

**THE EFFECTS OF SEED  
PRODUCTION  
PRACTICES ON THE  
PRODUCTIVITY  
OF THE SUCCEEDING  
WARE POTATO CROP**

**BY BRUCE MALCOLM BEATTIE**

**B. Agr. Sc.**

University of Melbourne

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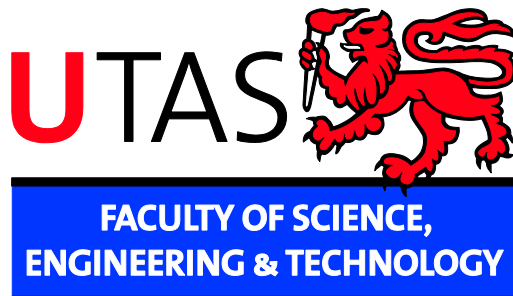
## **SUPERVISORS**

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Dr Philip Brown

Dr Mark Boersma

I wish to thank the University of  
Tasmania and the School of  
Agricultural Science for supporting  
this project



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## **DECLARATION OF ORIGINALITY**

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"The Lord himself decreed that the way of the man on the land shall not be easy."

Easing the life of those who feed us is a benefit to all.

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## ABSTRACT

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The project examined the effects of seed potato production on the performance of the seed in the following ware crop. The research was conducted in Tasmania, Australia, where the temperate maritime climate supports a lengthy growing season and a low aphid borne virus pressure permits crops to be grown to senescence, or defoliated if prevention of oversized tubers is desired. Harvest in the relatively cool autumn/winter may be delayed many weeks after skin set as soil temperatures do not fall below -1°C often. These factors permit a greater range of seed crop management options than is present in most other seed production regions of the world. Significant variability in the performance of seed lots grown in Tasmania has been documented, and could not be accounted for by differences in storage conditions, suggesting that seed crop production conditions may be responsible. Recognition of this possibility by the potato industry in Tasmania was the impetus for this project.

Seed tubers of cultivar **Russet Burbank** produced under various nitrogen and phosphorous nutrition, and planting density treatments were found to perform in the following season without significant differences in emergence date stem number or yield. Significant seed production practice effects on seed performance were found where planting date, time of defoliation and time of harvest following defoliation treatments were imposed. The results of the study confirmed that differences in ware crop growth and yield may be at least partially attributed to seed crop management practices. Sufficient evidence was generated to support the conclusion that, under Tasmanian production conditions, planting seed crops early in the season and defoliating prior to full crop maturity along with harvesting shortly after defoliation will increase the likelihood of producing seed tubers with higher productivity in the following season.

The seed performance responses found following seed crop defoliation date treatments were not consistent, ranging from no differences between defoliated and non-defoliated treatments to ten percent differences in yield. It was

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concluded that the stage of development or physiological status of the plant at the time of defoliation determines the effect on seed physiological status at harvest. In addition, significant differences in seed performance were noted between seed harvested shortly after defoliation and seed harvested after extended storage in the soil following defoliation. The behaviour of in ground stored seed following the stress associated with defoliation suggested that recovery from stress may be possible during seed development even when stems are removed. This capacity for recovery may explain differences in seed tuber responses between studies examining effects of early defoliation treatments.

The effect of seed production practices in seed physiological quality was shown to be complex, but with increasing importance placed in ware crop production on attaining consistent high yields of tubers in narrow size ranges, the capacity to manage seed physiological quality is very relevant to the potato industry.

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**ACRONYMS/ABBREVIATIONS**

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<b>ANOVA</b>	Analysis of variance
<b>Bravo</b>	chlorothalonil
<b>DAP</b>	days after planting
<b>DD</b>	Degree days
<b>DPIWE</b>	Department of Primary Industry Water and Energy
<b>FRS</b>	Forthside Research Station
<b>LB</b>	Lower Barrington
<b>Metribuzin</b>	[4-amino-6-(1,1-dimethylethyl)-methylthio-1,2,4-5(4H)-one triazine-]
<b>P-age</b>	Physiological Age
<b>ppm</b>	parts per million
<b>S</b>	Staverton
<b>Set(s)</b>	seed piece about 55g cut from a tuber
<b>SG</b>	Specific Gravity
<b>Spray seed</b>	135g l <sup>-1</sup> paraquat a.i. plus 115 g l <sup>-1</sup> diquat a.i. mixture
<b>Tato dust</b>	mancozeb 8% a.i.
<b>Ware</b>	the potatoes consumed or processed

**LEVELS OF STATISTICAL SIGNIFICANCE**

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<b>*</b>	P<0.05
<b>**</b>	P<0.01
<b>***</b>	P<0.001
<b>ns</b>	not significant



# CHAPTER 1

## GENERAL INTRODUCTION

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The potato, *Solanum tuberosum* L. subsp. *tuberosum* and *andigena*, is the most important dicotyledonous food plant in the world. Potato tubers have numerous end uses; food for human consumption as fresh or processed product (including French fries, crisps, canned, flakes, and miscellaneous frozen products), animal food, industrial purposes such as alcohol and starch, and arguably the most important use as vegetative propagules or seed (Talbert and Smith, 1975, Struik and Wiersema, 1999). The other major global food crops, wheat rice and maize, are grown from seeds produced by sexual reproduction whereas once a seedling potato has been selected from a breeding program, its novelty can only be maintained through vegetative reproduction. Specific management practices for potato seed tuber production, storage and handling have been recommended (Allen, *et al.* 1992, Rowe, 1993, Struik and Wiersema, 1999, Love, *et al.* 2003). The storage and handling of seed for Tasmanian conditions has been presented by Blaesing (2004 b). Most emphasis is placed on maintaining tuber health (freedom from, or low levels of pathogen infection), physiological aging during storage and, the preparation of sets for planting. Relatively little attention has been paid to the effects of seed crop management practices on the performance of the seed in the succeeding ware crop.

In most major potato production regions the acceptability of seed for the production of ware crops is based on the freedom from, or low levels of pathogens that reduce yield. Legislation has been enacted in many countries that state the acceptable levels of pathogens that apply to each multiplicative generation. However, In Tasmania, and the other eastern states of Australia,

there is a mutual agreement concerning seed potato certification. (Anon2007) In addition, trueness to cultivar type, tuber size, incidence of mechanical damage and the presence of contaminating soil and other debris are noted in these seed certification programs. Programs to eliminate or minimise “degenerative” virus diseases were the primary reason for the introduction of certification. As such, the crop husbandry required for the production of seed is similar to that of ware crops but with greater attention to plant health, tuber handling, storage and seed piece or set preparation. Seed is often grown in isolation from ware crops because of the carryover of pest and diseases, and the frequency of potatoes in the rotation is usually three to five years. Despite evidence that seed production practices may affect tuber productivity (Struik and Wiersema, 1999), the effects of crop husbandry practices on seed physiological status that may affect performance of the ware crop, analogous to vigour in true seed, are not included in seed certification schemes.

In countries such as Australia where seed certification schemes ensure high phytosanitary quality of the seed tubers, variations in performance between seed from different seed crops may be expected to be caused by differences in either the tuber physiological status or in the agronomic practices, soil type and microclimate of the ware crop. Of interest, large differences in seed performance have been noted between seed lots in replicated trials in Tasmania, Australia, where different seed lots of the same variety are planted at the one location (Brown, 2002). The local industry has recognised this variability (Mulcahy, personal communication) as an opportunity to improve the productivity of the ware crop sector by identifying production factors that affect seed quality. Seed of consistently high yield potential can then be produced by developing crop husbandry recommendations based on this knowledge. This project focused on the identification of seed crop management practices that affect performance of the succeeding ware crop.

MacKerron (2004), when discussing decision support systems in potato production commented that most systems, while they often have wide spread applicability, frequently do not have the precision to apply to a single cultivar.

Thus, the emphasis in the experimental work in this project is restricted to a single cultivar grown on a narrow geographic latitude of production and predominantly on one soil type, the Ferrosols (Cotching *et al.* 2009). The investigation used the cultivar **Russet Burbank** because it is the pre-eminent cultivar for French fry production in Australia, and in Tasmania, constitutes some 80 per cent of the States' crop. The areas of seed production examined in this study relate to the manipulation of field practices whilst maintaining good agronomic technique; and how this may impinge on the productivity of the subsequent ware crop. These effects on the performance of seed are described as intergenerational effects.

# CHAPTER 2

## LITERATURE REVIEW

### ORIGIN

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The potato *Solanum tuberosum* is endemic to South America, and the species is now cultivated in nearly all populated areas of the globe. Genetic analysis has placed the domesticated potato's origin as Peru, and selection for desirable attributes is thought to have commenced some 7 000 years ago (Spooner *et al.*, 2005). Introduced into Europe in the 16<sup>th</sup> century, the potato has since spread throughout the world. Detailed archaeological and historical investigations on the domestication of the crop can be found in Hawkes, (1992). The common name "potato" is considered to have originated from a local name for the unrelated sweet potato. This word had its origin in the Caribbean where the Arawak Indians described *Ipomoea batatas*, the sweet potato, as *batata*. (Hawkes, 1992). The Spanish also referred to the potato, using an Indian name, *papa*, but when the potato reached beyond the Iberian Peninsula, the name *batata* was erroneously used. A corruption of this name has since produced the English name potato.

When introduced to Europe, the tuber forming species *S. tuberosum* subsp. *andigena* was not adapted to those northern latitudes where day lengths are up to 16 hours. Consequently, haulms (stems) two to three metres long were reported in the 1600's and maturity occurred in late autumn or winter (Hawkes, 1992). The adaptation of the *S. tuberosum* subspecies at this new latitude occurred in the 17<sup>th</sup> and 18<sup>th</sup> centuries through propagation via seed. Through selection, a similar but distinct form of the subspecies evolved at the hands of the Indian tribes who lived at about 45°S in Chile. More recently Ames and Spooner (2008) have shown through DNA analysis of herbarium specimens that



the Andean potato was important in the 1700's but, the Chilean influence commenced by 1811.

Evolution of the modern commercial potato cultivars has resulted not only from within the original types taken to Europe (and subsequently North America), but also from the introduction of characteristics from other tuber-bearing species. The desirable attributes of these species have improved yield through resistance or tolerance to pests and diseases, or by altering physiological parameters. Examples of cultivars with genetics from other tuber-bearing *Solanum* species include **Cariboo**, with *Solanum phureja* and *S. demissum* in its parentage (Maurer *et al.*, 1968), **Tobique**, *S. demissum*, (Davies *et al.*, 1977), and **Allagash Russet**, *Solanum chacoense*, (Reeves *et al.*, 1980).

Internationally the potato crop has a major geographic peak distribution between 45° and 57°N where it is grown as a summer crop. Summer crop production in this zone has declined in the past 50 years, whilst in the same timeframe, the tropical concentration between 23° and 34°N has increased as a winter crop (Hijmans & Spooner, 2001). While a day length of 12-15 hours and diurnal temperature in the range 10°-25°C dictate a general zone of production, soil types and the availability of water more closely define the final cropping location and season. The final determinants for extensive production are efficiencies of scale, associated transport costs and the proximity of markets.

## PLANT DESCRIPTION

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The potato plant is a herbaceous annual grown for its tubers (modified underground stems) as food and for vegetative propagation of the crop. Due to its significance as one of the world's most important food crops, the structure and development of the potato plant is extensively documented through a number of excellent reviews. Growth of potato plant is generally described as a series of stages covering the lifecycle of the crop.

### **PHASE 1 - SET AND SPROUT DEVELOPMENT**

Potato crops are almost exclusively propagated vegetatively, and growth from the planted tuber represents the first stage in crop development. In Tasmania potato plants are produced from a portion of a tuber (a modified stem) that has been cut into pieces (sets) with at least one eye containing three buds. The primary bud is subtended by two lateral buds above a vestigial leaf scar or eyebrow. This portion of the tuber is a set (usually 50g) and is cut after dormancy has broken and the buds in the eyes are more than 2mm long. When the sets are placed in warm (10°C), moist soil, the eye will commence to grow, with bud growth emerging from the tuber, referred to as sprouting.

### **PHASE 2 - CANOPY GROWTH**

The below soil surface portion of the sprout or stem produces roots and stolons at each node. Stolons are underground stems that display diageotropic growth, and on which tubers may form. The above ground stem produces compound leaves subtended by stipules at each node. The leaves are produced in a spiral pattern. During this vegetative stage, in response to day length, temperature and plant development, florets are initiated. Flowers may fully develop, but in **Russet Burbank**, abortion usually follows. A number of stems emanating from a set is commonly known as a plant and all the plants present in the crop form the crop canopy.

### **PHASE 3 - TUBER INITIATION**

Whilst the stem develops, the stolons (which have scales and root hairs) elongate, and those at the lowest nodes commence to swell. The sub-apical regions of the swelling stolons become hooked and, when the diameter of the swollen tip is twice the 'normal' stolon diameter, tuber initiation has commenced. Stolons at higher nodes follow in sequence and many tubers may be initiated. Many are resorbed and one to five tubers becomes the main storage organ(s). In the early stages of development, the surface lenticels are open,

permitting the entry of pathogens and pests into the tuber. (During excavations, the writer has observed that the lower nodes have the smallest tubers and often these occur as a hollow sphere of skin only.)

#### **PHASE 4 - TUBER BULKING**

After initiation of tubers, shoot growth declines and then ceases, with dry weight accumulation in the plant predominantly occurring through tuber growth. For processing cultivars in Tasmania, at about 45 days from planting the largest tuber on a stem is about 20-30mm long and over the ensuing 60-70 days the main increase in tuber weight (size) occurs. During this phase, new leaf production and expansion stop and yellowing of the older leaves commences, beginning with the oldest. It is worth noting that when an illustration is used in descriptions of plant structure during the tuber bulking phase, the diageotropic rhizome or stolon is often shown to be geotropic (Rowe, 1993). To the ill informed this creates a false impression, and has undoubtedly been the source of the concept of tubers *growing down* into the soil!

#### **PHASE 5 - FOLIAGE DEATH**

Often, the drying stems are referred to as haulms. In this phase they carry golden leaflets that turn brown, this then followed by stem collapse to complete senescence. Tubers commence maturation by the hardening of the skin or periderm. The tuber becomes detached from the stolon, and its previously open lenticel structures are finally blocked, and the perrenating organ awaits harvest.

For research and/or agronomic purposes, a technique for describing the plant's developmental status is a useful tool (Dwelle, 2003). Cutter (1992) has presented an in-depth review of the morphology and development of the potato plant while Rowe (1993) has a very practical description that illustrates the plant's developmental cycle. Struik and Wiersema (1999) presented a description more allied to the production of seed. The general appearance of the plant may be affected by environmental conditions such as day length (Steward

et. al., 1981) and temperature (Menzel, 1985). Under field conditions, a phenological key such as the numerical code system developed by Jeffries and Lawson (1991) may be useful to describe the stages of development. Identification of key developmental stages such as tuber initiation is important in allowing comparisons to be drawn between published studies, particularly in studies examining crop performance.

## **WORLD DISTRIBUTION AND PRODUCTION**

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Recent statistics indicate that the potato is grown in some 150 countries worldwide and some 350 million tons are produced annually (FAO, 2004). In most developed countries the proportion of crops devoted to processing, and in particular par fried frozen products such as French fries and crisps, has risen spectacularly in the past 60 years. In the USA, European Community, New Zealand, Canada and Australia the change has been from zero to 60-80percent of the national crops over a 25-year period (Taylor, 2003).

## **THE FROZEN FRENCH FRY INDUSTRY**

As dehydrated potatoes are a readily transportable food stuff, during World War II large quantities of dehydrated potatoes were produced in Australia (Taylor, 2003) and the USA for troops operating in the Pacific, especially by the J R Simplot company (Attebery, 2000). Post war, water-blanching French fries became more popular (Talbert and Smith, 1975), becoming even more so with the development of the Dunlap–Kuneman process of preparing par fried French fries. These fries could be frozen for transport and then finished by the retailer or consumer by deep-frying (Attebery, 2000). Simplot had developed this process using **Russet Burbank**, the cultivar in use for dehydration during World War II. In Tasmania, the location of the research presented in this thesis, the production of frozen French fries was introduced to Ulverstone in 1963 (Taylor, 2003) under the guidance of Kueneman from Simplot. The choice of cultivar was then restricted to **Kennebec**, a cultivar released in 1948 from a

USDA breeding program and introduced by the Tasmanian Government's Department of Agriculture.

### **CULTIVARS FOR PROCESSING**

The attributes necessary for an acceptable French fry cultivar include long, generally cylindrical tubers of high dry matter content greater than 18%. Specific Gravity (SG), the weight in air and weight in water method (Stark & Love, 2003), has been used in Tasmania for many years (Stephens personal communication) to evaluate cooking quality. Values >1.070 and preferably 1.080 or greater are suitable for processing. White flesh and a fry colour rating of 00 for strips cooked in frying oil at 190°C (Anon1990) is required. In addition, a cultivar must have good cool-store characteristics that result in low reducing sugars at the time of processing and, the potential to have a good finish following the second fry prior to consumption (Talbert and Smith, 1975). Most importantly, a suitable cultivar must have a high recovery (a term used to describe the proportion of the initial tuber that remains after the preparation of the raw French fry, an average value of 50 per cent is common) and "very favourable marketing and processing characteristics" (Talbert and Smith, 1975).

With the rise in popularity of convenience and fast foods in developed economies, potato-processing companies such as Simplot and McCain's have found that **Russet Burbank** has had the greatest acceptance in the retail market, for example, with fast food companies such as McDonalds. It should be noted however, that **Pentland Dell** and **Bintje** (pale yellow flesh) are respectively acceptable in UK and Holland and, that a number of other cultivars are produced in significant quantities for processing.

