds were treated they were sown 20 seeds per tray into UC mix and drenched with an inoculum suspension of *Pythium aphanidermatum* (isolate #1339 (8) ex. mature wilting beetroot, Peter Lerch). Explanatory notes describing the application methods are provided in Table 25. Seeds treated with each fungicide and application method combination were planted into 3 trays. *Pythium* inoculum was prepared by scraping 7-day-old cultures into de-ionised water (1 culture/200mL). Each tray was drenched with 50mL of inoculum. Untreated seed planted into UC mix and untreated seed planted in UC mix drenched with *P. aphanidermatum* inoculum were the controls in the experiment.

Trays were assessed twice weekly until 3 weeks after sowing. At each assessment time dead seedlings were counted and removed. The experiment was analysed as one-way ANOVA with blocking structure with Genstat 6 for Windows.

**Table 25:** Explanatory notes describing how the fungicides were applied to the seed

Application Method	Procedure
1. Dry dust	- seed and fungicide shaken together in bag
2. Slurry	- fungicide mixed with water and seed coated in solution
3. Steep in fungicide (room temp, 8hr)	- seed shaken in a fungicide solution on orbital shaker (130rpm) for 8hrs
4. Steep in fungicide (40°C, 8hr)	- seed stirred in a fungicide solution (magnetic stirrer) on a hotplate at 40°C for 8 hr
5. Acetone infusion of fungicide	- fungicide mixed with acetone. Seed shaken in solution in a stoppered flask for 2 mins (130rpm). Excess acetone drained off and remainder left to evaporate
6. Primed in NaCl followed by slurry	- seed shaken in a 0.34M NaCl solution for 30mins. 6 x 30min water washes. Shake for 6 days in 0.34M NaCl. 2 x 30 min water washes. Air dry seeds. Fungicide mixed with water and seed coated in solution
7. Primed in NaCl/fungicide combination	- seed shaken in a 0.34M NaCl solution for 30mins. 6 x 30min water washes. Fungicide added to fresh 0.34M NaCl solution and seed shaken for 6 days in solution. 2 x 30 min washes in fresh fungicide solution. Air dry seeds.

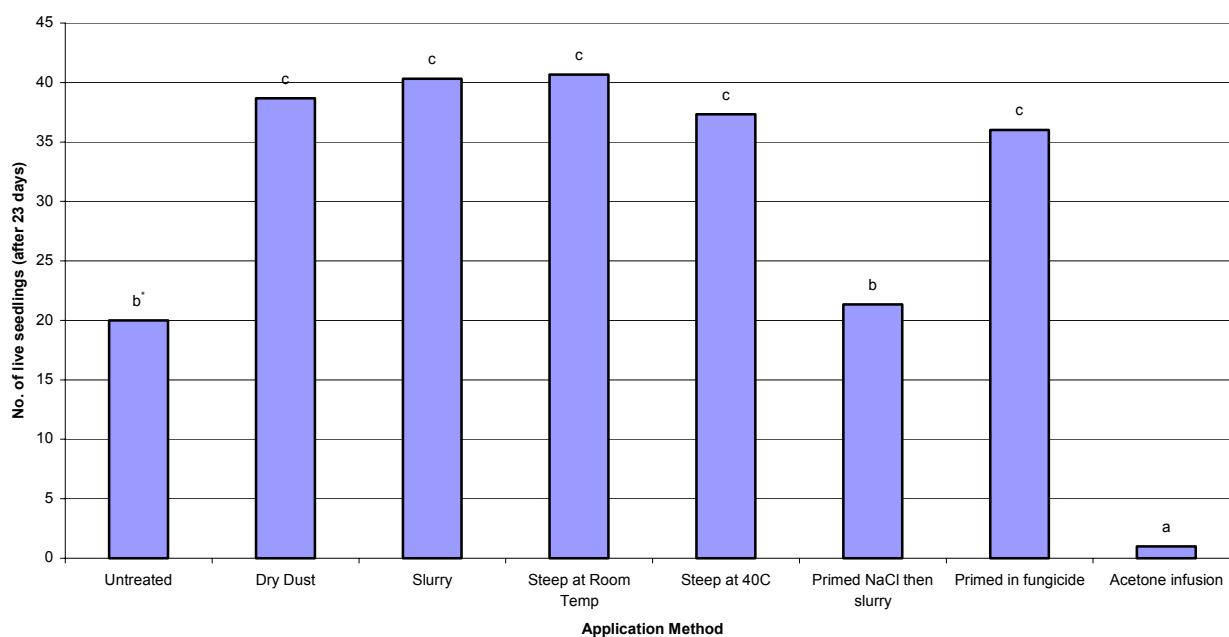
## Results

The acetone steep treatment killed the beetroot seeds. Thiram alone did not reduce disease caused by *P. aphanidermatum* regardless of how it was applied to the seed. Apron alone and the Apron + Thiram combination reduced disease significantly compared to the untreated ( $P<0.05$ ), and all the application methods were equally effective for these two fungicide treatments.

Seeds primed in the solution of NaCl and fungicide were killed for the Tachigaren and Tachigaren + Rizolex combinations. These two fungicide treatments were also ineffective in controlling *Pythium* infections when they were applied via either of the two steep methods. The Tachigaren + Rizolex combination only reduced disease when it was applied to seed as either a dry dust or slurry ( $P<0.05$ ).

For the Apron + Rizolex combination, seed that was primed and then coated with a slurry was as severely affected by disease as the untreated seed. All the other application methods (except the acetone steep) provided equivalent levels of disease control for this treatment (Figure 52).

**Figure 52:** Comparison of application methods for Rizolex/Apron combinations to beet seed for control of *Pythium*



\* Treatments with the same letters are not significantly different at the 5% level



## ***Assessment of methods of application of fungicides to beetroot seed for control of *Rhizoctonia****

### **Materials and Methods**

Six fungicides were applied to beetroot seed cv. Detroit Dark Red via 6 application methods as follows:

Fungicides	Application Methods
Thiram (5g/kg seed)	dry dust
Apron liquid formulation (1mL/kg seed) + Thiram (5g/kg seed)	slurry
Rizolex 500 WP (8g/kg seed)	steep in fungicide (room temp, 8hr)
Rizolex 500 WP (8g/kg seed) + Apron (1mL/kg seed)	steep in fungicide (40°C, 8hr)
Rizolex 500 WP (8g/kg seed) + Tachigaren 70WP (7g/kg seed)	primed in NaCl followed by slurry
Untreated seed	primed in NaCl/fungicide combination

After the seeds were treated they were sown 20 seeds per tray into UC mix and drenched with an inoculum suspension of *Rhizoctonia* (isolate #1669 (4) ex. soil Voight #2). Explanatory notes describing the application methods are provided in Table 25. Seeds treated with each fungicide and application method combination were planted into 3 trays. *Rhizoctonia* inoculum was prepared by scraping 14-day-old cultures into de-ionised water (1 culture/200mL). Each tray was drenched with 50mL of inoculum. Untreated seed planted into UC mix and untreated seed planted in UC mix drenched with *Rhizoctonia* inoculum were the controls in the experiment.