## **PRINCIPLES OF PROCESSING CROP PRODUCTION**

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The processing industry requires a near year-round supply of high quality tubers. For French-fry processing, large elongated tubers of high SG that are free from bruising, deep lesions caused by pests, diseases and internal defects are needed. In addition to the requirement for near year-round supply of high quality tubers, the through-put of a processing plant dictates the necessary planting area on an annual basis. The latitude and climate of Tasmania allows a growing season of about 200 days, with planting taking place in the spring and early summer to utilise the available growing conditions before growth effectively ceases at the end of March. The subsequent growing season of 120-140 days allows the use of processing cultivars that benefit from an extended duration of radiative interception to produce high yields of quality tubers.

Processing crops are generally planted at a wider spacing than crops grown for fresh market tubers. Individual tuber size is linked to the number of tubers per unit area in the crop, and wider plant spacing increases the likelihood of a smaller number of larger tubers being produced. Selection of physiologically young seed tubers is likely to produce low stem numbers, and this practice is often adopted in processing crop production to control tuber number per unit area. Management of crop nutrition, irrigation, and pest and disease status is practiced to allow the crop to achieve the yield and quality potential set by the growing season and cultivar selection. The nutrition of crops in Tasmania is based on soil analysis, specifically for phosphorus and potassium, and the appropriate type and rates of N. P. K fertiliser are applied at planting. Other elements are seldom necessary. The placement of fertiliser as parallel bands either side of the set has evolved as the most efficacious technique for application. Plant nutrient status may be monitored through analysis of petioles either by sap or ash analysis, with further fertilizer applied as a top dressing based on the analytical results.

In the Tasmanian environment, irrigation is required every season to supplement rainfall, with crops receiving a total of about 500mm of water

during growth (Chung *et al.* 1988). The quantities may be determined using any one of a range of instrumentation techniques currently available, or from evaporation tanks, and application is carried out using a range of systems from permanent sprinklers through to centre pivot systems.

Harvest may commence when the crop has a suitable SG and, sound tubers over 80 or 100g weight form the fry grade or processing grade. Tubers showing second growth, cracking or rot form the waste or discard category. This may occur when the canopy is green or immature, and processing is immediate. As the season progresses crops mature and once the soil is cool and moist, harvest for storage commences. Tubers for processing are bulk stored and require adequate curing conditions, and ultimately the whole storage unit may be treated chemically to prevent sprouting. Long-term storage also requires a close control of temperature to prevent the accumulation of reducing sugars and humidity to prevent losses from shrinkage.

An equally important aspect of the processing crop is the provision of high health tubers for seed. A production plan similar to that of the ware crop is followed with specific emphasis on rotation, geographic isolation and seed tuber size. Pre-grading satisfies the size limits for set cutting, and the tubers treated to prevent multiplication of soil borne diseases that may multiply in storage at 4°C. Most sets are cut after winter storage near to planting time and any necessary protectants are applied. Materials used include cement; fir bark and mancozeb alone or in combination, but not a cement and mancozeb combination.

Given that the productivity of the processing crop requires the provision of both appropriate genetics and production environment, it is not surprising that much potato research has focused on both breeding and processing crop agronomy.

## **POTATO BREEDING**

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Potato breeding is an exacting activity because of the tetraploid inheritance of genetic traits. Selection programs therefore involve many controlled crosses of

selected parents during the choosing of desirable genotypes for propagation of botanical seed. Any one year's seedling production could involve several hundred thousand plants, but 30 000 is considered an ideal number for a single breeder to evaluate (Stephens, personal communication). The back ground and requirements of breeding are presented by Calagari (1992) and Struik and Wiersema (1999). Continuous selection for the desired characteristics over seven to ten years may result in a superior hybrid suitable for cropping. The development of a new cultivar then is a numbers game exacerbated by time!

Once a superior hybrid is available, the maintenance of the type depends on asexual reproduction. At the commencement of the 20<sup>th</sup> century in Tasmania, and as in many parts of the world, the maintenance of a cultivar was often accomplished by the collection of small tubers remaining after the harvest and sale of marketable tubers. Later this practice was shown to be a source of "degeneration", a condition of decreased vigour and productivity usually associated with various symptoms described as leaf curl, mosaic, crinkle and poor tuber type. Quanjer (1921) described these leaf distortions as being the effect of filterable viruses on the potato plants metabolism. As decreased vigour was universal in seed stocks, this knowledge gave a great impetus for the development of Seed Potato Certification schemes. Throughout the world, this information gave rise to increased productivity through careful selection of seed stocks. The provision of certified seed is outlined by Allen *et al.* (1992), Slack (1993) and Struik and Wiersema (1999).

Reductions in Tasmanian potato productivity due to degeneration were noted early in the 20<sup>th</sup> century and, by the mid 1920's the Tasmanian Department of Agriculture had initiated attempts to reduce degeneration through the introduction of stud plots (Oldaker and Vinceny, 1928). Later, material showing the least viral disease was taken to the cooler clime of the Tewksbury Potato Station (Alt. 183m) to reduce the incidence of aphids, the vectors of some viruses (Oldaker, 1935). Whilst the effects of various viruses did cause degeneration, Rieman *et al.* (1951) also showed that the maintenance of a



superior clone of cultivar **Chippewa** by continual selection also reduced productivity. This highlighted that somatic variation within a cultivar may also have a deleterious effect on productivity.

Subsequently all the cultivars used commercially in Tasmania were freed of viruses, pathogenic bacteria and fungal organisms through meristem culture (Sampson, personal communication). By 1969 using stem cuttings, “Pathogen Free” tubers were being multiplied at the Mt. Pleasant research facilities (Anon, 1970) and the resultant tubers stored in aphid-free conditions at Tewksbury Potato Station prior to multiplication in isolation plots of virgin soil. Selected tubers were returned to Department of Agriculture Mt. Pleasant Laboratories for a further cycle of stem cuttings. To reduce the time span of the certification scheme, which reduced the number of potential occasions for pathogen re-infection, and to reduce the evaluation time of new cultivars to Industry, micro-propagation techniques have been introduced. In Tasmania, the writer designed the propagation facility and implemented the change from stem cuttings to tissue culture and mini-tuber production in 1985. Current seed production of the dominant processing cultivar **Russet Burbank** in Tasmania involves three to four field generations following minituber production from tissue-cultured stock.

## ORIGIN OF RUSSET BURBANK

The complex nature of traditional potato breeding programs may be contrasted with the breeding of the major processing cultivar, **Russet Burbank**. The ancestry of this cultivar has been traced to **Rough Purple Chilli**, a tuber named by the Rev. Goodrich in 1851, which he selected from an assortment obtained by the US consul in Panama. Goodrich believed Chile was the origin of this material. One of Goodrich’s self-pollinated **Rough Purple Chilli** flowers produced seed that gave rise to **Garnet Chilli** in 1857, and 10 years later, was similarly the origin of **Early Rose** in 1867. Goodrich went on to produce over 12 000 seedlings in 15 years, yet failed to produce another commercial cultivar (Stuart,

1921). In 1873, Luther Burbank found a self-fertilised fruit of **Early Rose**, and of the 23 seedlings subsequently produced, one was released three years later as **Burbank's Seedling**. The original **Burbank** was white skinned; however later a russet-skinned sport occurred and was listed as **Russet Burbank** in the "Farmers' Seed Co" catalogue of 1908 (Stuart, 1937). This selection soon became quite popular in California under the names **California Russet** and **Netted Gem**. Over the following 60 years further selections were made from somatic variations of the original cultivar. For example, Love *et al.* (1992) evaluated ten clones and showed that one was virus infected and had a reduced yield, whilst another from a maritime climate had poorer production attributes in the test continental climate whilst the remainder were suitable.

The Tasmanian processing industry centres on a **Russet Burbank** clone obtained from North America in 1963 by the Department of Agriculture (P. Fountain personal communication). By 1980 **Russet Burbank** was emerging as the leading cultivar and the volume of **Kennebec** was declining, although the latter remained the cultivar of choice for early harvest production (September and early October plantings). In 1981 six clones of virus free **Russet Burbank**, namely **Luthers**, **Starks**, **Ruen**, **Netted Gem**, **Regular** and the **Vancouver** clone were available for evaluation in Tasmania. When grown at two sites (Forthside Vegetable Research Station and Elliot Research Station) over three years and at a range of set densities varying from 1.5 to 6 sets per square metre, no evidence was found to justify industry change from the locally grown **Vancouver** clone (Beattie, 1988; 1989; 1990). This clone was given the name **Vancouver** in the 1990's for identification purposes (Beattie, 1992) allowing its differentiation from a number of other clones that were, and are currently available in Tasmania.

The Tasmanian potato industry has conducted annual cultivar evaluation trials, incorporating the **Vancouver** clone of **Russet Burbank** for comparison purposes, and while seasonal variation in yields has been recorded there is no evidence of degeneration or somaclonally-induced productivity decline in the

clone (Hingston, 2007; 2008). Higher yielding cultivars have been identified in the evaluation trials, but **Russet Burbank** has been retained by the industry due to its consistent yields of high quality tubers. The longevity of the **Russet Burbank** as the dominant cultivar has led to greater focus on agronomic research to boost crop productivity in the state.

## CROP PRODUCTIVITY

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In addition to cultivar selection, there are a number of factors which affect the productivity of the potato crop. Thornton and Hyde (1993) divided these factors based on the potential for farmers to manage them;

Those under the control of the grower:

- aspects of seed quality
- set populations, growing period
- nutrition
- timeliness of operations

Those partially grower controlled:

- soil moisture
- pests
- diseases

Those that are not controlled by the grower:

- environmental parameters
- soil type

Analysis of the literature relating to these factors is equally applicable to seed and ware production, and the information covered in the following sections has particular relevance to production of **Russet Burbank** in Tasmania.

## SEED QUALITY

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Seed quality is an all-encompassing term used in its simplicity by growers, inferring that a seed lot is of high health, suitable for planting and capable of producing a high yielding crop. However quality may be viewed from three perspectives. First, the physiological status of seed often referred to as physiological age (P-age), which encompasses environmental conditions of production and storage, and may affect performance. Secondly, genetic purity and a set of physical attributes are defined. Thirdly, quality is linked to a range of seed health requirements. Genetic purity and phytosanitary status are incorporated in the set of standards used as prerequisites for Seed Certification. Whilst seed certification is almost universal, the physiological status of the tubers is generally not included in certification standards. Aspects of P-age play an important part in European seed production and seed usage but, in Australia P-age is not linked to the certification process.

The concept of P-age was proposed by Toosey (1964). A more comprehensive definition was later developed by the European Potato Research Association (Reust, 1984; 1986) and stated: *“The physiological state of the tuber, which influences its productive capacity (the physiological age is influenced by chronological age and environmental conditions during growth and storage)”*. When reviewing seed production, Wurr (1978a) enumerated altitude, location, soil type, fertiliser, growing season, time of planting, water availability, growing conditions, temperature, defoliation and harvest as factors influencing P-age. Similarly, Struik and Wiersema, (1999) reiterated these concepts across many commercial cultivars, and reported more extensively on manipulation of the growing crop and the resultant seed to prepare seed for a particular use. It was apparent that groups and individual cultivars had specific requirements for preparation. The emphasis in all the European studies was related to whole tuber responses, and fewer studies have examined cut seed, which may display an altered pattern of aging.

In the USA, Iritani and Thornton, (1984) authored a bulletin presenting conclusions for the manipulation of **Russet Burbank** seed production, storage and cut set preparation. There was an emphasis on “physiologically old” seed being less productive in regions having a long growing season. The recommendations were relevant to a system producing large tubers (280g) for cut set production. Recommendations for production of young cut seed included; “short growing season with relatively cool growing conditions, seed for large tubers should be stored at constant temperatures of 4°C, and minimise exposure to high temperatures.”

Physiological aging of tubers is considered to commence at tuber initiation, and a sequence of changes associated with aging has been described in the literature. The initial stage, tuber dormancy, has been widely studied. Following senescence or defoliation of the parent plant, tubers enter a state of dormancy. A definition for this state was developed by the European Association for Potato Research (Reust, 1986); “....*dormancy is the physiological state of the tuber in which autonomous sprout growth will not occur within a reasonable period of time (usually two weeks) even when the tuber is kept in conditions ideal for sprout growth: i.e. in darkness at 15-20°C and a relative humidity of about 90%*”. Burton, (1963) considered dormancy to commence at tuber initiation and indicated biochemical controls, and the physical treatment of the growing plant were implicated in the recommencement of growth. The end of the dormancy phase is considered to have been reached when 80% of tubers have sprouts 2mm or longer (van Ittersum, 1992a). The time to the end of dormancy and the recommencement of bud growth was shown to be cultivar dependant. In the cultivar **Diament** dormancy was related to tuber weight, while in contrast, tuber size explained very little of the variability in length of dormancy in cultivar **Desiree**. Additionally, tuber dormancy was shown to have greater variability within a plant than between plants (van Ittersum, 1992a).

The manipulation of dormancy was altered by 5-8 days through rates and timing of nitrogen application in the seed crop (van Ittersum, 1992b). Exposure

of plants to high temperatures during growth in a growth chamber resulted in increased sprout number after dormancy (van Ittersum and Scholte, 1992). Shading a crop up to 75% had no effect on dormancy but an extension of photoperiod indoors had a small effect (van Ittersum, 1992c). While commercial treatments to manipulate the duration of dormancy are very rarely used, timing of production is commonly used to ensure dormancy is ended prior to the target planting date. To achieve early plantings using sprouted seed, production and seed storage may be manipulated by the time of seed crop planting and haulm destruction (Hutchison, 1978a; 1978b).

The progressive changes in the external appearance of the tuber after the dormancy phase, has been extensively investigated and reported (Krijthe, 1962; Fischnich and Krug, 1963). Physiological aspects of dormancy are discussed by Colman, (1987); Suttle, (2004) and Vreugdenhil (2007) but are not the focus of this investigation. The sequential changes that occur with P age are summarised in Table 1 (Beukema and van der Zaag, 1990). To show the concept as developed by Weirsema (1985), a pictorial presentation was used by Struik and Weirsema (1999).

**Table 1.** Description of external changes associated with physiological age from dormancy through to senility (after Beukema and van der Zaag, 1990).

Dormant	Apical Dominance	"Normal Sprouting"		Senility
No sprout growth	One sprout	Multiple sprouts	Branched Sprouts	Hair Sprouts, "Little potato" growth
Young Tubers		Old Tubers		

In a complex storage temperature and growing regime, Ittersum *et al.*, (1990) developed physiological aging indices amongst a range of cultivars. The derived classification order was very similar to the scale of dormancy that accompanies

the Dutch cultivar descriptive catalogue, which is scaled for 20 points of differentiation in the Netherlands in the NIVVA Catalogue; the current edition is available online at, [www.potato.nl/uk](http://www.potato.nl/uk). The ability to predict and control the time of sprouting has important ramifications for determining planting times and potential yields, especially in the European early fresh market production programs.

In Table 2 are shown the relative effects of tuber age extremes on the attributes associated with the developing plant.

**Table 2.** *The effect of P-age (young to old seed) on characteristics of tuber and plant performance (adapted from Struik and Weirsema 1999, and Iritani and Thornton 1988).*

Plant Characteristic	Young Seed	Old Seed
Emergence	Slow/later	Rapid / earlier
Stems	Apical dominance/fewer	Less apical dominance /many
Plant condition	Vigorous plant and roots	Smaller Plant and root system
Tuberisation	Later	Earlier
Tubers/stem	Higher	Fewer
Tubers /hill	Fewer	More
Tuber size	Larger	Smaller
Secondary growth	Less	More
Yield	Higher	Lower

## MEASUREMENT OF P-AGE

When evaluating seed and using a chronological time scale, Kawakami (1962, 1963) showed the age in months of seed, the growing season, and cultivar had an effect on subsequent production. The term “physiological degeneration” was proposed for the decline in productivity. Older seed produced more stems and usually more tuber of greater weight, but invariably the yield of saleable tubers was less. These experiences have been used to define or measure these changes through the use of Degree Days.

A simple and widely used measure of tuber P-age is through accumulated

degree-days (DD) or heat units. These are based on daily mean temperature above a prescribed temperature (often 4°C) to describe the differences between respective seed lots. This method of measuring P-age has been used in the majority of published studies of tuber physiological status. For example, there is an experiment examining the manipulation of P-age for a range of early cultivars, by accumulating DD from 0 to 800 after dormancy break, using a base of 4°C. O'Brien *et al.* (1983) showed aged tubers (higher DD) resulted in higher early yields than young tubers but later harvests showed a reversal or similar yields depending on cultivar.

The base temperature used to calculate degree-days varies between studies. A temperature 4°C is most commonly used, with an assumption that this temperature is above the potential damage thresh-hold for sprout development (Struik and Wiersema 1999). However lower temperatures have been used; Davidson (1958) 1.6°C, Toosey (1963) 2°C, and Wurr (1978 b) 3°C.

Currently seed in Idaho is held at 0-2°C (N. Olsen personal communication), with no mention of temperatures below 4°C being deleterious, suggesting that for the processing cultivars commonly grown in Idaho a base temperature as low as 0°C may be appropriate.

In contrast to DD an alternative physical measure of aging was developed by Caldiz *et. al* (2001) and termed physiologic age index (PAI) and relates defoliation day and incubation period. Under Norwegian conditions, Johansen *et. al* (2006) found the concept unsuitable because the incubation time was too long and planting occurred before the PAI could be determined. Coleman (2000) reviewed P-age and covered not only DD but also the physiology and biochemistry of aging and indicated the development of a suitable biomarker(s) was an area for further research. To further elucidate plant (cell) function, Bachem *et al.* (2000) followed the developmental stages, and metabolic pathways, through functional genomic analysis and indicated that various genes were operative for various phases of tuber life. This approach may in the future be an avenue to P-age evaluation and define a set of relevant biomarkers.



In a short overview of P-age Struik (2006) covered these points and suggested breeding for a favourable physiological condition may be a future possibility.

## FACTORS AFFECTING SEED QUALITY

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The physiological quality of seed has been reported to be affected by a wide range of factors: place of production, cultivar, tuber size, storage conditions (temperature, relative humidity, atmosphere composition light chemical treatments), the duration of storage, seed treatments, seed crop growing conditions (time of planting, time of defoliation, seasonal temperature, soil type, low soil moisture, low nitrogen fertility, degree of tuber maturity at harvest) and post storage management (warming, degree of sprouting, cutting) (Wurr 1978 b, Struik and Weirsema 1999). Of these factors, seed crop location and growing conditions have been poorly studied while storage conditions have received extensive coverage in the literature.

## SEED PRODUCTION LOCATION AND GROWING CONDITIONS

In the northern hemisphere it has been considered for many years that seed produced at higher latitudes showed superior performance (Burton, 1966). In a large-scale investigation of the “Northern Effect”, seed of the cultivars **Norland** and **Russet Burbank** was sourced within the USA and northern Saskatchewan in Canada and grown at three sites of differing latitude; Colorado, Michigan and Saskatchewan to evaluate seed productivity (Wahab *et al.*, 1990). The more northerly grown seed had superior yields at mid and late harvests compared with the more southerly produced seed but, as the timing of seed production was not described, the differences may be a function of P-age resulting from differing times of harvest and durations in storage. The “Northern Effect” was included in a study (Knowles and Knowles, 2006) of **Russet Burbank** and **Ranger Russet** seed from sites between latitudes 53°N and 47°N over four years. The ware evaluation was conducted at a single site, 46°N. Seven P-age

treatments were imposed by varying storage temperatures. Aging **Russet Burbank** beyond the minimum of 80 DD for either seed source was found to be detrimental to the production of processing potatoes. When seed production location was considered the results indicated Southern seed produced a significantly higher proportion of small tubers than Northern seed. Olsen (2002) also reported results not dissimilar to those reported by Knowles and Knowles (2006). No difference in the productivity of **Russet Burbank** was found in the assessment of a total yield from 30 seed sources within Washington State (Iritani, 1967). Similarly, in a follow-up comparison, Iritani (1968) found no difference in productivity between cooler grown higher altitude seed compared to a warmer, lower altitude source (see change with time in Iritani and Thornton, 1984).

Seed origin has been recognised as a potential confounding factor in cultivar evaluation (Flack, 1983). When two yield stable cultivars, **Desiree** and **Pentland Crown**, were grown at two seed production sites to examine the possibility of site of production effects on subsequent crop yield, **Desiree** showed no difference when tested at 55 sites but **Pentland Crown** showed significant differences over 65 sites, with consistently higher yields from seed produced at one of the two sites of production. In similar investigations O'Brien and Allen (1992a; 1992b) examined the influence of site and altitude on three early cultivars: **Home Guard**, **Red Craig's Royal** and **Arran Comet**. There were no differences for several growth parameters at early harvests. In later harvests, however, seed from "cooler up-land sites" out-yielded seed from other localities. In addition they concluded that repeated production in warm localities did not lead to poorer performing seed. This suggests that the cooler grown seed was P-age young and had the potential to utilize the growing-out environment.

In the only published study examining effect of latitude of seed production on seed performance in Australia, no difference was found between four clones of **Russet Burbank** grown at various sites in both Victoria and Tasmania. These were grown from latitude 38° to 42°S, and at varying altitudes (Fennell and de

Jong, 1996). Thus, latitude of production *per se* is unlikely to be a major contributor to seed performance. However when seed from different production areas is grown at a common site, the studies including latitude do support the conclusion that growing environment and management practices may influence seed performance (Goodwin *et al.*, 1966).

The location of seed production is often mandated on the requirement for a short growing season with relatively cool growing conditions and a low aphid population to maintain phytosanitary quality (Iritani and Thornton, 1985). To maintain quality, management practices may also need to be employed at selected production locations. For example, early foliage destruction is often required in Scotland because of aphids and soil borne diseases (McKerron *et al.*, 1996). The combination of management practices used in seed production and features of the growing environment such as temperature and moisture availability may be factors affecting physiological seed quality. Burton (1966) and Wurr (1978a) have indicated that many agronomic aspects may influence the productivity of seed, but little definitive research has been done to substantiate these claims.

In greenhouse experiments Went (1959) found single eye sets grown at 20/14°C day/night temperature versus 26/20°C resulted in tubers that showed a positive response in crop yield for the following three generations. Similarly, seed production in a temperature range of 25-28°C was found to reduce yield when compared with cooler grown seed at 16-22°C (Bodlaender, 1972). In contrast to these studies, McCown and Kass (1977) found no difference in seed tuber productivity from **Kennebec** seed when produced under 26/20°C and cooler 20/14°C conditions.

#### **TIME OF PLANTING, DEFOLIATION AND HARVEST**

Seed harvested in mid-summer (August) or in the autumn (September) may result in the early harvested seed having a superior yield in the subsequent crop (Henriksen, 1972). This is contrary to a later study when four times of seed crop

defoliation were examined (Wurr, 1978 b) and early harvest gave the lowest yield in replanted **Desiree**. However in another series, early defoliation of the seed crop resulted in higher initial yields at early harvest, but by senescence, late harvested seed gave the highest yield across four cultivars (Wurr, 1980). The potential for control of seed production and storage to plan economic ware production was presented in the study.

In a complex growing and storage production system for the cultivar **Bintje**, Perenec and Madec (1980) sought to influence P-age over five seasons. Seed was produced from four planting dates about 30 or 60 days apart; haulms were removed 69 to 99 days after planting, whilst harvest occurred 31 to 64 days after defoliation. In storage, seed was partitioned to either 170 days at 2 to 4°C; or 80 days at 2 to 4°C followed by 90 days at 16 to 18°C. The results indicated that the long period of low temperature storage had little effect on total yield. However, the younger the seed, the higher the proportion of large tubers (>55mm) harvested. In contrast, the seed stored for the final three months at 16–18°C had decreased yields for the first three plantings, whilst the youngest seed behaved similarly to the long term, low temperature seed. Within each storage temperature regime the number of tubers per plant decreased with chronologically younger seed. A similar finding occurred when ware crops of four cultivars; **Wija**, **Record**, **Maris Piper**, and **Saturna**, were grown from seed produced from either a spring or two summer plantings (O'Brien and Allen, 1992b).

Cho *et al.* (1983) produced **Russet Burbank** seed from three spring planting dates about 20 days apart and harvested on three or five occasions, about 14 days apart after the first mid growth harvest, and stored tubers at 15°C. Dormancy break was noted over a seven day period in all of the treatments apart from the first harvest of planting one and two late harvests in plantings one and two. The effects of the treatments on crop productivity were not explored. To circumvent the inherent problems associated with variable dormancy break as Cho *et al.* (1983) encountered, Knowles and Botar (1991)

prepared seed lots of 361, 616, and 891 DD prior to sprouting in addition to a 66 DD control. Although dormancy break was not recorded, emergence for all treatments under glasshouse conditions occurred in a span of two days. When compared with the control, stem numbers more than doubled to three per seed piece for the youngest seed to over seven for the oldest. This response is consistent with the previous studies demonstrating that seed production and storage conditions may impact on stem and tuber number without always affecting total yield.

## **SEED STORAGE**

In contrast to the dearth of research on the effects of seed production practices on seed, much attention has been given to the effects of storage conditions on seed quality. In reviewing seed storage conditions Wurr (1978 b) stated “the temperature has a large effect on their subsequent performance” and indicated the degree of sprouting and the length of the sprouting period was important in the final performance. Furthermore, manipulation to produce either physiologically old or young seed was shown by Allen and Scott (1992) to affect leaf area production, which varied depending on the planting time.

To define mutual obligations between growers and store operators and other seed handlers, an Australian best practice and handling guide has been established through industry consultation (Blaesing, 2004b). The publication highlights that 25% of crop production costs is associated with seed tubers. Continuing, the guide exhorts seed growers to maintain certified seed integrity, and lists step wise all the activities from harvest through to cut seed, and indicates within each (e.g. curing has four headings and problems listed), technique, steps to reduce risk and the best approach to achieve the goal.

In Tasmania the most common commercial practice is to store seed tubers in 500 or 1000 kg wooden bins in cool stores at 4°C (some are converted apple stores). However, there remain a small number of producers who use on-farm storage facilities that rely on ambient conditions. Tubers are boxed, covered

with waterproof material and stored under trees to maximise cool air movement during winter. During storage, given the importance of temperature management on seed performance (Grice, 1989; Struik and Wiersema, 1999), use of on-farm storage is likely to contribute to the variability in seed performance in the Tasmanian potato industry.

Before storage the harvested tubers are graded to retain sound seed in the range of 35-270g and then treated with fungicide for gangrene (*Phoma foveate*) and two species of *Fusarium* (*Fusarium solani* var. *coeruleum* and *Fusarium sulphureum*). After seed selection, tubers are held in a sheltered out-doors site at ambient temperatures to promote wound healing (i.e. first, development of a suberised layer followed by the formation of wound periderm) before storing at 4°C for three to seven months. This temperature was shown by Burton (1966) to be at the lower end of the test range, 4-12°C, where the respiration rate for stored tubers was lowest.

In standard stores the control of O<sub>2</sub> and CO<sub>2</sub> concentrations is important as low O<sub>2</sub> levels have a long history of causing the physiological condition black heart in stored tubers (Stewart and Mix, 1917). The regulation of the O<sub>2</sub>/CO<sub>2</sub> ratio and ethylene in controlled atmosphere stores may have a place in regulating seed performance. This is because of the effects of gas proportions on dormancy and sprouts (Struik and Wiersema, 1999).

## **PREPARATION OF SETS**

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The new potato plant has its origin from an eye, essentially a compressed stem comprised of an apical bud with a number of subtending axillary buds. In most European countries and New Zealand (Struik and Wiersema, 1999) the entire tuber forms the set piece. In contrast, in Australia (Blaesing, 2004 b) and North America (Rowe, 1993), seed sets containing one or more eyes are cut from the tubers. The practice of cutting tubers for seed appears to have evolved on a

regional basis and is probably related to the prevailing environment and seed costs. Wigginton (1974) showed that suberisation and the development of wound periderm following cutting were dependent on temperature, humidity and oxygen (at least 10 per cent). Not only is it important at cutting, the development of wound periderm is also equally important at seed harvest when mechanical penetration of the skin is possible. Physical damage at this time is an ever-present threat to tuber health and is more likely when the soil is dry and cloddy. Any damage site can provide for chance inoculation by soil borne pathogens such as fusarium or gangrene, with the risk of infection increased if coupled with unsatisfactory curing conditions.

McGee (1985a, 1985b) showed that 15 cultivars grown in UK could be ranked according to their wound healing capacity, demonstrating a genetic component to the process, and that wound healing could improve as maturity increased up to crop senescence. Other studies have also shown that wound healing decreases with tuber age during storage (Kumar *et al.*, 2004), with a seven-fold increase in young compared to old seed, of NADPH oxidase, the enzyme responsible for the production of reactive oxygen species associated with suberisation (Razem and Bernards, 2003). Lulai (2005) investigated the development of the intact suberised tissue, and found that the stepwise development of this layer was necessary for water regulation as well as the exclusion of bacteria and fungi from the set.

In Tasmania, when seed tubers are removed from 4°C storage, warming to at least 10°C is considered necessary prior to cutting. This warming reduces the effects of mechanical damage and deleterious shattering, and also promotes subsequent wound healing. Protection of the cut surface with a drying agent such as cement, coal ash, pine/fir bark dust or some combination may be used. A further alternative is to use a proprietary protectant such as the fungicide dust Tato Dust in combination with fir bark to reduce tuber and soil-borne diseases such as common scab (*Streptomyces scabies*), Fusarium (*Fusarium spp*) and Rhizoctonia (*Rhizoctonia solani*).

Sets in Tasmania tubers are mechanically cut, with the aim of achieving the desirable range of 35-85g and with a target 50g mean size. Excessively large sets can cause inefficiencies in the planter mechanism, resulting in irregular plant stands. Tubers between 35 and 80g are occasionally used uncut, while those up to 350g are cut that blind (eyeless) sets will be minimised up to this size. However as tuber size increases above this upper limit the incidence of blind sets will increase (Bohl *et al.*, 2003). Currently in Tasmania to minimise blind sets, the 250-280g range is considered a more appropriate upper limit. The upper size limit is cultivar dependant, as for example, **Kennebec** and **Nooksack** have fewer eyes than **Russet Burbank** and require smaller tubers to avoid blind sets. The ability of cultivars to provide cut sets/seed pieces of designated mass from the range of tubers available in a seed lot was examined by Nielson *et al.* (1989) for **Russet Burbank** and **Nooksack**. Data was presented that showed the number of eyes present on seed tubers from 85 to >311g varied from 15 to 25 for **Russet Burbank** and 7 to 10 for **Nooksack**. Similarly, as set size increased from 28 to 70g, the average eye number increased from 2 to 6 for **Russet Burbank** and the number of blind sets decreased as set size increased. Tubers between 85 and 198g had 2.3 eyes, 1.69 stems, and the highest yields in a field evaluation.

Fresh cut sets need to be handled with care to minimise damage and maximise suberisation. Lengthy exposure to the sun post cutting is considered deleterious to viability (Anon, 1987). Thus shade / dark coupled to an ambient temperature in the 10-15°C range (Anon, 1987), and good aeration are necessary to aid in adequate suberisation.

## **SEED HANDLING AND BRUISING**

The timeliness of the planting operation is critical to the establishment of target plant stands that maximise grower returns. This is reflected in the time between cutting and planting that may be quite variable because of rain and contractor availability. Most growers in Tasmania commonly hold seed for two to three



days after cutting before planting providing soil conditions are favourable. The recommendation that the set be placed in a warm moist soil (Anon. 1987), however this is not always feasible in practice. Early plantings occur at soil temperatures of six degrees or lower which often encourages rhizoctonia infection and in the author's experience fresh cut untreated sets are very vulnerable to loss, however this can be remedied through effective pre-cutting procedures.

The practice of pre-cutting, or cutting and curing the seed prior to or during storage, is often used in Tasmania. A study of pre-cutting carried out by Sparks *et al.* (1962) showed that sets fully suberised when held at 7°C and 90-100% relative humidity for at least seven days. Chase *et al.*, (1989) held sets for eight days as short term, pre cut seed before planting and found the cultivars **Shepody** and **Yukon Gold** had a quicker emergence and a 15 percent yield advantage over fresh cut seed. There was a significant difference in plant stand, but no mention was made of effects, if any, on stem number. These workers did however quote work from as early as 1934 on the advantages of pre-cutting several months before planting, and concluded that the failure to implement the practice commercially was because growers were unable to provide optimum conditions for the process.

In Tasmania, Chapman and Jolly (1991, 1992) examined the potential of pre-cutting over the seasons 1990-91-92. In the first season seed was harvested in April and June and cut in those months as well as the conventional pre planting time of October. The greatest plant losses occurred with the conventionally cut treatments which, in turn resulted in lower yields. The autumn/ winter pre-cutting took place at a relatively quiet time in seasonal work and the resultant sets that were well suberised ensured a greater likelihood of establishing the desired plant population. In the following season there was a very late June harvest and the seed was mechanically cut late July prior to storage. A range of venting and dusting treatments was applied, followed by controlled or ambient curing conditions for eight days before cool storing below 4°C. The control

treatment was cut nine days prior to planting in October. The pre-cutting and curing at 15°C, under non-vented and dusted treatment gave the highest processing yields. During storage, non-dusted treatments had the greater set loss while a mancozeb-based dust had the least. Cutting immediately prior to planting had the highest incidence of black leg (*Erwinia atroseptica*). In both years, the effect of pre-cutting highlighted the possibility of controlling the planting program and achieving better returns.

### **TUBER DAMAGE**

The quality and value of tubers for ware and seed purposes is reduced by damage. Mechanical damage is most obviously seen as scuffing and cuts to the skin. In addition shatter and thumb-nail (moon) bruising is easily discerned. Tubers in this category are usually removed during harvest in the paddock or during the grading process in the case of seed. Black spot bruising is less obvious and usually becomes obvious when the tuber is peeled for further processing. Harvest bruising was shown by Thornton *et al.* (1973) to reduce income from ware potatoes by 20 per cent and this outcome was influenced by the degree of tuber hydration and the interaction with soil temperature. Poor calibration of the harvester chain speeds and the matching forward speed of the harvester were responsible for most damage. McRae, (1980) described mechanical damage in the UK and found similar results to those of Thornton and in addition, provided information on the influence of tuber damage to stores packing for the fresh market.

When applied to seed, the implications of these findings were expanded by Thornton and Hyde (1992). They reported the evaluation of seed from bulk storage to grower storage and cutting, and found a 7% loss from handling and up to 14% loss in production from seed preparation and planting and the crop. When sets were examined 60 days after planting, the physical quality of sets was shown to be lower as the level of bruising increased. The condition of the cutter knives was also important and those that were blunt reduced seed

quality. Bruised seed often is more disposed to disease and in this situation *Fusarium spp.* was detected with an overall reduction of large tubers by 48%, whilst under size tubers increased by 24%.

## **EFFECT OF WITHIN-TUBER SET ORIGIN, SIZE AND SPACING ON STEM NUMBER AND PRODUCTION**

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Total dry matter production in a crop is limited primarily by the genotype of a species interacting with the environment (Woolhouse, 1981) and the main controlling factor is the number of plants per unit area. The pattern of dry matter accumulation also varies with species, plant organs or spatial distribution. For instance Frappell (1969) showed in *Beta vulgaris* that while the total dry matter yield was asymptotic, the yield of the roots was parabolic. For carrot, yield increases in an exponential manner over a limited plant density range, and further density increases beyond this limit result in an asymptotic relationship i.e. as density increases yield remains virtually constant but individual plants (roots) become smaller (Bleasdale and Thompson, 1969). Spatial distribution can influence carrot yield, and the ideal spacing to maximise carrot crop yield is a rectangularity of 1:1 while at 4:1 a yield loss of at least 5% occurs (Frappell and Beattie, 1978).