Trays were assessed twice weekly until 3 weeks after sowing. At each assessment time dead seedlings were counted and removed. The experiment was analysed as one-way ANOVA with blocking structure with Genstat 6 for Windows.

### **Results**

The acetone steep application method was not examined here because it killed the beetroot seeds in the previous experiment. The Rizolex + Apron and Rizolex + Tachigaren treatments were the only ones in the trial to reduce disease caused by *Rhizoctonia* ( $P < 0.05$ ).

The Rizolex + Apron treatment reduced disease when it was applied to the seeds via all the methods except for the room temperature steep in fungicide. The highest level of disease control was achieved when the Rizolex + Apron combination was applied as a slurry to primed seed or when the seed was primed in a solution of the fungicide.

Priming seed in a solution of Rizolex + Tachigaren or steeping the seed for 8 hours in a Rizolex + Tachigaren solution at 40°C, killed the seeds. Disease was reduced by the Rizolex + Tachigaren treatment most effectively when the treatment was applied as a slurry to primed seed.

## ***Assessment of methods of application of fungicides to beetroot seed for control of mixed infections of Rhizoctonia and Pythium***

### **Materials and Methods**

Eight fungicides were applied to beetroot seed cv. Detroit Dark Red via 6 application methods as follows:

Fungicides	Application Methods
Thiram (5g/kg seed)	dry dust
Apron liquid formulation (1mL/kg seed) + Thiram (5g/kg seed)	slurry
Rizolex 500 WP (8g/kg seed)	steep in fungicide (room temp, 8hr)
Rizolex 500 WP (8g/kg seed) + Apron (1mL/kg seed)	steep in fungicide (40°C, 8hr)
Rizolex 500 WP (8g/kg seed) + Tachigaren 70WP (7g/kg seed)	primed in NaCl followed by slurry
Untreated seed	primed in NaCl/fungicide combination
Apron liquid formulation (1mL/kg seed)	
Tachigaren 70WP (7g/kg seed)	

After the seeds were treated they were sown 20 seeds per tray into UC mix and drenched with an inoculum suspension of *Rhizoctonia* (isolate #1669 (4) ex. soil Voight #2) and *Pythium aphanidermatum* (isolate #1339 (8) ex. mature wilting beetroot, Peter Lerch). Explanatory notes describing the application methods are provided in Table 25. Seeds treated with each fungicide and application method combination were planted into 3 trays. Inoculum was prepared by scraping 14-day-old cultures of *Rhizoctonia* and 7-day-old cultures of *Pythium* into de-ionised water (1 culture of each isolate/200mL). Each tray was drenched with 50mL of inoculum. Untreated seed planted into UC mix and untreated seed planted in UC mix drenched with inoculum were the controls in the experiment.

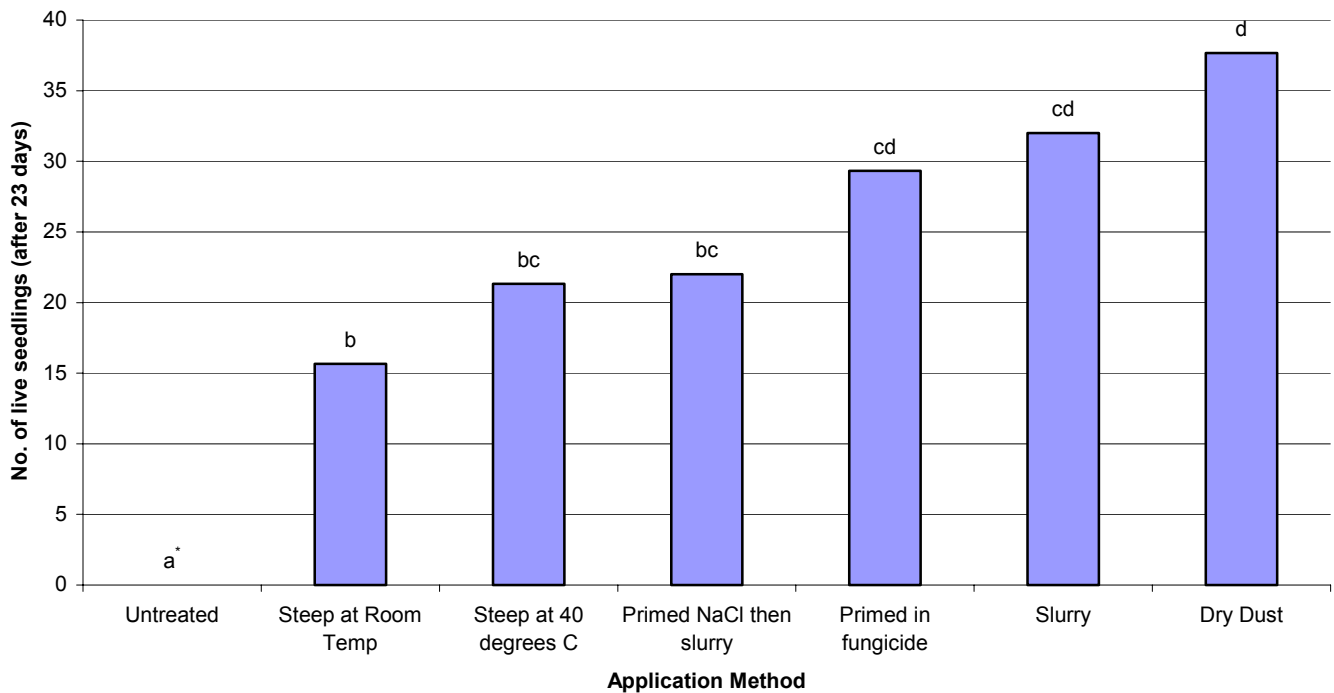
Trays were assessed twice weekly until 3 weeks after sowing. At each assessment time dead seedlings were counted and removed. The experiment was analysed as one-way ANOVA with blocking structure with Genstat 6 for Windows.

### **Results**

The Thiram, Apron and Apron + Thiram treatments were all ineffective for controlling mixed infections of *Rhizoctonia* and *Pythium*. In this experiment Rizolex, when applied as a single treatment to seed was still able to produce significant disease control (even though it has no activity against *Pythium*), indicating that the *Rhizoctonia* was the more pathogenic of the two diseases used in this experiment.

The Rizolex + Apron combination was the most effective treatment in the trial. This fungicide combination reduced disease significantly ( $P < 0.05$ ) regardless of how it was applied to the seed, however it was most effective when applied as a dry dust, a slurry, or as a slurry to primed seed (Figure 53).

**Figure 53:** Comparison of application methods for Rizolex/Apron combinations to beet seed for control of mixed infections of *Pythium* and *Rhizoctonia*



\* Treatments with the same letters are not significantly different at the 5% level

The Rizolex + Tachigaren combination was not as effective as the Rizolex + Apron combination at reducing disease. When applied as a dry dust or slurry however, the Rizolex + Tachigaren combination did significantly reduce disease development ( $P < 0.05$ ).