In the case of the potato, a set may produce one or more stems and each stem becomes an independent plant when the set decays or is exhausted of nutrients. Therefore the development of target set spacings is complicated by the potential variability in the number of stems per set to modify effective plant density. Frappell and Fountain (1972) presented results using **Kennebec** at plant densities ranging from 1.56 to 44.5 m<sup>-2</sup> and a rectangularity of 1:1, and confirmed the asymptotic relationship of yield with plant spacing and the commercial practice of using six sets per square metre.

Past seed crops in Tasmania, although proposed for certification, were often grown at ware set densities to provide an outlet if rejected as seed. In particular, this practice has been applied to seed used in the processing industry (M Lette

personal communication). Set spacings of 4.5 to 5.5 m<sup>-2</sup> are more usual for seed production. Almost all seed is cut mechanically and as a 50 to 60g set is required, the size grade distribution of the mother tuber is important. Thornton and Hyde (1992) reported on USA studies indicating mother tubers between 100 and 280g would produce 80 per cent of sets averaging 57g with minimal discarded pieces. This approach for set preparation became part of Tasmanian commercial cutting services that provided a statement on set size distribution (D. Abblit, personal communication).

### SET SIZE

Iritani *et al.* (1972) examined the effect of set size and spacing on stem numbers and yield of **Russet Burbank**. Sets weighing 14, 28, 42 and 56g were grown at 3.6, 4.8 and 7 sets m<sup>-2</sup> in rows 914 mm apart. The two larger set weights had the higher yields within each spacing, and yields also increased with higher set densities. The weight of set tissue available per stem was calculated from that data and showed that as the initial reserve increased from 9 to 25g, the total yield increased from 45, to 60 tha<sup>-1</sup>. This work also indicated that higher stem numbers were not always indicative of higher yields.

When Regel (1989) examined the productivity of 25, 50 and 100g tubers of **Russet Burbank** grown as uncut sets, he found that yield increased with increasing set size up to 50g but the larger 100g set did not increase yield. Beattie and Regel (1986) conducted two similar but independent studies with the **Vancouver** clone of **Russet Burbank** grown at two sites on a ferrosol soil. In these trials, to simulate the seed tuber size range then currently acceptable, seed tubers weighing from 35 to 450g, were cut to produce 50g sets having 100, 60, 30 and 0 per cent rose end seed pieces. Set spacings of 1, 2, 3, 4, and 12 m<sup>-2</sup> produced yields that increased over that range, with tuber size grade distribution varying between treatments. The yield was similar for both whole and cut seed. Higher processable yields were obtained at 3 to 4 sets m<sup>-2</sup> or 10-15 stems m<sup>-2</sup> whilst the highest seed yields occurred at 25-30 stems m<sup>-2</sup>. Lower

densities had losses due to second growth and splitting. In this experiment stem number increased to nearly 30 per square metre and yield appeared to be approaching the asymptote. A retrospective examination of yield variation showed that at the same set densities, stem numbers were affected because sets were cut from different sized tubers to achieve the desired rose end proportions. This result indicates that a tight control of seed tuber size is necessary to control/predict stem densities.

Using **Russet Burbank**, de Jong (1993) examined the effect of tuber size, set size and spacing on yield and found 80g sets yielded 7% higher than 40g sets. It was also shown that seed from 175g tubers out-yielded seed from 350g and was associated with higher stem number. The stem numbers were in the range of 10 to 17m<sup>-2</sup>, which was similar to the results of Lynch and Rowbery (1977). While the preceding results indicated a target stem population, the costs associated with variation in seed cost were not taken into account.

These observations indicate a closer inspection of seed production practices is necessary to elicit a greater understanding of factors affecting seed quality and may contribute to better management of stem density

## SUMMARY

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The aspects of seed handling and set preparation outlined above provide an indication of the control necessary in the production of seed and in set preparation. Such control facilitates the examination of potential effects on the next generation, i.e. the ware or processable yield. The control of stem numbers is paramount in achieving a high yield of the processing tubers. The previous evaluation of seed production from seed set to ware set showed there were many aspects of the environment interacting with the potato plant growth cycle which could be manipulated by the grower. The timing of the production, the season, and the age of the crop when terminated have effects on the productive capacity of the seed. Most manipulation of seed has taken place during the storage period, whilst the tuber is dormant and or in an enforced dormancy

because of low storage temperatures. In Tasmania the storage aim is to remove stored seed with minimal sprout movement in preparation for set cutting. With the adaptation of both local and external practices, it remains difficult to predict stem numbers per set and to maximise the output of processing-size tubers. Local experience has also shown that whilst standard storage practices occur, there is sufficient handling variation to affect P-age as has been encountered in grow-out observations in industry.

The variability in locally grown seed indicates there is a potential in examining agronomic practices during seed production that may affect the performance of the ensuing ware crop.

# CHAPTER 3

## GENERAL MATERIALS AND METHODS

### OVERVIEW OF THE STUDY

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The project focused on identifying aspects of seed potato production that impact on the performance of the seed in the following ware crop. The study was undertaken in Tasmania, Australia, and examined the cultivar **Russet Burbank**, the dominant potato cultivar used by the processing industry in the state. The impetus for the project originated from a commercial assessment of seed tuber quality in the state. In this assessment, seed tubers produced at various localities and under varying growing conditions were held in standard storage prior to planting at a single site. Despite all plots being grown under the same conditions, a yield variation of up to 30 per cent between plots containing seed of the same clone but sourced from different seed crops was found. This effect was noted over a number of seasons, but no consistent links to production location or growing conditions were found (Mulchay, personal communication). The results suggested that seed production practices may have a significant influence on seed performance in **Russet Burbank** in Tasmania.

The maritime climate the potato production regions of Tasmania has resulted in a seed production system where the environment has a limited impact on the duration of the growing season. Seed producers are therefore able to plant over an extended period in spring and summer. As there is a low aphid borne virus problem, crops are grown to senescence or defoliated if prevention of oversized tubers is desired. Harvest in the relatively cool autumn/winter may be delayed many weeks after skin set as soil temperatures do not often fall below 0°C. Seed producers also have the option of selling oversized tubers to the processing sector, with many growers treating seed crops in a dual purpose fashion.

Following harvest, overwinter storage at 4°C is the adoption of the American practice and is satisfactory to the needs of industry. In addition the Tasmanian industry is dominated by two North American processors, Simplot and McCain that predominantly use **Russet Burbank**.

Many of these aspects of potato production in Tasmania are different from those in Western Europe, where the majority of research on seed potato physiological quality has been conducted, and to a lesser extent the USA. In particular, the large spread in planting and harvest dates, adoption of both natural senescence and defoliation practices at the completion of crop growth, and use by some growers of 'in-ground' storage following senescence or defoliation, may be expected to result in greater variability in seed physiological status when entering storage than in areas where more uniform seed crop management exists. In the UK and the Netherlands, for example, a long seed growing season is often prevented by defoliation requirements associated with potential virus infection. Manipulation of the growing period is restricted, and defoliation always practised, resulting in limited scope for production environment and practice effects compared to controlled storage temperature variations. P-age manipulation based on consistent seed status prior to storage has proved effective in enhancing the profitable early market yields, especially in early season cultivars (O'Brien *et. al.* 1983).

Growers in Tasmania have "Learnt the art" of growing **Russet Burbank**, producing high yields in processing crops, but seed production practices in Tasmania which mirror many of the processing crop production practices, have produced large unexplained effects in performance. Intergenerational effects created by customary agronomic practices may contribute to the variability in seed performance.

The research trials presented in this thesis tested the hypothesis that varying seed crop production practices result in significant differences in the performance of succeeding ware crops of the following year. The trials also



investigated a range of production practices that may affect seed tuber physiological quality.

## TRIAL SUMMARY

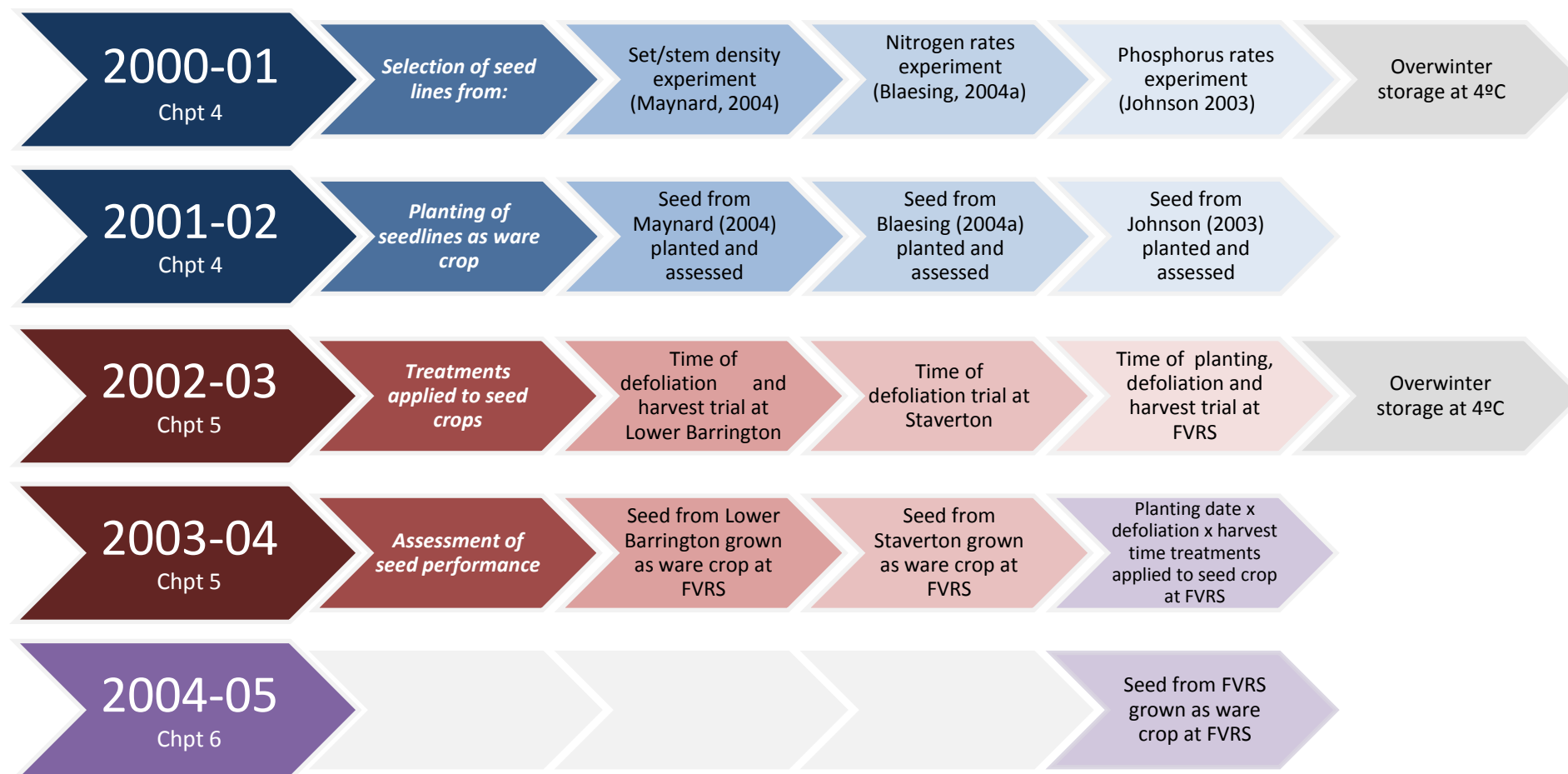
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This research was undertaken on a part-time basis between 2002 and 2010. All field trials were conducted on ferrosol soils in North West Tasmania using the cultivar **Russet Burbank**. The project timeline is outlined in Fig. 1.

Early studies of the soils were conducted by Stephens (1937) and the basaltic soils were described by the colours; chocolate, red-brown, dark brown and very dark brown; with the majority between pH 5.5 and 6.5. The high ferric oxide content was noted along with “a well developed crumb structure”. The Russian term krasnozem was suggested by Leeper (1948) as a name for red loams or red earths or red brown earths. He also suggested a “new word” descriptive of the soils “be invented” to reduce the confusion that existed as the term krasnozem was used to describe various types that had developed on basalt and to some developed on dolerite (Loveday 1955, Loveday and Farquhar 1958). More recently Cotching *et al.* (2009) have used the term ferrosols to describe these deep, well structured soils that have a minimum of 5% free iron oxides but may be as high as 18% iron. Depending on location, these clay soils (50-70% clay that is predominantly kaolin) may vary in depth from 1 to 7m.

Trials examining the effects of seed crop management on performance of that seed in the following production crop must be conducted over two seasons. In order to investigate these influences over a shorter timeframe at the start of the project, an initial set of experiments used tubers produced in trials undertaken by other researchers in the season before the project commenced. Each trial had a range of treatments that were identified as likely to influence the physiological status of the tubers. These investigations used credible experimental design and examined the effects of various management practices on the tuber yield of production crops. Each of the trials was grown from certified seed. The tubers sourced from each trial were harvested following crop senescence and skin set.

## RESEARCH TRIAL TIMELINE



**Figure 1.** This figure illustrates the sequence, year and at which stage of production (seed production vs. ware crop) each trial in this study was conducted. Items in shades of blue represent work conducted in the first cycle of seed and then subsequent ware crop production. Those in shades of salmon represent the second cycle. The thesis chapters in which this work is represented are listed under each year. FVRS = Forthside Vegetable Research Station.

Tubers suitable for experimental purposes were selected after grading and stored at 4°C till the following spring (Blaesing 2004b). All seed for hand cutting was selected from tubers weighing between 110 to 150g (J. G. Stevens, personal communication). The evaluation took place the following season from a mid-November planting and harvested after full crop maturity. Seed tubers were sourced from the following projects:

1. Variation in planting density, from a study of the economics of producing round seed (Maynard, 2004).
2. An investigation of nitrogen application rates on ware yield (Blaesing, 2004a).
3. A study of the effects of starter phosphorous (Johnson 2003).
4. The effect of haulm removal over time on processable yield (Beattie, unpublished data).

Further large scale field trials examining the effects of planting date, harvest date and timing of haulm destruction were commenced in the 2002-03 season at two locations. These two commercial crops were grown for certified seed and selected to overlay treatments of 1:- time of defoliation and time of harvest variations in a mid-season planted crop (November) and 2:- time of defoliation and late harvest in a late December planted crop (grown at higher elevation). Each trial was located within the respective crops avoiding irrigation and tractor pathways. The final positioning was determined by evenness of aspect, crop density and integrity of canopy post row closure. In 2003-04, the seed from each location, overwintered in a cool store at 4°C, was prepared and grown as a ware crop at a single location utilising a single planting date.

Also in 2003-04, seed was produced in a program requiring the introduction of three planting dates in addition to three times of defoliation and two times of harvest. The production schedule spanned some eight months from November when planting commenced to June when the final seed lots were placed in a cool store at 4°C. In following season 2004-05 this seed was prepared and planted to assess the effects of production at the same location as the previous two ware crop evaluations. Seed performance was also examined using tuber sprouting index assessment during the seed storage period.

Detailed descriptions of the materials and methods for each field trial are provided in the following chapters in the thesis. A number of methods and materials were common to all trials, and details of these are presented in the following section.

## GENERAL MATERIALS AND METHODS

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### CULTIVAR

Due to its commercial importance to the Tasmanian potato processing industry, the cultivar **Russet Burbank** was used in all studies. The **Russet Burbank** material grown in Tasmania was introduced from Canada and given the name *Vancouver* for ease of identification, and consists of five separate seed lots or units. These units of *Vancouver* were selected circa 1970 and continuously maintained as individual entities to ensure limited genetic diversity within the population. No appreciable differences in performance have been noted among the units. All five units are combined for the production of certified seed and used across the various trials.

### SOIL

The acid ferrosol soils used for the field trials in these studies are agriculturally important for vegetable and pasture production in Tasmania and over 20 000 ha annually are used in various crop rotations including potatoes.

### SETS

All trials in the project utilised cut seed tubers, with the cut seed pieces referred to as *sets*. The sets for the experiments were either machine or hand cut and, prior to cutting, all seed was warmed to approximately 10°C or to the ambient temperature if higher. Seed tubers for machine cutting were selected, using the current commercial seed grade of 35-280g (adoption of USA Pacific NW practice by Simplot and McCain) and, were prepared using standard commercial practice

All seed for hand cutting was selected from tubers weighing between 110 to 150g. The selected tubers were held at ambient conditions for wound healing and then stored at 4°C till spring. Sets were hand cut with a single longitudinal cut to produce seed pieces in the range 55-75g. This was to minimise potential set weight and within tuber effects and potentially reduce stem number variation. As well the cut sets satisfied current commercial practice. As a protectant, sets were treated with Tatodust (mancozeb 15% a.i. powder) plus pine bark or commercial cement as a drying agent. The prepared sets of each treatment were bagged and the appropriate block and plot tag number was attached.

## **PLANTING**

Sets were held for two days and then planted with the cut surface down at a 300mm spacing in two rows, 810mm apart. To reduce the introduction of any error through planting technique, the one person or team was responsible for planting each block. Plots were separated by coloured tubered cultivars or a measured distance. Lateral buffering was achieved using a row of the test cultivar. A pair of rows formed the plot width and the length varied depending on the space available but this was always greater than 1.5 m. Each trial consisted of six or more replicates depending on the space available for each experiment. Blocks were laid out across the slope and plots numbered from the left block highest up the slope. No trial plots were located on flat ground. The sets were covered with 100 mm of soil and the rows hilled after full emergence.

## **NUTRITION**

Soil samples were analysed for pH, phosphorus and potassium and the appropriate fertiliser mix selected on the test results together with the previous cropping history. Fertilizer N:P:K mixes of either 11:12:13 or 11:12:19 ratios were selected. Rates varied from 1000 to 1719 kg per ha. Fertiliser was placed in

bands either side of the set and a 200mm soil mould was raised with the covering coulters. In hand planted experiments the covering coulters of a Faun planter were removed, the fertiliser placed mechanically and the sets placed by hand in the open furrows before being manually covered with about 100mm soil.

### **CONTROL OF WEEDS AND DISEASES**

Weed control was achieved by applying a Sprayseed and metribuzin (Sencor) or Sprayseed alone at emergence. Protective fungicide applications of Bravo at 10 days and mancozeb at 7 days were made at commercial rates for foliage diseases. In some instances, mechanical weed control was required before row closure.

### **IRRIGATION**

Irrigation was site dependent and applied whenever the evapotranspiration estimates (determined by the Bureau of Meteorology) exceeded 25 or 35 mm depending on site and year. An overhead sprinkler system was used in all cases however the method of application varied between trials, as mobile gun irrigators, small hand moved sprinklers or a fixed solid set sprinkler system were employed across the different trials.

### **CROP OBSERVATIONS, DEFOLIATION AND HARVEST**

The commercial seed production plots were defoliated and harvested according to the trial design. During defoliation, which involved hand pulling stems, the number and weight for each plot was recorded, noting any underground branching. For the evaluation of seed (the ware crop) all plants were allowed to reach full senescence before recording stem numbers. This also was an opportunity to check plant stand (set survival).

During emergence, until all sets were accounted for, plants in each plot were counted on a near daily basis. During the growing phase, crop observations mostly took place at weekly intervals. The seed treatments were harvested

according to planned schedule and the last harvests were after full senescence and skin set. The plots were hand harvested for all experiments except the final experiment where a twin row mechanical harvester was employed to dig the plots because of a labour shortage. However plots were hand bagged. Stem material was collected from each seed production plot at each harvest date, and weighed to obtain fresh stem weight. Haulm weight, expressed as kg per ha, was calculated from the mean data for each treatment and using a conversion factor based on the plot area used in the particular experiment that the assessment was undertaken.

### **TUBER GRADING AND ASSESSMENT**

All tubers were hand-picked into jute bags and then removed to ambient storage where grading took place.

To ensure operator accuracy over time electronic scales were used to constantly check tuber weight during the hand grading process. Seed tubers were sorted by weight into grades of <35g, 36-280 and >280g and the range 36-280g formed the seed grade, and after selection, seed tubers were allowed to cure (suberise) at ambient conditions before placement in cool storage at 4 °C. In a similar fashion ware tubers were graded into the ranges of <100, 101-250 and >250g, corresponding to the commercial grades applying to processing tubers. Tuber number and weight were recorded for each plot.

Specific Gravity (SG) was determined using the ratio of the weight in air and weight in water, as described by Stark & Love (2003). Values >1.070 and preferably 1.080 or greater are suitable for processing. Fry colour was assessed using processing company procedures, with strips cooked in frying oil at 190°C (Anon1990) and colour compared to a standard colour chart.

### **CLIMATE**

For a number of the prepared seed studies it was possible to record soil temperature during crop growth and postharvest tuber temperatures to the end

of cool storage. Ambient conditions at the Forthside Research Station were also available from the Bureau of Meteorology weather station records, situated about 500m distant from seven of the investigations.

## STATISTICAL ANALYSIS

The designs of individual experiments are documented in the following chapters. For the majority of experiments, results were analysed with ANOVA using the general linear model procedure of SPSS (v14.01) or SAS. For comparison of means, Fishers protected least significant difference (LSD) was calculated at 0.05 level of probability unless otherwise specified. Standard errors of means are presented in tables and figures throughout the thesis.

## PRELIMINARY OBSERVATIONS

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As the growth patterns of potato cultivars may vary with production environment and practices, observations of the typical pattern of development under Tasmanian conditions are useful. They promote better understanding of the performance of the Vancouver clone of the **Russet Burbank** cultivar. In particular, the growth pattern of plants grown from cut seed (sets) may vary from that observed in regions where whole seed is used. A plant throughout this thesis refers to the stems produced from a single set. In the author's previous experience with this cultivar, a plant grown from cut seed typically has between two and three stems, yet the full range of stem number may vary from one to six or more within a population. Stems generally have between two and four tubers.

An experiment conducted by McPhee *et al.* (1996) provides an illustration of variability in **Russet Burbank** when planted as cut seed under Tasmanian conditions. This experiment evaluated the effect of spacing variability on the performance of single machine cut sets (plants) at a constant density of four per metre square. The seed tubers were in the weight range of 35-350g and were cut on a Bridgestone mechanical cutter. A 50g set is the mean commercial size



with an acceptable range of 35-85g (D. Abblit, personal communication). The set profile provided for the experiment was as follows: a mean 52g with 92 per cent in range of 26-99g and a Coefficient of Variation (CV) of 32 per cent. Fertiliser was predrilled and sets hand planted. The control planted at a constant spacing of four sets per square metre provided 76 consecutive plants for individual harvest. Stem number, tuber number and weights were recorded for each plant and the results are presented in Table 1.

**Table 1.** *Performance of individual sets grown 300 X 810mm spacing (4 sets m<sup>-2</sup>) distributed according to the number of stems per plant. After McPhee et al. (1996).*

STEMS PER PLANT (No)	(n)	TUBERS PER PLANT (Mean)	TUBERS PER STEM (Mean)	YIELD PER PLANT (g)	MEAN TUBER WT( g)	PROCESS ABLE (>100g) %	PROPOR- TION >250g(%)
1	15	5.3	5.3	1280	241	94	79
2	28	8.7	4.4	1546	177	92	45
3	18	12.0	4.0	1603	134	87	21
4	12	11.3	2.8	1525	135	87	26
5	3	19	1.3	2259	119	85	19

The results show the variation that may occur in a typical ware population. The grand mean stem number was 2.47 per set and is not dissimilar to the value observed for this cultivar in other experimental data and processing crops. These results reiterate the necessity to manipulate stem number to achieve a desirable tuber population structure that optimises economic return, exemplified as the proportion of tubers > 250g to maximise the ware return. The proportion in this category was 41 per cent and this is considered to be in the range of 35-50 per cent that is in the writer's experience. Previous investigations (e.g. Beattie and Regel, 1984) showed that tuber size distribution was greatly affected by rose and stem end sets through the effects on stem number. The difficulty arises in predicting the outcome of a cutting program but this result is not atypical of normal expectations

# CHAPTER 4

## PRELIMINARY STUDIES

### INTRODUCTION

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In Australia potatoes are the only major vegetable crop that is reproduced vegetatively. To guard against the introduction and dispersal of diseases through vegetative propagation, seed certification schemes have operated throughout the country for about 70 years. Initially seed-borne viruses were the main pathogens limiting plant growth, and the effect of 100 per cent Potato Leaf Roll Virus infection reduced yield by up to 35 per cent (Lehman, 1970). In Tasmania the approach taken to remedy the condition was reported by Oldaker and Dowson (1930). Virus was finally eliminated from seed stocks in Tasmania (Anon, 1970) with the introduction of pathogen tested clones of all cultivars grown. This improvement allowed the full potential of improved nutrition and water use to achieve a four-fold increase in yield in twenty-five years (Taylor, 2003).

To improve productivity further, a study of P-age management was undertaken by Grice (1988). The results were inconclusive for **Russet Burbank** and at crop senescence the 0, 750 and 1200 DD treatments all had the same total yield. In early work on P-age conducted in Idaho, Iritani *et al.* (1983) had established the positive effects of controlled aging of seed through storage for prescribed periods above a base temperature of 4°C. Later, in an advisory bulletin by Iritani and Thornton (1984) to Idaho growers, and as an explanation for the apparent failure of the treatments designed to manipulate P-age, numerous complicating production factors were invoked as having an effect on seed performance. Factors including soil fertility, temperature, irrigation effects on either seed or

soil-borne pathogens or some other stress that may affect plant growth were identified as influencing seed tuber physiological status.

A large range of factors may potentially impact seed tuber physiological quality prior to storage. This presents many possibilities for treatments to examine seed production effects on subsequent seed performance. In order to identify one or more factors having a significant effect on seed quality the initial experiments in this project examined a broad range of treatments that could be examined in more detail in further experiments.

## **MATERIALS AND METHODS**

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Trials examining the intergenerational effects of treatments during seed production on performance of that seed in the following crop must be conducted over two years. In order to investigate a range of factors during seed production in a shorter timeframe, experiments undertaken at the commencement of the project utilized tubers produced in trials undertaken by other researchers. A trial examining time of haulm removal on seed tuber size distribution was also conducted by the author. Seed from this work was retained for planting in an experiment reported on in this project. In all cases these trials investigated the effects of various management practices on seed tuber yield, and were identified as likely to influence physiological status of the tubers. Tubers suitable as seed were selected from the following projects:

- Variation in planting density, from a study of the economics of producing round seed (Maynard, 2004)
- An investigation of nitrogen application rates (Blaesing, 2004)
- A study of the effects of starter phosphorous (Johnson, 2003)
- Time of haulm removal during seed crop development (Beattie, unpublished data)

## EFFECT OF SEED CROP PLANTING DENSITIES

To determine the economics of using whole round seed of **Russet Burbank** for ware production, Maynard (2004) examined a range of set densities with both cut and whole seed compared at set densities ranging from 1.5 to 20 sets m<sup>-2</sup> to examine the proportion of tubers suitable as whole seed. Previous work (Beattie and Regel, 1986) had established that total yield plateaued at a set density between six and twelve per square metre and stem numbers up to 30 per square metre.

At such high set densities it was surmised that, production might be restricted to about one useable tuber per stem. As well it was thought that this might produce a one age cohort of tubers possessing similar physiological attributes and have some effect on the performance in the ware crop. There could have been differences when seed tubers of the same size from a lower stem density population, producing say three seed tubers each were compared. The null hypothesis was that a constant tuber size from a variable size grade population would have no effect on plant performance.

To verify this premise, tubers weighing between 110 and 140 g were selected from 6.5, 12 and 20 sets m<sup>-2</sup> populations of a plant density experiment (Maynard, 2004). Tubers were cured at ambient temperatures in the light, with some greening of the tubers, and stored at 4°C till the following October when the tubers were placed in ambient conditions prior to cutting. At this time, all tubers had sprouted from most eyes and apical dominance was essentially absent. The sets for each row were treated when cut (tuber sliced longitudinally) with either cement (left side) or iron pyrites residue (right side) as the drying agent. The trial was planted in a split plot design. Each plot consisted of a pair of rows 10 sets long, cut from ten tubers, such that each row was the mirror of the companion row.

The trial area was cultivated prior to planting and 1000 kg ha<sup>-1</sup> of 11:12:19 N:P:K pre-placed in the furrows. The trial was planted November 10, 2001 and a buffer zone of a red-skinned cultivar was planted between each plot. The site

was laid out as a split plot with 12 blocks and individual plots split for set dressing. The sets were hand planted skin side up and covered with 70-100 mm of soil. Weeds were controlled by an application of the herbicide Sprayseed as emergence commenced. Prior to row closure the trial was scarified, followed by molding. Irrigation was applied when an A pan deficit of 35mm had accumulated. A preventive fungicidal program for target spot (*Alternaria solani*) and late blight (*Phytophthora infestans*) using mancozeb and Bravo was followed. No additional fertiliser was applied during the growing season. Following senescence, stem numbers were counted. The plots were hand dug and the tubers graded into the following size grades: <80, 81-250, >250 g and reject tubers. The results were evaluated using a split plot analysis of variance.

### **EFFECT OF NITROGEN NUTRITION DURING SEED PRODUCTION**

The seed for this investigation was derived from an experiment conducted by Blaesing (2004a) studying the effect of four rates of nitrogen on the performance of a **Russet Burbank** crop. The rates of N were 100, 150, 200 and 300 kg ha<sup>-1</sup>. Tubers were graded after harvest and those weighing between 110 and 140 g were selected for this study. The seed tubers were cured at ambient temperatures in the light with some subsequent greening of the tubers. The tubers were then stored at 4°C till the following October when the tubers were placed in ambient conditions. At cutting all tubers had sprouted from most eyes and apical dominance was almost absent. Sets were prepared from tubers with a single longitudinal cut and dusted with cement.

The treatments were laid out as a randomised complete block with sixteen replicates. Based on soil test results, 11:12:19 N:P:K fertiliser at 1000 kg ha<sup>-1</sup> was pre-placed in furrows prior to planting. Each plot consisted of a pair of rows 810 mm apart and 3.6 m long, separated by sets of a red skinned cultivar. The sets were hand planted, 300 mm apart, skin side up and covered with about 70-100mm of soil on November 10, 2003. Weeds were controlled by an

application of the herbicide Sprayseed at the first sign of crop emergence. Prior to canopy closure the inter rows were scarified, followed by molding. The crop was grown with water applications at 35 mm A-pan deficits and a fungicide program implemented for the prevention of target spot and late blight using mancozeb and chlorothalonil was followed. No additional fertiliser was applied during the growing season. Following senescence, stem numbers were counted. The plots were hand dug and the tubers graded into the following size grades: <80, 80-250, >250 g and rejected tubers. The results were evaluated using analysis of variance.

#### **EFFECT OF PHOSPHORUS NUTRITION ON THE FOLLOWING GENERATION**

Tubers were sourced from a Russet Burbank experiment in which six phosphorus application rates from 0 to 300 kg per ha were used (Johnson, 2003). Petiole P concentrations were 0.027% P at 0 Kg P ha<sup>-1</sup>, 0.030% at 150 Kg P ha<sup>-1</sup>, and 0.038% P at 300 kg P ha<sup>-1</sup> were significantly different ( $P < 0.05$ ). Unfortunately the effect on stem and tuber numbers was not reported.

At the conclusion of grading, tubers weighing 110 to 150 g from the 0, 150 and 300 kg ha<sup>-1</sup> P treatments were selected for this study from each of the three replicates of the trial. The tubers were cured at ambient temperatures in the light and stored at 4°C till the following October when the tubers were placed in ambient conditions. At cutting, two days ahead of planting, the tubers had sprouted from most eyes. Sets were prepared with a single longitudinal cut and dusted with cement as the drying agent. The trial area had been opened up and fertiliser was pre-placed at 11:12:19 N:P:K at 1000 kg ha<sup>-1</sup>. The three treatments were laid out as sixteen replicates in a randomised complete block. Each plot consisted of a pair of rows 810mm apart and 3.6 m long, separated by 1 m section in the row planted with a red-skinned cultivar. The sets were hand planted, 300 mm apart, skin side up and covered with 70-100 mm of soil on November 10, 2003. Weeds were controlled by an application of the herbicide Sprayseed at emergence. Prior to canopy closure the inter rows were scarified,

followed by molding. The crop was grown with water applications at 35 mm A pan deficits and a fungicidal program for the prevention of target spot and late blight. No additional fertiliser was applied during the growing season. Following senescence, stem numbers were counted. The plots were hand dug and the tubers graded by number and weight into the following size grades: <80, 80-250, >250 g. The various classes of reject tubers were recorded as a group irrespective of size. The results were evaluated using an analysis of variance.

The increase of tuber yield from tuber initiation to foliage senescence generally follows a sigmoid curve (Morby and Milthorpe, 1975). During this period there is an exponential phase of about three weeks followed by a near linear phase until the leaf area index falls to 1. Continual change in the growth and development of individual tubers is mediated by the physiological status of tubers (Struik and Ewings, 1997).

The experiment from which the tubers were sourced was initiated to follow changes in yield and size grade distribution during the final 28 days of the crop growth cycle up to foliage death. **Russet Burbank** seed tubers were planted November 01 1992 with 1500 kg per ha 11:12:13 N:P:K in 810 mm rows at 300mm spacing. Weeds were controlled by applying metribuzin, (500g ha<sup>-1</sup>) at emergence and protective applications of Bravo and mancozeb were made at the appropriate 10 and 7 day intervals respectively. Irrigation was applied whenever evapotranspiration exceeded 35 mm.

## **EFFECT OF DEFOLIATION**

The site was located in a crop and was not disturbed by irrigation or fungicide spray runs such that there were five pairs of rows for the trial site. Following the final irrigation and fungicide application on February 23, a 5 x 5 Latin Square design was laid out with the sampling date treatments allocated to the respective plots, with weekly defoliation over a 4 week period. At each date, there was an estimation made of ground cover and the stems pulled (removed by hand), counted and weighed. Three weeks after the final haulm removal all

plots were harvested; i.e. seven, six, five, four, and three weeks from the initial defoliation. The tubers were graded into the following categories: <100, 100-280 and >280 g, whilst defective tubers were classified separately. Tuber numbers and weights for all categories were recorded.

At the conclusion of grading, an all replicate, composite sample of about 50 kg of 200 g tubers was taken of each treatment was selected and cured for three weeks at ambient temperatures during May, before storing at 4 °C till the second week of October. The tubers were removed from storage and allowed to warm to 10°C before 50g sets were cut by quartering the tubers, and dusted with cement. At this time dormancy was complete and all tubers had shoots and almost no apical dominance was evident. Planting took place on November 8 1994 with 12 replicates of two treatments: tubers from the earliest and latest defoliation treatments. Each plot was a single row of 16 sets at 300mm spacing and rows 810mm apart (4.2 sets per square metre). The trial was managed according to standard crop practice. Three weeks after full senescence, harvesting took place followed by tuber grading to sizes that related to processing and seed requirements. The results were evaluated using analysis of variance.