All three fungicide application experiments indicate that the Rizolex + Apron combination is the most effective for controlling both *Pythium* and *Rhizoctonia* infections. It should be applied as a dry dust or slurry, or used as a priming solution for maximum disease control.

### ***Assessment of Seed Dressing Efficacy and Seed Germinability after Storage of Seed for Different Lengths of Time at a Range of Temperatures***

#### **Introduction**

The quality of beetroot seed at sowing will affect the yield and quality of harvested product. Before the farmer sows the seed, he needs to have confidence that seed viability is high and that any fungicide seed dressings are present in sufficient quantities on the seed coat to afford effective disease control. Seed companies complete germination tests on seed lots before they are packed and provide this information with the seed, however it seems reasonable to conclude that how the seed is stored (in particular, the temperature and relative humidity at which it is stored) between supply by the seed company and sowing in a farmers field, may alter the seed viability. Additionally, certain fungicide seed dressings have been reported to

degrade relatively quickly after application to the seed, which will limit their effectiveness for disease control unless the seed is planted soon after the seed dressings are applied. Anecdotally, some seed lots that were stored by Golden Circle and planted by the industry in the following growing season seemed to have poorer establishment levels. This experiment was designed for two main reasons. First, we wanted to test how long beet seed could be stored at certain temperatures before viability was reduced. Second, we wanted to assess how well a range of seed dressings retained their efficacy after being applied to seed that was stored at a range of temperatures.

## Materials and Methods

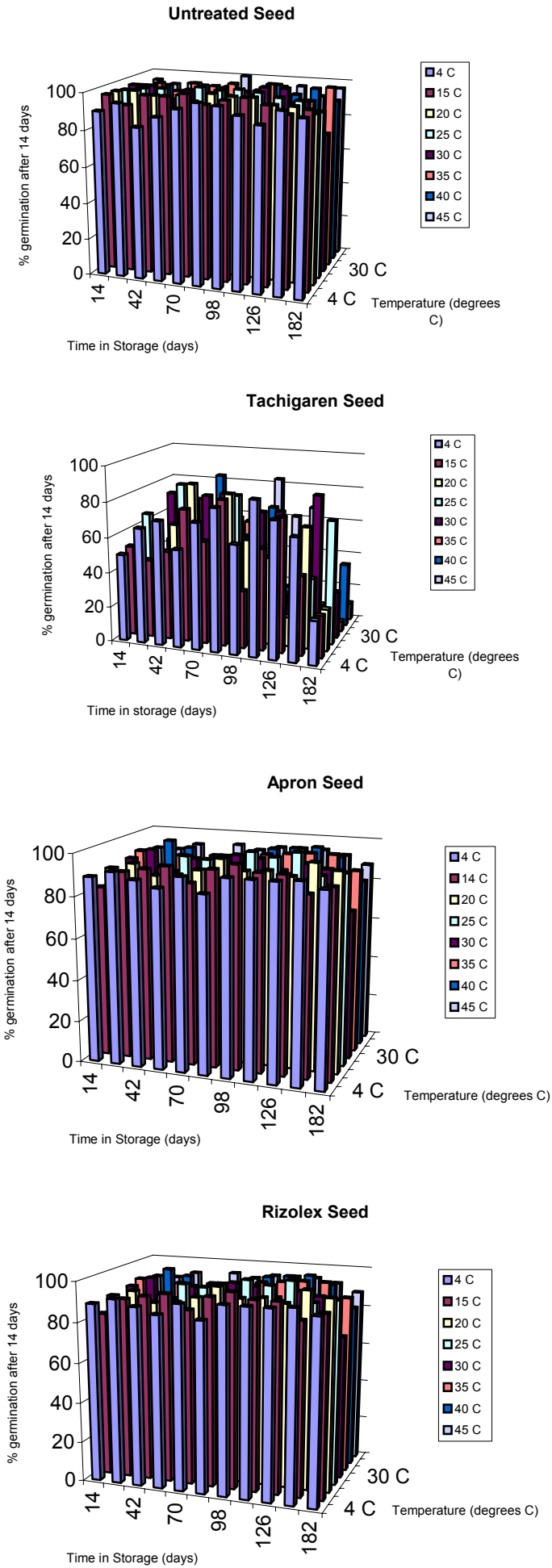
Three lots of beetroot seed (cv. Detroit Dark Red) were dressed with one of each of the following fungicides: Tachigaren 70WP (7g/kg seed), Rizolex 500 WP (8g/kg seed), Apron liquid formulation (1mL/kg seed), and the fourth lot was left untreated. Seeds that were treated with fungicide were counted into lots of 200, which were sealed in paper packets. Untreated seeds were counted into lots of 250 seeds. Twelve packets of each treatment were placed in each of 8 compartments of a multi-range incubator, so that each compartment contained 48 packets (10 200 seeds). Each compartment of the incubator was running at a different temperature: (4, 15, 20, 25, 30, 35, 40 45°C). One packet of each treatment was removed from each compartment after 12 incubation intervals (14, 28, 42, 56, 70, 84, 98, 112, 154 and 184 days of incubation).

Once the packets of seed were removed, 100 seeds of each treatment were used to complete a seed germination test (International Rules for Seed Testing, International Society of Seed Technologists, 1996). The remaining seeds were sown into trays of UC mix, 50 seeds per tray. One tray of Apron dressed seeds and one of Tachigaren dressed seeds was inoculated with *Pythium aphanidermatum* (isolate #1339 (8) ex. mature wilting beetroot, Peter Lerch) and the other 2 trays were left uninoculated. For inoculation, the *Pythium* was grown on sterile oat seed for 10 days, and then 200mL of seed was incorporated evenly into the UC mix. One of the trays containing seeds dressed with Rizolex was infested with *Rhizoctonia* (isolate #1669 (4) ex. soil Voight #2) by incorporating oat seed inoculated with the *Rhizotonia* (200mL/tray) into the UC mix, and the other was left uninoculated. One tray of untreated seeds was inoculated with *Pythium*, one was inoculated with *Rhizoctonia*, and the other was left uninoculated. Trays were assessed weekly for 4 weeks. Seedlings were counted and the dead seedlings were counted and removed.

## Results

Seed germination percentages did not vary much regardless of how long the seed was stored or the storage temperature (Figure 54). The type of fungicide used to dress the seed influenced the seed germinability far more than either storage time or temperature. The mean germination % of Tachigaren treated seed was far lower (49.97%) than untreated seed (93.40%) or seed treated with Rizolex (94.66%) or Apron (90.98%).

**Figure 54:** The type of fungicide dressing influenced seed germination more than storage time or temperature



In terms of the efficacy of the Tachigaren and Apron seed treatments against *Pythium* after storage, the interaction between storage time and temperature was not significant ( $P<0.05$ ) indicating that the effect of storage time on the percentage of surviving seedlings was similar across all temperatures. The interaction between temperature and fungicide dressing was also not significant ( $P<0.05$ ) which indicated that the efficacies of all the fungicide seed dressings were affected by temperature in a similar way. A non-significant temperature x soil treatment interaction indicated that storage temperature affected the survival of seedlings similarly in both inoculated and uninoculated soil.