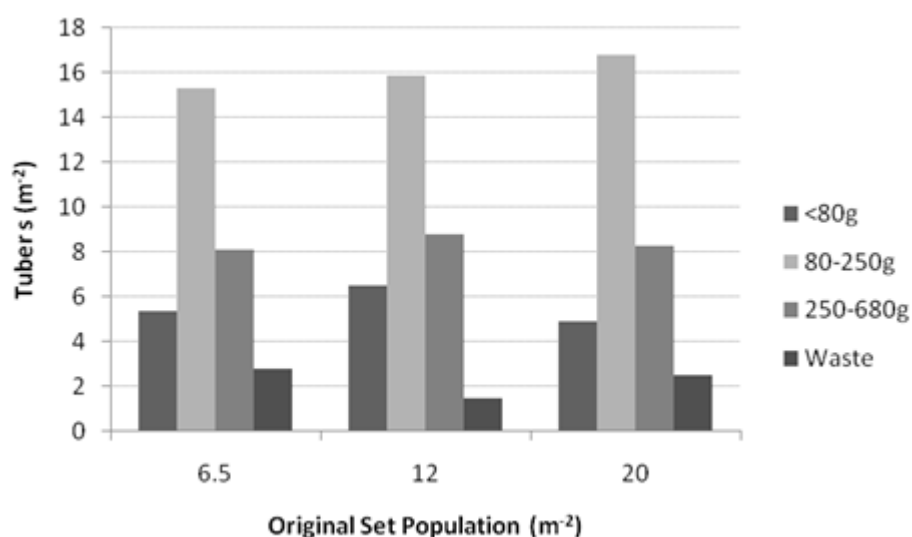
## RESULTS

### EFFECT OF SEED CROP PLANTING DENSITIES

Emergence was uniform across all treatments and repeated observations throughout the growing season indicated no treatment differences in growth or vigour of the plants. The stem population of the treatments was also similar (Table 1.) and there were no significant differences in total tuber number or tuber number in the different size grades (Figure 1).

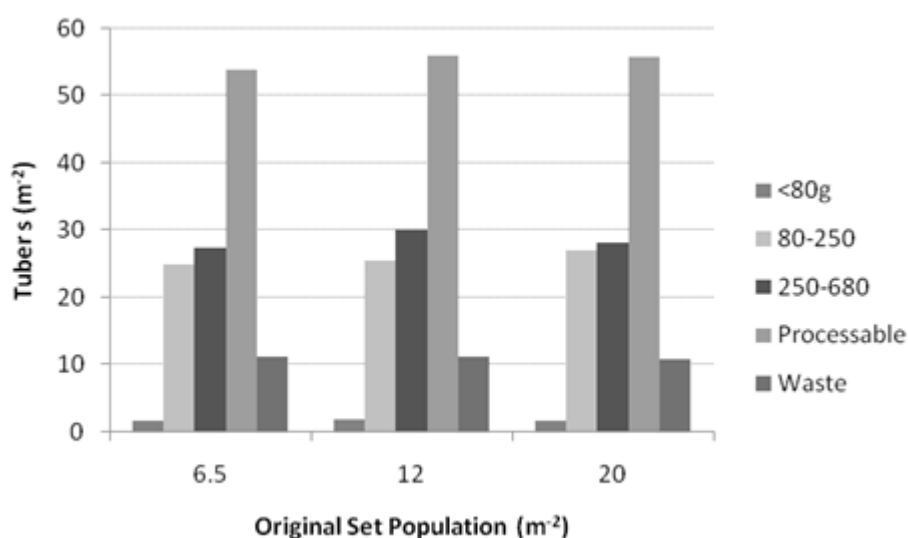
**Table 1.** *Effect of seed crop tuber planting density (sets.m<sup>-2</sup>) on stem and tuber number in the succeeding ware crop.*

Original Set Population (No.m <sup>-2</sup> )	6.5	12	20	Sig.
No stems /m <sup>-2</sup>	6.5	6.6	6.8	ns
Tubers/stem	4.9	5.2	4.9	ns
Total tuber No. m <sup>-2</sup>	32	34	33	ns



**Figure 2.** *Influence of the original seed set population on the size distribution of seed tubers.*

The planting density under which the seed was produced had no significant effect on tuber numbers or yields in the following season. Total yields from the set density sources, 6.5, 12 and 20 sets  $\text{m}^{-2}$ ; were, 67.0, 69.2 and 68.5  $\text{t}\cdot\text{ha}^{-1}$  respectively. Among the treatments no significant differences in total yield or yield in any of the size classes were found, indicating that planting density in the seed crop had no effect on the performance of the seed.



**Figure 3.** Influence of the original seed set population on the size distribution of tubers in the succeeding ware crop.

The stem population was low, but showed an upward trend with tubers from higher densities. The small difference was also reflected in the high tuber numbers and fry grade yield but these differences were not significant ( $p < 0.05$ ).

As shown in Table 2, cement treatment of sets resulted in a significantly higher tuber number of reject tubers and associated yield loss.

**Table 2.** The effect of dusting sets with iron pyrites or cement dust, on stem numbers ( $m^{-2}$ ), ware yield ( $t\ ha^{-1}$ ) and quality of the succeeding crop.

Set Treatments	Tuber ( $m^{-2}$ )		Ware Crop Yield ( $t\ ha^{-1}$ )	
	Iron Pyrites	Cement	Iron Pyrites	Cement
Stem No./ $m^{-2}$	6.4	6.6	6.4	6.6
Ware Grade	25.2	23.5	56.6	53.9
Misshapen	0.7	1.5	2.8	7.3
Cracked	1.4	1.9	5.5	6.7
Total waste	2.0	3.4	8.3	14.0
Total	33.3	32.4	67.0	69.5

*Tuber numbers: Misshapen  $LSD = 0.7m^{-2}$ ; ( $p > 0.05$ ) Tuber yield Misshapen  $LSD 3.1\ t\ ha^{-1}$  ( $p > 0.05$ )*

## EFFECT OF NITROGEN NUTRITION DURING SEED PRODUCTION

Assessment of stem number and tuber number during the production of the seed tubers used for the trial revealed no effects from nitrogen application at different rates. Between treatments there were no significant differences with respect to stem number, tuber number or tuber size distribution.

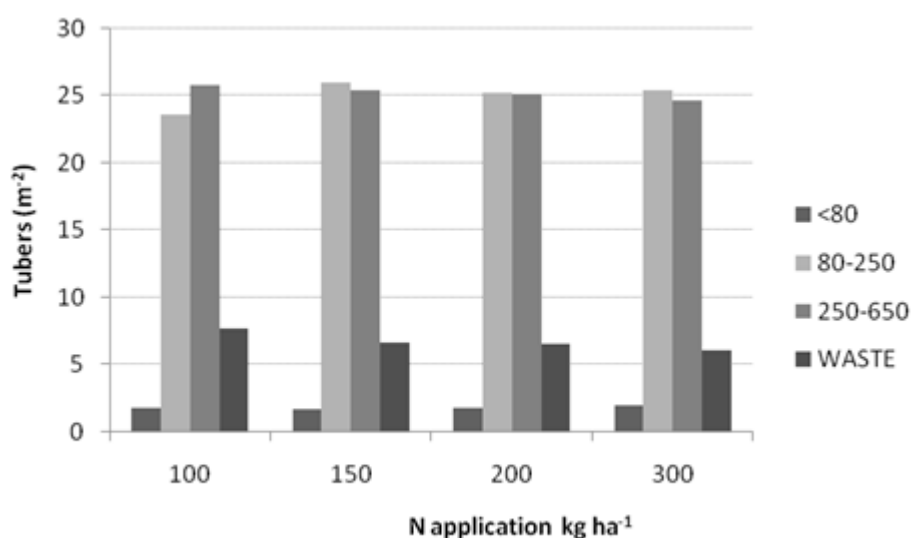
In the following season when performance of the seed was assessed, frequent inspections of the trial site were undertaken. Plant emergence was noted to be uniform and there were no observable differences between the treatments. Senescence also was uniform across the experimental area.

There were no significant differences between treatments with respect to tuber number (Fig. 4) or tuber yields (Table 3) when the data was analysed as a randomised complete block by one way ANOVA for each parameter (e.g. Size class). A low CV of 4.9% for total tuber number ( $m^{-2}$ ) pooled within each block indicates that neither the trial site nor trial management introduced little extra variation and, that the trial itself was an accurate reflection of the treatment effects.

**Table 3.** Effect of four nitrogen rates applied to the seed crop, on tuber yield ( $t\ ha^{-1}$ ), total tuber number ( $m^{-2}$ ) and stem numbers ( $m^{-2}$ ) of the following crop.

	Seed Crop Nitrogen Rates ( $kg\ ha^{-1}$ )				Sig.
	100	150	200	300	
Tuber Size grade ( $t\ ha^{-1}$ )					
<80	1.8	1.7	1.8	2.0	NS
80-250	23.6	26.0	25.2	25.4	NS
250-650	25.8	25.4	25.1	24.7	NS
Waste ( $t\ ha^{-1}$ )	7.7	6.7	6.6	6.1	NS
Total tuber ( $m^{-2}$ )	29.3	30.2	29.3	30.6	NS
Stems ( $m^{-2}$ )	6.6	6.7	6.9	7.4	NS

No significant differences in tuber size distribution were found between treatments.



**Figure 4.** Effect of applying nitrogen at four application rates to the seed crop on tuber size distribution ( $m^{-2}$ ) in the following ware crop.

Across all of the seed performance parameters measured, the nitrogen application rate used in the production of the seed had no effect on the physiological quality of the seed.

## EFFECT OF PHOSPHORUS NUTRITION ON THE FOLLOWING GENERATION

Observations of the trial through the season did not reveal any differences among the three treatments. Senescence was uniform and the dead haulm stem count did not show any differences.

There were no effects of the treatments applied to the seed crop on the performance of the seed in the following season. No significant differences between treatments were found for stem number, tuber number or tuber yield (Table 4). In the trial a high proportion of misshapen and cracked tubers was found across the three treatments

**Table 4.** *Effect of seed crop phosphorus application on tuber number  $m^{-2}$ , processing yield ( $t\ ha^{-1}$ ) and quality of the following processing crop.*

	Phosphorus $kg\ ha^{-1}$ Applied to Seed			
	0	150	300	Sig.
Stems ( $m^{-2}$ )	10	9.2	9.6	NS
<b>Tuber Number</b>				
<80	7.5	7.8	7.3	NS
81-250	17	18.4	19.5	NS
251-680	6.1	5.7	5.9	NS
681-850	0	0.9	0	NS
Processable	23.1	24.2	25.3	NS
Total tubers ( $m^{-2}$ )	35.5	36.2	36.7	NS
<b>Tuber Weight (<math>t\ ha^{-1}</math>)</b>				
Misshapen	8.4	7.2	6.1	NS
Cracked	8.9	7.0	9.4	NS
Waste percentage	26.1	21.9	23.1	NS
Percentage >250g	42.4	38.9	36.5	NS
Processable	46.2	47.5	48.8	NS
Total weight	66.4	64.8	67.2	NS

The coefficient of variation for tuber number and yield was 14.6 and 10.6 per cent respectively. Tuber size distribution did not differ among the three treatments

### EFFECT OF TIME OF HARVEST OF SEED CROP

Results obtained from the trial from which the seed tubers for this study were sourced were consistent with previously reported patterns of tuber development. The number of stems and tubers was similar across all harvests, indicating the uniformity of the crop (Table 5). At the third harvest, ground cover had fallen to 25 per cent and the foliage fresh weight reduced by 40 per cent. At the final harvest the foliage was completely dead but there was a residual stem weight of five t ha<sup>-1</sup>. Over the first two weeks for both total and processable yield a significant increase in yield, of 11 and 9 percent respectively was recorded, with no change in the proportion that was processable.

**Table 5.** *The effect of time of defoliation of the seed crop on plant attributes of that crop. NR = not recorded.*

Date of Defoliation	25Feb	4Mar	11Mar	18Mar	25Mar	LSD ( <i>p</i> =0.05)
%Ground cover	92	75	26	1.8	>1	NR
Haulm weight (t ha <sup>-1</sup> )	26.0	21.6	15.6	6.0	5.0	2.2
Stems No /m <sup>-2</sup>	9.9	9.8	9.4	9.7	9.9	NS
Tubers/No m <sup>-2</sup>	32.5	33.7	35.1	35.9	36.3	NS
Total yield (t ha <sup>-1</sup> )	68.6	70.5	75.2	76.6	76.3	2.9
% Processable	84.4	83.0	83.8	82.0	83.2	NR
Processing yield (t ha <sup>-1</sup> )	64.2	66.1	69.9	70.2	71.0	4.4

Seed tubers sourced from the February 25 and March 25 defoliation date treatments performed differently when grown the following season. During the growing period there was no discernable difference between the two treatments. Unfortunately stem numbers were not recorded prior to harvest. The ware tuber numbers were significantly higher from seed of the first foliage destruction compared with seed of the fully senesced treatment (Table 6). Similarly, the 9.0% greater ware yield from the early defoliated seed crop was significant.

**Table 6.** The effect of time of defoliation during seed production on the performance of the following ware crop.

Defoliation Date	Tuber (number m <sup>-2</sup> )			Yield (t ha <sup>-1</sup> )			Total
	<100g	100-280g	100-450g	<100g	100-280g	100-450g	
Feb. 25	12	17.8	30.1	7.8	26.8	34.2	42.0
Mar. 25	9	16.8	26.0	5.7	25.3	31.3	37.0
LSD ( $p>0.05$ )	1.8	NS	2.6	1.4	NS	2.8	

NS = Not Significant ( $p < 0.05$ )

## DISCUSSION

Of the seed crop management practices examined in this chapter, one only affected the performance of the seed the following season: the time of foliage destruction. The effect of foliage destruction on seed physiological quality has previously been noted by Maas (1971) who obtained a positive result from early defoliation on the following ware crop; however Holmes and Gray (1972) found no difference between early and senesced seed origins. These results and those reported in the local studies did not have a thorough background of seed origin. This highlights the possibility of P-age influencing plant responses. Murphy *et al.* (1967) touched upon this in an extensive study that showed four seed growing periods had no effect on yield, yet a storage temperature of 3.3°C resulted in a higher yield than either 0°C or 6.7°C. The various seed lots were held at a common storage temperature, 4°C, as extra P-age was not considered relevant to the respective evaluations.

Following defoliation, the plots were left exposed from seven to three weeks prior to harvest. This length of time would be very common in commercial practice where harvest may occur one to four months after crop senescence. The difference between early defoliation and senesced seed origin result may then be a combinational effect of defoliation and time in the soil prior to harvest. This situation may have had some effect on P-age, which is different from the

aging of tubers Grice (1988) adopted. This involved the sprouting of tubers from dormancy in the light at a continuous 20°C and accumulating DD calculated from a base of 4°C. Her results indicated a possible advantage in yield of **Russet Burbank** for older seed at 750 DD compared to younger seed.

The density at which the seed crop was grown, as well as nitrogen and phosphate nutrition during seed production, did not affect seed performance. The range of nutrition and density treatments in the experiments was limited, and therefore effects of nitrogen, phosphate and planting density on seed physiological status cannot be ruled out. Indeed, it would be surprising if extreme nutrition or density treatments did not affect the physiological status of the seed tubers. However, within the range of adequate nutrition for seed crop production and the range of planting densities generally employed in seed production, little evidence for significant effects of nutrition and density on seed performance exists. First, Smith (1968) cited from a seven year investigation (Quinn and Walsh, 1956) where seed produced with a continued deficiency of nitrogen, phosphorus and potassium there was no effect on the growth or vigour of the following crop. Secondly, (Reichard, 1964) showed nitrogen and potassium had no effect on the performance of seed in the subsequent ware crop. Similarly, Schepers *et al.* (1969) indicated that the amount of phosphorus and potassium did not influence the mineral content of seed nor did it act upon the productivity of a subsequent crop. Nitrogen however, did affect tuber chemical composition and there were fewer main stems, but they concluded the amount of fertiliser was of little importance for the following ware production. The application of various rates of nitrogen, 75-275 kg ha<sup>-1</sup> (van Ittersum, 1992b), and varying times of application to seed crops of dissimilar cultivars effected dormancy by five to nine days. Under Tasmanian conditions this difference would be considered of little consequence.

Comparing the results of applying either iron pyrites or cement to cut sets produced an unexpected result. In the past, iron pyrites have been tested as a soil-acidifying agent (C. Bath, personal communication) and in the current



context, was considered an agent that may reduce incidence of common scab if present (no infection found). The alkaline cement, which has been used for many years as a drying agent, resulted in plants with a significantly higher yield of second growth tubers. Chung *et al.* (1992) conducted an irrigation investigation with cement treated cut seed and concluded that the high proportion of second growth found in the study was not stress related. The possibility that the application of cement can lead to second growth tubers needs further investigation at another time.

This study has shown that for the production of seed there may be an alternative approach which has implications for the production of ware crops. There was no indication of the mechanisms that could be involved. It is proposed to explore the timing of harvest and this effect on productivity in future studies.

## **CONCLUSIONS AND DIRECTION OF FUTURE INVESTIGATIONS**

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The results of the investigations undertaken indicated that three elements in the generation of the seed crop did not influence the outcome of the ware crops: plant density, nitrogen nutrition and phosphorus nutrition. Certainly in the production of seed crops the studies point to two directions being worthy of further investigation: the length of the growing period and the time interval to harvest. A third variable requiring investigation is the planting time of the precursor seed crop, or certified crop.

# CHAPTER 5

## EFFECT OF TIMING OF DEFOLIATION ON SEED PRODUCTION AND RESULTANT SEED PERFORMANCE

### INTRODUCTION

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In the seed potato industry the selection of production practices used is most commonly based on the need to use and maintain healthy seed. The virus status is particularly important. Far less attention has been given to the physiological and, to a lesser extent to the structural characteristics of seed tubers and the impacts of production practices on these. The size of tubers is the most important tuber structural characteristic managed during seed crop production as it influences decisions on the need for set cutting as well as affecting the number of eyes present on the planted seed or seed piece and consequently the stem population in the ware crop (Iritani, 1972; Nielson *et al.*, 1989; Bohl *et al.*, 2007). Tuber size when cutting seed may also affect crop uniformity, with large tubers more likely to produce sets with a broad range of eyes per set as well as variability in sprouting vigour (Nielson *et al.*, 1989; Beattie and Regel, 1986).

The most common crop management practice used to control tuber size in seed tuber crops is defoliation of the crop when an appropriate tuber size has been reached. Both physical and chemical methods are commonly used to defoliate seed crops. While the effect of defoliation on seed tuber size has been widely investigated (O'Brien and Allen, 1992a; O'Brien and Allen, 1992b), the effect of defoliation treatments on the physiological status (P-age) of seed tubers has been poorly documented.

Thornton (1993) enumerated many production factors that impinge on the production and productivity of potato crops. The quality of the planting material is one of the factors influencing crop productivity. The physiological status of the tuber, which is generally described as the P-age of the tuber, is an important component of the quality of the planting material and has been shown to be influenced by a range of seed tuber production and storage treatments (Struik and Wiersema, 1999). The simplest description of P-age is the physiological condition of tubers achieved following harvest, through storage and after dormancy break. Differences in P-age may be measured by calculating the number of DD, a measure calculated by taking the average temperature over 24 hours and subtracting a base temperature. The differences are accumulated and used to describe the development within the tuber. A base of 4°C has been used in many studies (O'Brien *et al.*, 1983; Allen and O'Brien, 1986; Scholte, 1987; Jenkins *et al.* 1993; Burke and O'Donovan, 1998)

Physiologically young seed of around 100 DD, produces more single-stemmed plants and fewer tubers than old seed, say 800-900 DD, but may retain canopy coverage for a longer duration and produce a higher yield in a long growing season. This effect is used to advantage in early maturing cultivars required for fresh market purposes where physiologically old seed produces higher yields than younger seed in a short growing season (O'Brien, *et al.*, 1983). As the date of harvest is delayed, the differences in yield potential between young and old seed decrease and may, in late harvests, show a cross over effect whereby young seed produce superior yield. As many other factors also affect yield, the P age response is not always as clear-cut with later-maturing cultivars, as has been noted for **Russet Burbank** (Grice, 1988) and **Desiree** (Van Der Zaag and Van Loon, 1987).

Storage temperature and duration are generally considered to have the greatest impact on tuber P-age, although most authors acknowledge that aging may occur during the growing season. Aging during seed crop production is most often attributed to stress, a conclusion supported by observations such as high

soil temperatures under dry conditions in sandy soils stimulating sprouting before harvest. Climatic and crop management factors including low moisture, high temperatures, inadequate fertility, frost damage, and disease pressure are potential stress factors that may age the seed tubers produced (Bohl et al., 1995). Stress imposed on seed crops during tuber bulking may lead to early crop senescence, and tubers from plants that die prematurely are considered to be physiologically older (Pavlista, 2004). While the effects of crop defoliation on tuber aging have not been examined previously, premature senescence of a crop through mechanical or chemical defoliation may be expected to impose stress on the developing seed tubers and therefore influence the rate of aging. Investigations in the UK (Allen *et al.*, 1991; Jones and Allen, 1983) and France indicate that manipulation of planting and harvest time of seed is of little consequence in manipulating seed for ware production (Perenec and Madec, 1980). Temperature regimes applied prior to or after dormancy break have greater effect on performance than seed crop planting or harvest dates (Firman, personal communication). In many of these experiments and in seed production in general the seed crop has a very short life, usually less than 100 days and often 60-80 days from planting which seems to be of advantage in the earlier maturing cultivars. It is apparent from published data and industry observation that each cultivar, particularly within the early maturity group, has a set of parameters that gives the cultivar a set of recommended seed treatments for reliable performance in the ensuing ware crop. Late maturing cultivars such as those used in the processing industry in Tasmania require a longer growing season that introduces more production variables, and greater variability in performance in the ensuing ware crop is often observed (Russel, 2007). Cutting of seed tubers to produce uniform-sized planting sets is one of the production practices used in later maturing processing cultivars. Allen and Wurr (1992) stated that in UK cutting of seed is “of no practical significance”. Previously Allen (1979) had shown seed either cut or whole of the same weight (56g) could produce similar yields. Allen and Wurr (1992) also cited problems with seed borne diseases causing eye loss which could result in loss of stems. The physical

act of cutting may break dormancy, remove possible apical dormancy and advance P-age (Struik and Wiersema, 1999). Furthermore, these authors made note of the potential for spreading bacterial disease and the set decay that may also occur in the soil. Whilst these problems exist and are acknowledged, cutting is the standard practice of seed preparation in Australia and USA. In Australia **Russet Burbank** is invariably grown to senescence for seed production. However crop desiccation is necessary when tuber size exceeds seed size specification limits.

Preliminary evidence (Chapter 4) suggested that timing of haulm death in **Russet Burbank** produced in long growing season conditions may impact on performance of the cut seed pieces (sets) in the following season. A 9% yield increase in plants grown from seed in early defoliated plants compared to late defoliated plants suggests that, in contrast to the conclusion drawn from studies of other cultivars in shorter growing season conditions, seed production practices may have an effect as great as storage temperature effects on seed performance. The objective of the trials presented in this chapter was to gather further evidence of the effect of the various haulm deaths and harvest date treatments on the productivity and quality of seed production.

## MATERIALS AND METHODS

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Two trials were conducted utilising certified seed crops and involving defoliation and harvest date treatments. Performance of the seed was evaluated in the subsequent ware crop year. The evaluations were undertaken under crop husbandry conditions applicable to tubers suitable for French fry processing. The first trial (Lower Barrington) involved a crop planted mid season, with five weekly defoliation treatments and two harvest dates, the first two weeks after the final defoliation and the second at the time of commercial seed harvest. The second site (Staverton) was in a late planting, with five defoliations and a single harvest as late as possible, again simulating commercial practice. Following over winter storage under standard 4°C cold store conditions, the replanted seed was

grown to detect any yield and quality effects associated with the treatments imposed during seed production.

### **TRIAL 1. LOWER BARRINGTON SITE: TIME OF DEFOLIATION, TIME OF HARVEST AND REPLANTING EFFECTS**

The crop was established from machine-cut certified seed that had been treated with a protective fungicide and planted on November 26, 2002 in the Lower Barrington district (Lat. 41° 23' 17" Long. 146° 17' 5" and altitude 226m). Fertiliser (1500kg ha<sup>-1</sup> N:P:K, 11:12:19) was band placed at planting with a set spacing of 250mm or 5m<sup>-2</sup>. The crop was grown according to the prevailing agronomic practices and processing company field staff advised on any specific crop requirements. Crop emergence was observed to commence on December 17 2002.

The crop was inspected 90 days after planting and the most even and accessible site within the crop was chosen for the trial. The experiment was laid out between two irrigation runs with planter pairs of rows for harvest and two row buffers between plots that were six metre long with half a metre buffers at the ends of plots. A split plot experimental design was used with five defoliation times as main plots and two times of harvest as sub plots. The times of defoliation were seven days apart and commenced 91 days after planting. The first harvest was made two weeks after each defoliation treatment and the second harvest at the end of the season at the time of the commercial seed harvest. As the season progressed, the rate of senescence was slow and on this basis the final defoliation was delayed 28 days to approximate current commercial practice. There were eight replicate plots of each treatment.

Observations during the defoliation period showed no untoward disease or stressed areas within the trial area. The foliage was lush and some weaker stems in the bottom of the canopy were lost throughout the season. The experiment terminated at the final defoliation (i.e. removal of senesced stems)

because the commercial crop had been desiccated and harvested, thus the paddock had to be vacated, as the land was required for the following crop.

Defoliation of both early and late harvest plots took place at weekly intervals, commencing 91 days after planting and followed every seventh day except for the last date, which was delayed for 28 days to simulate commercial practice when foliage is fully senesced. At each defoliation date, stems were counted and weighed and values recorded for each plot and haulm returned to the plot. The early and late harvest plots were hand harvested. A single harvest date occurred for the final defoliation treatment because the grower required the trial area to be cleared for the next crop and a delayed harvest following defoliation was therefore not possible.

The tubers were bagged and labeled with a plot number and treatment coded tag. The seed was graded after 14 or more days to allow skins to harden prior to grading. Tuber number and yields were determined for the size classes 0-35g, 36-100g, 101-250g, 251-380g and <380g and waste. From each of the ten treatments, in excess of 500 tubers between 110 and 150g were selected as seed and held a further 14 days in jute bags at ambient conditions to cure prior to cool storage at 4 °C.

The evaluation of seed performance was conducted at Forthside Research Station (41° 11'S, 146° 20'E) on a ferrosol soil, pH 6.2 and soil phosphorus 111mg kg<sup>-1</sup> and potassium 222 mg kg<sup>-1</sup>. The two previous crops grown on the trial site were poppies and barley respectively. Ploughing had taken place in the autumn and left-fallow and following dry conditions in the spring resulted in a rather cloddy seedbed. Fertiliser, 1000 kg ha<sup>-1</sup> of N:P:K, 11:12:19, was pre-placed in two bands 100mm apart when the drills were opened prior to planting. The crop was grown according to the current agronomic practices.

**Table 1.** Sequential events in the experiment at Lower Barrington 2002-03. All figures are presented as days. NH denotes not harvested.

Defoliation Treatments	A	B	C	D	E
	Defoliation Dates				
	25.2.03	5.3.03	12.3.03	19.3.03	16.4.03
<i>Days to event</i>					
Planting to defoliation	91	98	105	112	140
Planting to 1 <sup>st</sup> harvest	105	112	119	126	140
In ground curing	14	14	14	14	0
Planting to 2 <sup>nd</sup> harvest	141	141	141	141	NH
In ground curing	50	43	36	29	NH
<i>Days after 1<sup>st</sup> Harvest</i>					
Grading	27	20	13	21	17
Cool store	35	28	21	29	24
<i>Days after 2<sup>nd</sup> harvest</i>					
Grading	37	37	37	38	NH
Cool store	44	44	44	44	NH

The seed lots were removed from the cool store on November 10, 2003 for preparation of sets. The seed was allowed to warm from the 4 °C storage temperature to ambient conditions prior to handling. Three days before planting tubers from each treatment were divided into six lots and sixteen uniform tubers were selected, cut longitudinally and dusted with cement as a drying agent. The sets were bagged and the appropriate block and plot numbers attached. Two rows 810 mm apart with 32 sets at 300mm spacing and, each set planted cut surface down on November 25. Each plot was separated by a buffer section of a distinctive, coloured tuber cultivar. The sets were covered with about 100mm of soil. Emergence was recorded over a number of days and a contact herbicide was applied for weed control at the commencement of emergence. Later the plots were scarified and molded prior to row closure. The trial was observed at frequent intervals throughout the growing period and following senescence stem counts were taken prior to harvest.

Plots were machine harvested, hand bagged, tagged and taken to the grading station where tuber number and yields were determined for the following tuber size classes: 0-80g, 81-250g, 251-450g and >450g, and reject tubers of all



descriptions. The twenty largest tubers were cut longitudinally to assess the incidence of hollow heart and brown centre. A composite sample of each treatment was collected for SG determination.

## **TRIAL 2. STAVERTON SITE: TIME OF DEFOLIATION AND REPLANTING**

The site was chosen to examine the effects of late planting and to lesser degree a possible altitude effect linked to the defoliation treatments of the seed crop that may influence the following ware crop. The trial was located in a commercial seed crop of cultivar **Russet Burbank** that had passed inspection and was granted provisional certification by the DPIWE Inspector.

This site was located at Staverton, Latitude 41° 24'65" Longitude 145° 18'5" and an elevation of 550m. The soil was a transitional ferrosol with a 5.9 pH and had been in long term pasture prior to seed crop planting. The crop was planted December 22, 2002 with 1600 kg ha<sup>-1</sup> 11:12:19, N:P:K applied at planting. To control weeds and both early and light blight the grower followed commercial practice. A travelling irrigator was used throughout the season to apply supplementary water when required.

The experiment was laid as a randomised block of five treatments (across the slope) and eight replicates (down the slope). The plots were located as two 3m long rows that were the planter pair. In addition, the trial was located to avoid irrigation runs and tractor pathways used for spraying. The defoliation treatments commenced very early in growth at 74 days after planting (6.03.03) and then at 81, 90, 96 days with the final treatment at 143 days (16.03.03) to simulate commercial practice. Stem numbers and weights were recorded at each occasion. The harvest of all plots occurred two weeks after the last defoliation and coincided with harvest of the commercial crop and, as the land was required for the next crop a second, later harvest date was not possible.

Tubers were hand dug and bagged with a plot number and treatment code tag included with the tubers in addition to the standard external labeling. All bags were taken to a grading station where the seed was graded 14 days or more

after harvest to allow skins to harden prior to grading. Tuber number and yields were determined for the size classes 0-35g, 36-100g, 101-250g, 251-380g and >380g. From each of the five treatments in excess of 200 tubers between 110 and 150g were selected as seed and held a further 14 days to cure at ambient conditions in jute bags prior to cool storage at 4 °C.

The sequence of defoliation and subsequent activities is presented in Table 2.

**Table 2.** Sequential events in the experiment at Staverton 2002-03. All figures are presented as days.

Defoliation Treatments	A	B	C	D	E
	Defoliation Dates				
	6.3.03	13.3.03	21.3.03	27.3.03	16.4.03
Planting to defoliation	74	81	89	95	120
Planting to harvest	134	134	134	134	134
In ground curing	60	53	45	39	14
<i>Days after harvest</i>					
Grading	30	30	31	31	31
Cool Storage	57	57	57	57	57
<i>Days from planting</i>	191	191	191	191	191

The seed evaluation of this experiment was conducted at Forthside Research Station as described for the Lower Barrington Trial. The five seed lots were removed from the cool store November 10 for preparation of sets. The seed was allowed to warm from the 4 °C storage temperature under ambient conditions prior to handling. Very few tubers showed any sprout development at this time, but almost all tubers had shot (budded) at cutting and apical buds were mostly absent. Tubers for seed were selected from the 110-150g range. There was no sign of dry rot or fusarium (*Fusarium spp.*) or gangrene (*Phoma foveate*). Three days prior to planting, tubers from each treatment were divided into six lots of sixteen uniform tubers and cut longitudinally (bud to stem end) and dusted

with cement as a drying agent. Planting and harvest were as described for the previous trial.

## **RESULTS**

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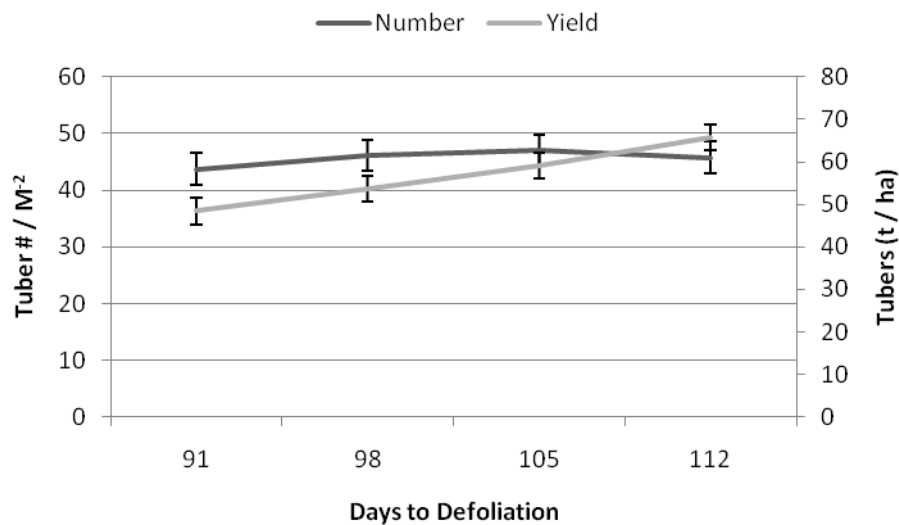
### **TRIAL 1: LOWER BARRINGTON SITE**

#### **SEED CROP PRODUCTION**

The selection of the trial site within the existing crop was based on uniformity of plant stand and tuber population between and within the applied treatments. The mean stem population of 19.8 m<sup>-2</sup> was a density expected to provide the majority of seed tubers within the commercial limits. Analysis indicated stem number remained constant across the treatments and varied between 18.6 and 21.1 stems m<sup>-2</sup>.

The mean haulm weight of 50.5 t ha<sup>-1</sup> was indicative of a lush crop; randomly measured stems exceeded 2m in length and 15-20 mm in diameter. As expected, haulm weight declined over time with plant age and changing season, falling from 54.4 t ha<sup>-1</sup> at the first defoliation to 48.4 t ha<sup>-1</sup> by the fourth defoliation.

Tuber number was found to have plateaued prior to the first defoliation and no significant differences in tuber number were found over the defoliation period (Figure 1) under all treatment combinations. As total tuber numbers would be expected to remain constant at this crop stage, the consistency in tuber number indicates that replication was sufficient to account for any site or crop variations. A 44 per cent increase in seed yield was observed over the five defoliation dates for the early harvest. In any commercial situation these values could be of economic importance, depending on the price commanded by the seed.



**Figure 1.** The changes in tuber numbers (No.m<sup>-2</sup>) and tuber yield (t ha<sup>-1</sup>) over the defoliation period from February 25 to March 19, at Lower Barrington 2003, pooled across early and late harvests. Error bars are the LSD ( $p=0.05$ ).

While total tuber number remained constant, the number and weight of tubers in each size class changed under the defoliation treatments (Table 3).

The change within the classes was indicative of a continued but slowing rate of increase in tuber size with crop growth. The <35g tubers, normally not harvested but invariably discarded, show a decline over the sampling period but still do constitute over 10 per cent of tuber numbers. The pattern of declining numbers is again present in the 36-100g class, and tuber number in the larger 250g seed class displayed an increase with delay in defoliation date. A similar pattern is reiterated in the weight of tubers (Table 4), but shows a more definite pattern of decline and increase in the lower and upper weight classes used for seed. Tubers produced in the combined classes >280g, increased with time. Tubers in this class, while an inevitability of growth, are less profitable and need to be constrained where possible.