The relationship between storage time and storage temperature for the untreated, Apron coated and Tachigaren coated seeds in soil inoculated with *Pythium*, is best described by the following regression equations:

$$\begin{aligned} \text{\% survival of seedlings}_{\text{Untreated}} &= (77.44-35.02) + (0.2869-0.1730)*(\text{Storage time}) \\ &\quad + (-0.001253+0.000684)*(\text{Storage time})^2 + 0.1714 \text{ Temperature} \\ \\ \text{\% survival of seedlings}_{\text{Apron}} &= (77.44-57.31-35.02+44.16) + (0.2869+0.731-0.173)*(\text{Storage} \\ \text{time}) &\quad + (-0.001253-0.003065+0.000684)*(\text{Storage time})^2 \\ &\quad + 0.1714 \text{ Temperature} \\ \\ \text{\% survival of seedlings}_{\text{Tachigaren}} &= (77.44-18.30-35.02+36.51) + (0.2869+0.190-0.173)*(\text{Storage} \\ \text{time}) &\quad + (-0.001253-0.000857+0.000684)*(\text{Storage time})^2 + 0.1714 \\ &\quad \text{Temperature} \end{aligned}$$

The temperature at which the seed was stored did not affect the efficacy with which the Rizolex seed dressing controlled *Rhizoctonia* infections. Also, the interaction between storage time and temperature was not significant ( $P<0.05$ ) indicating that the effect of storage time on the percentage of surviving seedlings was similar across all temperatures. The interaction between temperature and fungicide dressing was also not significant ( $P<0.05$ ) which indicated that survival of seedlings arising from untreated seeds and the survival of those from Rizolex coated seed were affected by temperature in a similar way. The relationship between storage time and storage temperature on the survival of seedlings arising from untreated and Rizolex coated seeds in soil inoculated with *Rhizoctonia*, is best described by the following regression equations:

$$\begin{aligned} \text{\% survival of seedlings}_{\text{Untreated}} &= (74.72-69.99) + (0.417+0.472)*(\text{Storage time}) \\ &\quad + (-0.001651-0.003895)*(\text{Storage time})^2 \\ \\ \text{\% survival of seedlings}_{\text{Rizolex}} &= (74.72+11.62-69.99+43.70) + (0.417-0.310+0.472)*(\text{Storage time}) \\ &\quad + (-0.001651+0.001066-0.003895)*(\text{Storage time})^2 \end{aligned}$$

## CHAPTER 5: Other Research Activities

### *Organic Amendments Field Trial 2002-2004 (Glenn Lerch)*

#### **Introduction**

Soil-borne diseases of beetroot increase in severity when soils are continually cropped to beetroot. It seems probable, that methods that reduce the quantity of disease inoculum in beetroot soils may help to reduce the severity of disease epidemics in the longer term. Fumigation of soils with a high inoculum potential has been found to reduce soil-borne disease severity in a range of crops. In beets however, due to tight margins between production costs and returns, it seems likely that a beneficial response to fumigation would need to be observed across several cropping cycles, and/or to crops grown in rotation with beets, for fumigation to be economically feasible. In addition to fumigation, there are various products that are commercially available that are purported to “improve soil health”, and as well as these, there are commercial biocontrol agents that may offer benefit in a beetroot growing system by helping to lower soil inoculum potential.

We established a trial on-farm with several objectives. Firstly, we wanted to test whether fumigation with metham-sodium was effective in reducing beetroot losses due to soil-borne diseases. Secondly, assuming fumigation did effectively reduce disease, we wanted to test whether soil amendments including commercial composts, green manure crops and biocontrol agents could help to extend the efficacy of fumigation by limiting the re-establishment of pathogen inoculum.

#### **Materials and Methods**

At the time the trial was started we had not yet completed our soil-indexing analysis of beetroot soils from farms in the Lockyer Valley. Consequently, the site was selected based on anecdotal information provided by the grower of high losses due to disease at the site in previous years.

Thirteen treatments were compared in a randomised complete block design with 3 replications. Plots were 20m long x 6m wide. Treatments were as follows:

1. Unfumigated soil
2. Fumigated soil
3. Fumigated soil + Bioverm (10t/ha)
4. Fumigated soil + Organic Life (10t/ha)
5. Fumigated soil + Enviroganics (10t/ha)
6. Fumigated soil + Poultry manure pellets (2t/ha)
7. Fumigated soil + Poultry manure pellets (5t/ha)
8. Fumigated soil + Poultry manure pellets (10t/ha)
9. Fumigated soil + Sorghum cv. Jumbo (25 kg/ha)
10. Fumigated soil + Oats cv. Moola (70 kg/ha)
11. Fumigated soil + BQ mulch (10kg/ha)
12. Fumigated soil + Trichopel R granular (9.5 kg/ha)
13. Fumigated soil + Poultry manure pellets (10t/ha) +Trichoflow Nursery (2t/ha) + Trichopel R granular (9.5 kg/ha)

The entire site (except for the plots marked out for the unfumigated soil treatment) was fumigated with metham sodium (800 L/ha) on 12 April 2002. Four weeks after fumigation, the green manure crops (sorghum, oats and BQ mulch) were seeded. The green manure crops were slashed in on 15 July 2002, and on this same day the remaining treatments were applied to the plots.

The Bioverm, Organic Life, Envirogenics and poultry manure pellets were broadcast evenly over the plots and then incorporated into the soil. For plots treated with a combination of poultry manure and Trichoderma, poultry manure pellets were broadcast over the plots (10t/ha), Trichoflow Nursery (2kg/ha) was then watered onto plots with watering cans and then both were incorporated into the soil. When the plots were sown to beetroot seed, Trichopel-R granular formulation was sown into the drill along with the beetroot seed at 9.5kg/ha. For plots treated with Trichoderma alone, Trichopel-R granular formulation was sown into the drill along with the beetroot seed at planting (9.5kg/ha).

The site was sown to beetroot cv. Garnet on 2 September 2002. Seed was spaced at 70mm. Side-dressings of urea were broadcast over the plots twice during the crop lifecycle. The plots were harvested on 3 December 2002. At harvest, beets from the centre 2 rows of each plot were removed manually and the tops were cut from the plants. The roots were graded into 7 categories previously given (Table 6). For each plot, the number of beets and the total weight of beets in each category were determined. Harvest data were analysed using the Analysis of Variance function in Genstat 6.0 for Windows.

In 2003 and 2004, the plots were again established on the same site. In 2003, green manure crops were slashed in and amendments applied on 17 May 2003 and the plots were sown to beetroot on 24 June 2003. The trial was harvested on 17 November 2003. In 2004, green manure crops were slashed in and organic amendments applied on 15 March 2004 and the plots were sown to beetroot on 22 April 2004. The trial was harvested on 21 September 2004.

For the 2003 and 2004 trials, as well as completing assessments at harvest, we used a Remazol Brilliant Blue dye assay to provide additional information about the soil microbial activity in each plot. Briefly, this involved burying cellulose strips impregnated with Remazol Brilliant Blue Dye into the soil (approx. 15-20cm deep) in each plot. Strips were removed from the plots at weekly intervals, the dye was extracted from the strips, and the quantity of dye extracted into solution from each strip was measured using a spectrophotometer (Moore *et al*, 1979). If the rate of cellulose decomposition was rapid (indicating high microbial activity), we expected only small quantities of dye to be extracted from the strip after burial and consequently, transmittance of light through the sample solution in a spectrophotometer would be high. Conversely, if the rate of cellulose decomposition was slow (indicating low microbial activity), large quantities of dye would remain in the undecayed strips after burial and consequently, once the dye was extracted from the strip, transmittance of light through the sample solution in a spectrophotometer would be relatively low. In this instance, we used microbial activity as an indicator of “soil health” – a high microbial activity indicating “good soil health” and a low microbial activity indicating “poor soil health”.

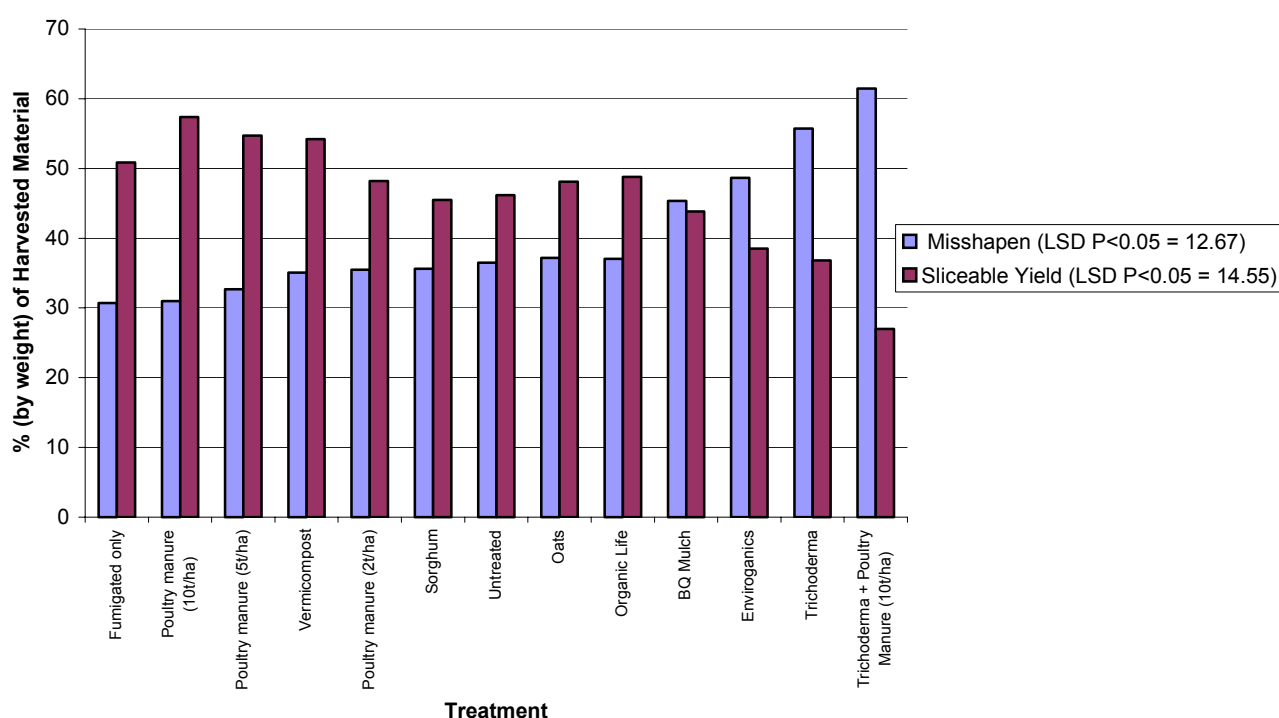


## Results

No significant differences ( $P < 0.05$ ) between the treatments in terms of their influence on microbial activity, were detected using the Remazol Brilliant Blue dye assay in either 2003 or 2004.

In 2002, plots treated with Trichoderma alone or the Trichoderma and poultry manure combination, yielded a significantly greater proportion of misshapen material ( $P < 0.05$ ) than untreated plots. The proportion of slicing material was also significantly reduced in plots treated with the Trichoderma and poultry manure combination (Figure 55).

**Figure 55:** Trichoderma treatments increased the proportion of misshapen material at harvest



In 2003, there were no significant differences between any of the treatments in terms of the quality and quantity of material in each grading category at harvest.

In 2004, the total yields, the proportion of slicing material (by weight) at harvest and the proportion of misshapen material (by weight) at harvest were equivalent in all treatments ( $P > 0.05$ ). Plots treated with Organic Life, poultry manure pellets (10t/ha) or those that were fumigated only did, however, yield fewer beets than the untreated plots ( $P < 0.05$ ). In addition, the Organic Life plots yielded fewer undersized beets than the untreated plots and, the number of cracked beets was reduced in plots treated with Organic Life, Enviroganics or poultry manure (10t/ha) (data not presented).

Organic Life also lowered the pH of the soil significantly. The pH of the soil from untreated plots was quite high (8.03). The pH of the soil from the Organic Life plots

was reduced to 7.7. Three of the other treatments (Bioverm, Envirogenics and Trichoderma) tended to increase the pH of the soil.

The level of disease at this site was very low (as indicated by the quantity of diseased beets harvested from the plots in all three years) (data not presented). The low level of disease at this site was also later confirmed via indexing assays of soil collected from the site before fumigation (G.Lerch #1) and again after fumigation (G. Lerch #2). With the benefit of hindsight this site was probably not the best choice for this trial. If we had used a site with a higher disease potential, we may have had greater prospects of detecting treatment differences.

### ***Varietal Improvement Program***

#### **Introduction**

At the commencement of this project the Australian processing beetroot industry utilised three varieties as standard slicing lines (Pablo, Detroit Dark Red and Garnet) and one line (New Globe) for baby beets. Detroit Dark Red, Garnet and New Globe are all open pollinated varieties, whereas Pablo is a hybrid type. Our trial work has consistently shown that Detroit Dark Red is a sub-standard line, with high rejection rates often directly attributable to high proportions of misshapen material. Concerns about the quality of product arising from New Globe seed, particularly from the seed lot supplied for season 2002, have also been raised during the project. Anecdotal information provided by the growers also indicates that the quality of Garnet has declined in the last 5 years.

Pablo is generally regarded as a superior slicing line to the other slicing types, producing a consistent globe shaped beet. The general consensus amongst the industry seems to be however, that it is more difficult to produce slicing type Pablo beets at the larger end of the size scale. This seems to be exacerbated at the extremities of the growing season when, under high temperatures, the tops on Pablo beets will collapse before the beet has reached the appropriate size. A beet with the consistent shape and processing characteristics of Pablo with the vigour and strong top of Detroit Dark Red would seem to be the ideal beet required by the industry.

The declining performance of the open-pollinated lines led the project team and others in the industry to speculate that seed production companies are not maintaining the genetic integrity of these lines. This conclusion seems well-founded because:

- 1) Most beetroot production in the rest of the world is now based on hybrid types
- 2) The size requirement for an Australian processing beet is considerably larger than in other countries
- 3) The beetroot industry in Australia is very small

Our small local industry is growing beet varieties that are no longer grown by other production areas (other growers have changed to hybrid types). Consequently, it would be surprising if a seed company would invest resources into seed maintenance activities for these open pollinated lines, solely to meet the requirements of the small Australian industry. This view has been further supported by discussions with Dr Irwin Goldman, head of the beetroot breeding program at University of Wisconsin-

Madison. According to Dr Goldman: “the deterioration of open pollinated cultivars is a big issue in plant breeding and is not being remedied by anyone at this time. The smaller seed companies are probably interested, but so far we are seeing more good open pollinated cultivars disappear than re-appear.”

Because of concerns about the supply of quality seed that has not deteriorated in genetic integrity because of genetic drift, the Australian beetroot industry has begun exploring the possibility of commencing its own seed improvement and production program for the open-pollinated lines in Australia.

### **Process and Progress**

Henderson Seeds became a commercial partner involved with the seed production activities in 2002. In August 2002, the growers, co-ordinated by the project team, hand-selected beets from a block of cv. Detroit Dark Red grown by Dudley Voight (Gatton-Forest Hill Rd). This block was known to have a high disease potential. Beets were selected based on the shape of their roots (globe-shaped), absence of disease, and top characteristics (strong top with no cracking or hollows in the crown). Approximately 1500 beets with desirable characteristics were selected from the block, the tops were removed and they were packed into crates and sent to Henderson Seeds at Lower Templestowe, Victoria. The beets were then planted out at Lower Templestowe in an attempt to provide a vernalisation period of sufficient length to initiate bolting. Unfortunately, the vernalisation requirement was not met in this first selection, and it was probable that the selections were made too late. Because of this, the process was repeated in 2003.

Selections of Detroit Dark Red were made again on 14 May 2003 from a block grown by Barry Lerch (Lester's Lane). The beets were harvested using the commercial harvest equipment, and then 2000 roots were selected and sent to Henderson Seeds, and a further 600 were selected and transplanted to DPI Applethorpe Research Station on 19 May 2003.

In addition to the Detroit Dark Red, about 200 cv. New Globe beets were hand selected from a crop grown on Merv Neumann's home farm on 15 May 2003 and these were also transplanted to DPI Applethorpe Research Station on 19 May 2003.

Selections from cv. Garnet were made from a block grown from seed with a use-by-date of 1999 (supplied by Merv Neumann). Moira Farms grew the block. Beets to be transplanted to DPI Applethorpe Research Station were hand-pulled from the site and the tops were removed. About 500 were selected. Part of the remainder of the block was harvested using commercial harvest equipment, and then approximately 2000 beets were selected, packed into crates and sent to Henderson Seeds at Lower Templestowe. Another section of the block was not harvested. It was retained at the site to test whether temperatures were sufficiently low in The Lockyer Valley for bolting to be initiated.

The Detroit Dark Red beets transplanted to DPI Applethorpe did not bolt, and we suspect that this may have been because soon after planting they were severely frosted (Figure 56)

**Figure 56:** The Detroit Dark Red beets transplanted to Applethorpe were severely frosted soon after planting



The beet breeding team at the University of Wisconsin indicated that roots are killed if they freeze in the ground.

The cv. Garnet selections bolted during October 2003 (Figure 57).

**Figure 57:** Garnet selections bolting at DPI Applethorpe after a vernalisation period July-September



Some of the cv. New Globe plants also bolted, however most did not, probably because they too were frosted after planting. Once the plants started bolting, we constructed frames made of PVC pipe around the beds containing the cv. New Globe. We covered the frames in nylon fabric of very fine weave (not greater than  $20\mu\text{M}$ ), so that pollen could not pass through (pollen from the *Beta vulgaris* plant is greater than  $25\mu\text{M}$  in diameter). We did this to prevent crossing between cv. New Globe and cv. Garnet plants.

Once flowering had finished and the seed had set, we took the frames away and let the seed mature on the plant. The beet seed was harvested when the seed balls at the base of each branch were mature and brown (Goldman and Navazio, 2003). This occurred

on 23 December 2003. At this time some of the seed heads were also completely dried on the plant. We also harvested this dried seed, but kept it separate from the “green” seed, so that we could check its viability.

After harvest, we let the seed air-dry in a cool, dry room. We then graded the seed into different size classes using a custom-made set of plastic sieves (2-3mm, 3-4mm, 4-5mm, >5mm). We completed germination tests on each seed lot of cv. Garnet. We did not complete a germination test on the cv. New Globe seed that we produced, because only a very small quantity of seed was available.

The Garnet that was retained at Moira Farms also bolted. We collected seed from this block when it had dried on the plants, graded it into size classes and completed germination tests.

The germination percentages for all the seed lots were very low (Table 26).

**Table 26:** The germination percentages for cv. Garnet seed produced at DPI Applethorpe were very low, but larger sized seed that was harvested when most of the seed balls were still green produced the highest quality seed.

Seed Type	Seed Size (mm diam)	Germination (%)
Garnet (dried)	2-3	1
Garnet (dried)	3-4	2
Garnet (dried)	4-5	8
Garnet (dried)	>5	17
Garnet (green)	2-3	2
Garnet (green)	3-4	5
Garnet (green)	4-5	23
Garnet (green)	>5	49
Garnet (Moira)	2-3	5
Garnet (Moira)	3-4	3
Garnet (Moira)	4-5	24
Garnet (Moira)	>5	38

The low germination rates of the seed lots we believe to be related to insufficient watering at flowering. Ensuring the roots have sufficient water at flowering is important to ensure adequate germination (Breitbach, pers. comm.). It was interesting, however, that the % germination was highest for the larger seed, and for seed that was harvested while most of the seed balls were still green.

In season 2004, Ashley Zelinski and Peter Lerch planted the seed produced at Applethorpe DPI. Germination, as expected, was low. To compensate for this, the seed was planted at a very narrow spacing. We made additional selections from the New Globe and Garnet 4-5mm and Garnet >5mm seed lots from crops at both Ashley Zelinski’s and Peter Lerch’s, and this material was transplanted to Applethorpe DPI in August and September 2004.

Mr Nick Breitbach ([dnbreitb@facstaff.wisc.edu](mailto:dnbreitb@facstaff.wisc.edu)) and Dr Irwin Goldman ([ilgoldma@facstaff.wisc.edu](mailto:ilgoldma@facstaff.wisc.edu)) of University of Wisconsin-Madison, provided additional useful information about root storage and seed cleaning. This information is listed below, as it may provide a useful reference for the Australian beet industry if it continues with its seed production activities.

### **Root Storage (method provided by Nick Breitbach, University Wisconsin-Madison)**

When you harvest the plants cut the tops as close as you can to the crown with out cutting the growing point. The less stem tissue the better. Leave the plants lay out in the cooler over night to cool down to cold room temp. Pack the roots into grocery size paper bags ( can double up bags, best) Fill up the bags 3/4 full or less. Fold the paper bags shut. Place these paper bags inside plastic bags. Seal bags shut with a couple air holes. I usually put one paper bags inside a single plastic bag, that's just a bit bigger than the paper bag. (I do this before I put the beets in.)

I also add some pine shavings, but you can do it without the pine shavings and still get good results. The fuller the bag the more pine shavings help. I can store beets up to a year this way. The real secret is the paper bags. The bags act as a blotter when moisture forms on the plastic. You want to keep the beets as close to 100% humidity without getting wet. Some time it's a good idea to replace the paper bags, if they get too wet. This is why you want the roots to be dry and cold before packing.

### **Seed Cleaning (method provided by Nick Breitbach, University Wisconsin-Madison)**

Let the seed mature on the plant until the seed is ripe. Cut the plants and place into paper bags and let the plants dry down until all the plant material is dry. Put these bags into a damp walk in cooler. The one you store your roots in should work. It's important that it's damp or you can make it damp by putting wet burlap bags on the floor. Usually I do this anyway to increase humidity. Now wait until the plants become soft. Usually over night, but may take longer. When the leaves are soft enough that they don't crumble and the tiny branches are soft and don't break, you are ready to strip off the seed. You should be able to strip off all the seed and not get all the sticks you usually deal with. After the seed is stripped off, dry the seed down again in a hot sunny greenhouse, any warm room or seed drier.

After the seed is dry I rub off the bracts with a wooden paddle with a handle, that has rubber ridges on the under side. I used a floor mat material to make mine. I rub this seed over a round holed seed sieve from Seed Burro. The holes are big enough so that the chaff falls through, but small enough that the seed doesn't. I have extended the walls of the sieve with aluminium sheeting. I made an exhaust unit that sucks the air downward. This way you utilize gravity and suction. I set the sieve over this unit and the chaff gets sucked outside. I made this unit to sit in front of and to fit into a window so that I didn't have to cut a hole in the wall.

If you don't have these seed sieves, you can put he seed into a seed blower, which does a good job as well.



## CHAPTER 6: Technology Transfer

- Workshops were held biannually throughout the project between the project team and key industry personnel (beetroot growers, Golden Circle employees, seed and chemical company representatives). The workshops have provided the industry with the opportunity to review progress and plan future research activities. At the first workshop (held in December 2000), each workshop attendee was provided with a copy of the literature review entitled “Management options for soil-borne diseases of beetroot”. At later workshops, attendees were provided with handouts detailing the results of latest research trials.
- In July 2001 and July 2002, as a component of the mid-year workshops, industry members and seed company representatives completed field walks of varietal trials at Merv Neumann’s farm (2001) and Moira Farms and Ashley Zelinski’s farm (2002) (Figure 58).

**Figure 58:** Field walks of varietal trials allowed the industry to assess the performance of beetroot varieties



- Several media releases have also highlighted the work completed by the industry and the project team. A story was filmed for “Landline” (ABC TV) on 10 September 2002 and was aired on 13 October 2002. A story was filmed for “Totally Wild” (Network 10) on 13 May 2003 and a newspaper article was published in “The Courier Mail” (Life liftout section) in June 2003.
- In July 2003, the project team compiled a survey that was sent to each beetroot grower from the Lockyer Valley and Bunny Bite Farms in the Fassifern Valley. The growers completed the survey anonymously. This survey was compiled to check the satisfaction of the industry with the work being done in the project. The survey was timed so that the project had been running for long enough for results to have been achieved, but in time for

improvements/changes to be made before the end of the project, if requested.  
A summary of the survey results are provided below:

### Beetroot Industry Questionnaire (no. of responses = 10)

1. How would you rate the level of difficulty associated with producing consistent, high quality beetroot?

1	2	3	4	5
no difficulty		moderate		extreme difficulty
<b>0</b>	<b>1</b>	<b>4</b>	<b>4</b>	<b>0</b>

2. On a scale of 1 (not important) – 5 (very important), how big a constraint are each of the following to your enterprise? If you are unsure, please mark with a U.

a) soil-borne diseases	<b>Av. 4.44</b>
b) inconsistent availability of high quality seed	<b>Av. 4.00</b>
c) poor performance of existing varieties	<b>Av. 4.11</b>
d) lack of water	<b>Av. 4.11</b>
e) insufficient space to rotate out of beetroot	<b>Av. 3.22</b>
f) insect pests	<b>Av. 2.33</b>
g) weeds	<b>Av. 3.22</b>
h) lack of information about best practice for beetroot production (2U)	<b>Av. 3.00</b>

3. On a scale of 1 (dissatisfied) to 5 (very satisfied), how satisfied are you with the research activities in the **current** beetroot project?

1	2	3	4	5
dissatisfied		moderately satisfied		very satisfied
<b>0</b>	<b>1</b>	<b>4</b>	<b>3</b>	<b>1</b>

4. Please list positive outcomes that you feel have arisen from the project.

- organised and concerted approach to the whole issue
- increased knowledge of disease types and presence (6)
- rapid improvement in cooperation with seed companies
- availability of wide selection of seed for trials
- collation of trial results and information
- trials of new chemicals
- variety trials – new varieties (8)
- moving towards creating a beet seed that suits our conditions (Seed improvement work) (2)
- fungicide permits
- identification of poor quality seed as a major issue



5. Please indicate areas that you think need improvement ie. what isn't the project team doing that we should be doing, or what are we doing poorly?

- no suggestions (3)
- more work in rotational crops and soil indexing
- more work on plant nutrition for our soils. Ensuring plant is healthy so that it is better able to combat disease
- not enough is being done on disease problems. Disease is a bigger issue than seed quality/beet varieties
- more research is needed into finding/developing better seed
- faster response to problems needs to happen and attention to "hotspots"
- response to grower inquiry is very good, but follow-up takes a long time

6. Which of the following statements do you feel are true? Please mark with T=true, F=false, U=undecided.

1. The return on investment in the **current** beetroot project has been poor (F (5), T (1), U (2))
2. The project team are willing to listen to the needs of the industry (T (10))
3. I have little confidence in the ability of research to help achieve solutions that are meaningful on-farm (F (8), U (1))
4. The DPI staff should be doing more to help the industry (F (5), T (3), U (1))
5. Beetroot growers should be doing more to help the industry (F (3), T (4), U (2))
6. Golden Circle should be doing more to help the industry (T (6), F (1), U (2))
7. The DPI staff dont understand the real issues facing the beetroot industry (F (8), U (2))
8. It is reasonable to expect that research should deliver solutions (T (9), F (1))
9. The research that is being done in the **current** project may be useful to some members of the group, but it is irrelevant to me (F (6), T (1))

7. How important is it for the beetroot industry to invest in another research project?

1	2	3	4	5
not important		moderately important		extremely important
<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>6 3</b>

8. Briefly explain your response to Question 7.

- need results on hairy root
- I don't want to go back to doing nothing
- We should continue with the work on soil-borne diseases. Seed production may have to be left to the seed companies because of the cost of our input plus theirs
- I would like to see some results first before investing in more projects
- I am very interested in the chemical and variety trials
- We need to continue the research, as long as it is targeted to where the growers see the greatest need
- There is still work to be done with disease and seed issues. If the day comes

when these issues are manageable and at an acceptable stage, other areas should be looked at for improvement. Whether it is at Golden Circle or DPI, research should never stop

**9.** Please list activities that should be the focus of future beetroot research,

- Diseases of beetroot (4)
- Variety trials (2)
- Variety trials – baby as well as slice (2)
- Rotational crops
- New herbicides for use in beetroot (3)
- Fungicide trials
- Residue testing for new chemicals
- Seed production (2)
- Hairy root problem
- Agronomy to improve yield. eg. Timing of fertiliser etc.
- Nutrition
- More efficient and effective irrigation

**10.** The following activities were suggested in the meeting held on 25/5/03 as areas where future research effort should be directed. Please indicate next to each activity how big a priority you feel each is (0 = forget it, 1 = minor importance, 2 = moderate priority, 3 = major priority, 4 = top priority).

- a) Continuation of variety trials (on-farm assessments) (0 (0), 1(1), 2(1), 3(5), 4(3))
- b) Development of varieties with better disease tolerance (0 (0), 1(2), 2(0), 3(3), 4(5))
- c) Overseas study tour (0 (0), 1(0), 2(4), 3(3), 4(3))
- d) Continuation of varietal selection program with Henderson Seeds and at Stanthorpe (with the aim of ensuring genetic integrity and providing a consistent supply of high quality seed) (0 (0), 1 (0), 2(1), 3(4), 4(5))
- e) Identification of the best rotational crops from the standpoint of disease management (0(0), 1(0), 2(1), 3(6), 4(3))
- f) Identify and assess alternative herbicides (0(0), 1(0), 2(3), 3(5), 4(1))
- g) Assess the influence of water quality on disease incidence and beetroot quality (0(1), 1(1), 2(2), 3(4), 4(2))
- h) Best practice for fungicide spray application (0(1), 1(1), 2(3), 3(4), 4(1))
- i) Identification of methods to improve soil health (0(0), 1(0), 2(1), 3(6), 4(3))

**11.** Other comments:

- problems identified need to be worked on
- The new project is a lot of money so we will need to see some positive outcomes. I know these type of trials can take time to see results
- I don't mind more research as long as Golden Circle are happy to keep putting money forward and the money we have been giving to QFVG covers it with help from grants
- I think growers need to stay in touch and direct the DPI in the direction they wish DPI to go in these projects

- not enough research is going into disease
- need to focus on the issues at hand rather than taking on a great number of projects and doing them poorly. We are doing trials and all learning and this takes time – very frustrating. The growers and Golden Circle have always directed where they wanted the project to go – as it should be. This survey gives everyone a chance to say their piece – very good.

## General Discussion

The soilborne fungal diseases currently jeopardising the Australian beetroot industry are not unique to Australia. The same diseases have been the focus of much research effort in sugarbeet and beetroot crops in many parts of the world. No single measure has been effective in controlling these diseases elsewhere, which, along with the research we have done in this project, supports the view that for Australian beetroot producers, a soil-borne disease management strategy comprising a combination of control tactics is likely to be required for effective disease control.

The fundamental issue that has led to an increase in prevalence of soil-borne diseases in this industry has been the extension of the growing window into periods of high disease risk. As a consequence of this extended growing window, growers, particularly those with smaller farms, have less opportunity to rotate out of beetroot, or if they are able to rotate it is only for short periods. The result is a continual increase in the quantity of disease inoculum in the beet soils and heavy losses due to disease, particularly in crops planted during periods of high disease risk. Unless measures are taken to reduce pressure on growers to grow more beets over a longer window, the gravity of the soil-borne disease issues faced by this industry will only increase.

Aside from this fundamental change that needs to occur if this industry is to survive, this project has identified several tactics that will assist the beetroot industry to better manage its soilborne diseases and improve the quality of its product.

First, we have identified that *Rhizoctonia* and *Pythium* are the most important soilborne fungal pathogens responsible for disease outbreaks on farms throughout the beet-growing areas of south east Queensland and, with the assistance of Dr Paul Scott (UQ Gatton), have characterised the species of *Pythium* responsible. The three most common disease-causing *Pythium* species differ in their abilities to cause disease on plants of different ages and only cause disease at certain temperatures. Consequently, there is the opportunity to reduce disease losses by manipulating when blocks dominated by particular species are planted. For example, since *Pythium aphanidermatum* is highly pathogenic to very young plants at temperatures greater than 15°C, blocks in which this pathogen predominates should not be planted early in the season.

Second, we have identified fungicides that will help reduce disease losses. A combination of Apron and Rizolex WP will give significant disease control and for best results, it should be applied as a slurry to seed. Although promising in initial field trials, Tachigaren would appear to be of limited use in beetroot because it slows germination and may inhibit it completely if applied at high rates. We obtained a minor use permit for Rizolex as a seed dressing or in-furrow treatment for beetroot. Additional residue and efficacy trials must be completed for Rizolex for this permit to be extended beyond 2005.

Third, in glasshouse studies we identified prospective crops that if grown in rotation with beetroot do not promote further disease inoculum build-up. Barley and Dolichos were the poorest hosts of *Pythium aphanidermatum* and *Rhizoctonia* of 22 crop types assessed. Therefore, they may be useful as rotational crops at sites with mixed infections of both pathogen types. These glasshouse studies should be verified in field trials in a future research program.

Fourth, we have assessed more than 90 different beetroot varieties and have identified types that are prospective alternatives to the current standard lines. Detroit Dark Red, one of the industry standards was consistently a very poor performer in our trials, leading the project team and the industry to speculate that seed companies are no longer maintaining this open-pollinated variety. A seed production and improvement program for the open-pollinated lines has commenced with Henderson Seeds as a direct consequence of our research.

This industry would also benefit by switching to monogerm beet types. We demonstrated a clear inverse relationship between plant spacing and the quantity of misshapen material produced. The current standard varieties are all multigerm types. With multiple shoots arising from each seed cluster, the plants encroach on each other as they grow, increasing the quantity of misshapen material and reducing recovery at the cannery. With monogerm seed, the quantity of misshapen product is reduced, because plant spacing can be controlled. Monogerm beet seed is significantly more expensive than that of the standard lines, however the economic gains associated with improved quality should far outweigh the increased initial cost. If Golden Circle P/L are committed to improving efficiency in beet production, they should complete a cost/benefit analysis for monogerm varieties.

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