**Table 3.** Distribution by size class for tuber number  $m^{-2}$  at five defoliation dates and two times of harvest at Lower Barrington 2002-03. NH = not harvested. Statistical significance is presented as *p* values from the ANOVA analysis. Defol<sup>n</sup> = defoliation. Inter<sup>n</sup>=interaction.

Time of Harvest	Size Class	A	B	C	D	E	Defol <sup>n</sup>	Harvest	Inter <sup>n</sup>
Early	<35g	5.2	6.1	5.7	4.7	8.7	<0.05	NS	NS
Late		6.5	6.4	6.1	3.3	NH			
Early	36-100	14.5	13.8	11.7	9.3	5.3	<0.001	NS	NS
Late		14.2	12.5	11.1	9.5	NH			
Early	101-280	22.6	24.2	27.0	27.9	25.3	<0.001	<0.01	<0.05
Late		22.9	23.4	24.9	27.3	NH			
Early	281-380	0.8	1.1	1.6	2.5	5.4	<0.001	<0.001	NS
Late		1.3	1.9	2.7	3.6	NH			
Early	>380	0.0	0.1	0.3	0.5	1.4	<0.01	NS	NS
Late		0.1	0.1	0.3	0.5	NH			
Early	Waste	0.0	0.1	0.1	0.0	0.0			
Late		0.0	0.0	0.0	0.0	NH			

**Table 4.** Tuber weights ( $t\ ha^{-1}$ ) for the five defoliation dates and two times of harvest at Lower Barrington 2002-03. NH = not harvested. Statistical significance is presented as *p* values from the ANOVA analysis. Defol<sup>n</sup> = defoliation. Inter<sup>n</sup>=interaction.

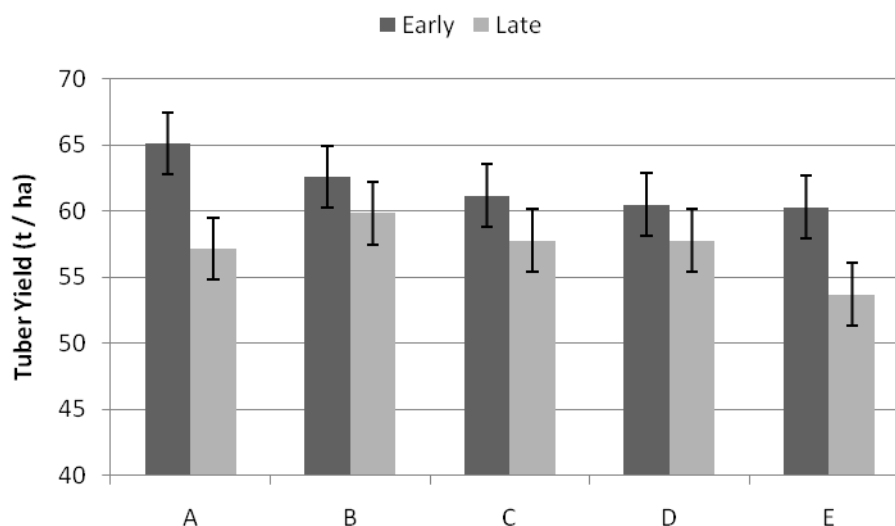
Time of Harvest	Size Class	A	B	C	D	E	Defol <sup>n</sup>	Harvest	Inter <sup>n</sup>
Early	>35g	0.8	1.0	1.0	0.8	0.8	NS	NS	NS
Late		1.1	1.2	1.0	1.0	NH			
Early	36-100	10.4	9.9	6.7	6.4	5.6	<0.001	NS	NS
Late		10.7	9.2	8.0	7.0	NH			
Early	101-280	33.1	40.2	48.5	50.4	41.9	<0.001	<0.001	<0.01
Late		33.9	36.6	38.4	38.4	NH			
Early	281-380	1.0	0.8	1.6	3.3	15.9	<0.001	<0.001	<0.01
Late		3.6	5.7	8.1	10.8	NH			
Early	>380	0.1	0.7	1.6	3.2	6.5	<0.001	NS	NS
Late		0.3	0.5	0.5	2.4	NH			
Early	Waste	0.0	0.4	0.1	0.0				
Late		0.0	0.0	0.0	0.0	NH			

There was a very few second growth and cracked tubers in the reject category at this site.

## ASSESSMENT OF SEED PERFORMANCE

The standard agronomic program of the Forthside Vegetable Research Station for potatoes was followed in the production of the ware crop. This included a prescheduled preventative fungicidal program for late blight and target spot. Only minor target spot infection occurred during senescence. Weeds were controlled by an application of the contact herbicide, Sprayseed at the commencement of emergence and by mechanical means at molding. Irrigation was generally adequate, however on two occasions the crop appeared slightly stressed. In the period between emergence and senescence, growth was uniform and the data collected (not shown) indicated there were no observable treatment differences in crop morphology or growth. Across the site there were no measurable differences in the occurrence of crop senescence.

The time of defoliation treatments in the seed crop did not influence total ware crop yield, although a trend towards higher yield from earlier defoliation was noted (Figure 2). Yield was influenced by an earlier harvest ( $p = 0.001$ ) which produced 5 t/ha greater yields than late harvested seed in the ware trial (Table 5).



**Figure 2.** The effects of five times of seed defoliation (A-E) and two times of harvest on total yield of tubers ( $t\ ha^{-1}$ ) harvested at Forthside Vegetable Research Station 2004. Error bars are the LSD ( $p=0.05$ ).

The increase in overall yield could be attributed to the production of more tubers from plants grown from early harvested seed (Table 5). The yield of processing (80-450g class) and fry grade (>80g) size tubers was similarly not influenced by defoliation while a delayed harvest lowered the processing yield ( $p = 0.001$ ) by approximately 6% (Table 5).

**Table 5.** The effects of five times of seed crop defoliation and two times of harvest at Forthside Research Station 2004 on numbers of tubers per plant, stems per plant, tubers per stem, stems  $m^{-2}$  and tubers  $m^{-2}$  and yield  $t\ ha^{-1}$  of size classes 80-450g, fry grade and waste components of total yield. Statistical significance is presented as  $p$  values from the ANOVA analysis. Defol<sup>n</sup> = defoliation. Inter<sup>n</sup>=interaction.

Time of Harvest		A	B	C	D	E	Defol <sup>n</sup>	Harvest	Inter <sup>n</sup>
<b>Number</b>									
Early	Tubers	11.58	11.76	10.57	10.44	10.43	<0.05	<0.001	NS
Late	plant <sup>-1</sup>	9.35	10.88	10.11	9.48	9.33			
Early	Stems	4.75	4.23	4.03	4.07	3.25	<0.01	<0.001	<0.001
Late	plant <sup>-1</sup>	3.35	3.77	3.53	3.49	3.66			
Early	Tubers	2.44	2.58	2.96	2.60	3.25	NS	NS	NS
Late	Stem <sup>-1</sup>	2.81	2.88	2.89	2.72	2.61			
Early	Stems $m^{-2}$	19.8	17.3	16.5	16.9	13.6	<0.01	<0.001	0.05
Late		14.0	15.6	14.4	14.4	15.2			
Early	Tuber $m^{-2}$	45.76	42.96	46.44	41.75	41.26	<0.05	<0.001	NS
Late		36.93	42.98	39.94	37.45	36.87			
<b>Yield</b>									
Early	80-450 (g)	58.23	54.69	53.30	53.51	52.82	NS	<0.001	NS
Late	yield	48.55	49.25	49.49	48.35	46.28			
Early	Fry Grade	58.53	55.21	53.73	53.82	53.11	NS	<0.001	NS
Late	(t / ha)	49.35	49.97	49.99	48.68	46.46			
Early	Waste	2.41	3.30	2.43	3.06	3.50			
Late	(t / ha)	4.88	5.26	3.91	5.96	3.95	NS	<0.001	NS

Later defoliation of the seed crop did however, reduce tuber number per square metre in the ware crop ( $p \leq 0.05$ ) as did delayed harvest ( $p \leq 0.001$ ), yet the influence of these two production factors did not interact ( $p=0.067$ ). The

reduction in tuber number was most likely due to a reduction in stem number per seed piece, as evidenced by the response to both delayed defoliation and harvest in the ware trial. Delaying defoliation tended to lower the number of stems for early harvested plants ( $p < 0.01$ ) as did a delayed harvest ( $p < 0.001$ ). Although not expressed in total yield, a later harvest seemed to override the stem number response to defoliation date ( $p < 0.001$ ). As the number of tubers per stem was consistent across treatments, it is deduced that both later defoliation ( $p \leq 0.05$ ) and late harvest ( $p \leq 0.001$ ) decreased stem numbers, leading to a lower number of tubers borne by each ware plant and a subsequent reduction in yield per square metre.

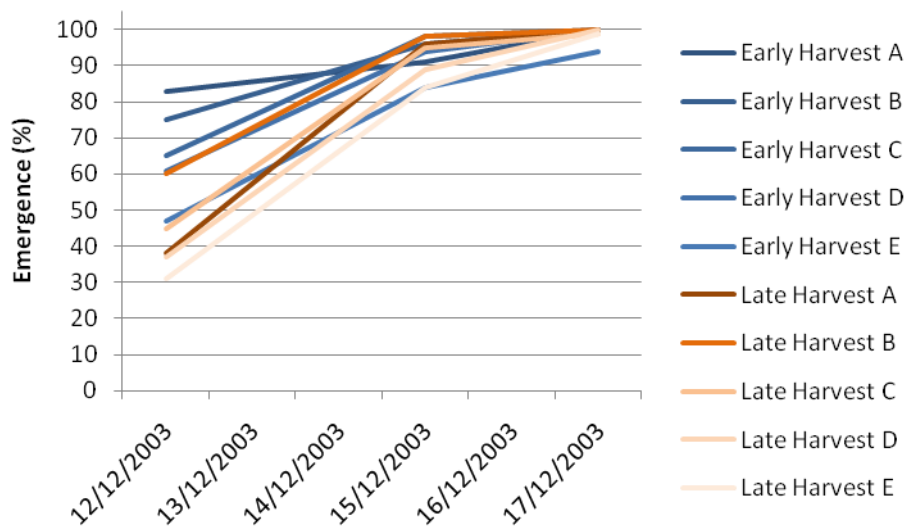
Performance of the seed from the different time of defoliation and time of harvest treatments was not correlated to accumulated day degrees. Strong relationships between day degrees and stems per plant ( $R^2 = 0.969$ ) and yield ( $R^2 = 0.788$ ), and a weaker relationship to tubers per plant ( $R^2 = 0.481$ ), were recorded for the early harvested tubers pooled across different defoliation date treatments. Using a base temperature of 4°C and calculating degree days from the date of first defoliation (91 days after planting), seed from the early defoliation, early harvest treatment accumulated the lowest number of degree days. This seed also displayed performance attributes such as higher stem number that are usually associated with older seed. The results were consistent with the early defoliation and harvest imposing a 'stress' on the tubers that resulted in physiological aging, but the effect was not related to accumulated day degrees. An extended duration of in-ground storage following early defoliation and prior to harvest appeared to remove the physiological aging effect associated with the early defoliation and earlier harvest treatments.



**Table 6.** The effect of *DD* based on air temperatures at Lower Barrington for five times of defoliation and two times of harvest on the attributes, stems per plant, tubers per plant and yield  $t\ ha^{-1}$

Defoliation	Harvest	DD	Stems /plant	tubers /plant	yield (t/ha)
A	early	1140	4.75	11.58	65.2
B	early	1269	4.23	10.88	62.6
C	early	1349	4.03	11.76	61.2
D	early	1398	4.07	10.57	60.5
E	early	1597	3.25	10.44	60.3
A	late	1597	3.35	9.35	57.2
B	late	1597	3.77	10.88	59.8
C	late	1597	3.53	10.11	57.8
D	late	1597	3.49	9.48	57.8
E	late	1597	3.66	9.33	53.7
Regression against DD			$R^2 =$ 0.969	$R^2 =$ 0.481	$R^2 =$ 0.788

Observations of crop emergence during the assessment of seed performance were consistent with the finding that early defoliation and early harvest tended to produce seed that behaved physiologically older than later harvested and later defoliated seed. Emergence was complete 26 days after planting and the early harvested treatments generally emerged earlier than late harvested seed (Figure 3). Early defoliation also appeared to increase the rate of emergence. Stem counts post senescence and prior to harvest indicated all plots had a full complement of thirty-two plants, indicating successful establishment by all tuber sets.



**Figure 3.** The emergence (%) of plants from early and late harvested seed produced by defoliation treatments (A-E) on five occasions from 91 days after planting.

## TRIAL 2: STAVERTON SITE

### SEED CROP PRODUCTION

The seed crop used for the trial was planted later than the Lower Barrington crop and did not develop a luxuriant canopy or achieve full ground cover. Ferrosol soils are free draining and irrigation was based on A-pan evaporation estimates provided by the Bureau of Meteorology. The effect of water stress was observed at harvest in some tubers that had pointed, apical ends in the latter part of tuber growth. Preventative fungicides were applied and neither late blight nor target spot were observed during the growing season.

### RESULTS

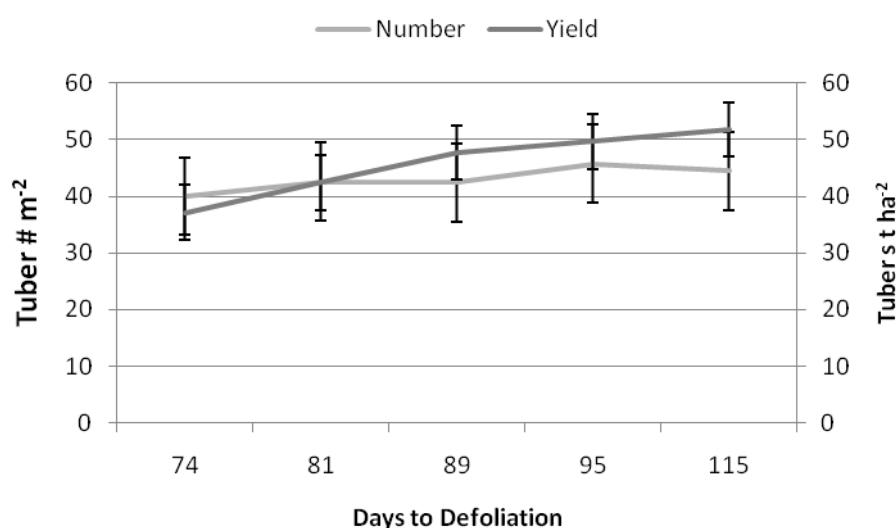
A grand mean for stem number of over 16 m<sup>-2</sup> was lower than that recorded at the Lower Barrington site, but was within the range of commercial standards for seed production. Greater variability between treatments was noted at this site. Treatment C (14.6 stems m<sup>-2</sup>) had a significantly lower stem population

(LSD = 2.3;  $p=0.05$ ) than A, and E (17.4 and 17.9 stems  $m^{-2}$  respectively); B (15.2 stems  $m^{-2}$ ) was significantly different from E.

At the first defoliation, early in the crop life at 74 days, a mean stem fresh weight of 21.6  $t \cdot ha^{-1}$  was recorded. The expected seasonal decline was observed (LSD = 2.3  $t \cdot ha^{-1}$ ;  $p=0.05$ ), with the fourth defoliation yielding 15.6  $t \cdot ha^{-1}$  and the fifth 7.6  $t \cdot ha^{-1}$  respectively.

The mean tuber number per square metre did not show a significant change with defoliation time, as was expected for a crop during the later stages of the tuber bulking phase. The changes in tuber yield recorded over time were indicative of the seasonal changes expected during normal crop development. An increase in tuber yield from 31.7 to 51.8  $t \cdot ha^{-1}$  was recorded at the sampling dates 74 and 120 days after planting respectively (Figure 4).

Significant differences in tuber, number (Table 7) and weight (Table 8) in the different size classes were recorded between defoliation dates. Both total yield



**Figure 4.** The change in tuber number ( $m^{-2}$ ) and tuber yield ( $t \cdot ha^{-1}$ ) at five sequential defoliation dates 74, 81, 90, 96 and 115 days after emergence (A-E) in the seed crop at Staverton, 2002-2003. Error bars represent the LSD ( $p \leq 0.05$ ).

and seed yield changed with a delay in defoliation, and the preferred seed grade of 36-250 g, showed an increase of 7t.ha<sup>-1</sup> (22%) between defoliations A and D. Less than 1t ha<sup>-1</sup> was gained in the final 24 days when the foliage rapidly senesced as growing conditions deteriorated.

**Table 7.** Distribution by size class for tuber number m<sup>-2</sup> at five sequential defoliation dates 74, 81, 90, 96 and 115 days after emergence (A-E) at Staverton 2002-03. Statistical significance is presented as *p* values from the ANOVA analysis. NS = not significant.

Size Class	Treatment					Sig ( <i>p</i> ).
	A	B	C	D	E	
<35g	6.1	7.4	6.7	6.9	6.5	NS
36-100	19.8	17.4	16.1	17.5	15.5	NS
101-250	13.3	16.4	17.5	18.8	19.6	<0.001
251-350	0.8	1.2	1.8	2.0	2.3	<0.01
>351	0.1	0.2	0.4	0.5	0.6	NS

**Table 8.** Distribution by size class for tuber yield (t ha<sup>-1</sup>) at five sequential defoliation dates 74, 81, 90, 96 and 115 days after emergence (A-E) at Staverton 2002-03. Statistical significance is presented as *p* values from the ANOVA analysis. NS = not significant.

Size Class	Treatment					Sig ( <i>p</i> ).
	A	B	C	D	E	
<35g	1.2	1.3	1.2	1.2	1.2	NS
36-100	13.9	11.6	10.7	11.7	10.4	NS
101-250	19.4	24.5	26.9	28.6	30.3	<0.001
251-350	2.3	3.8	6.2	6.1	6.7	<0.01
>351	0.5	1.4	2.7	2.3	3.9	NS

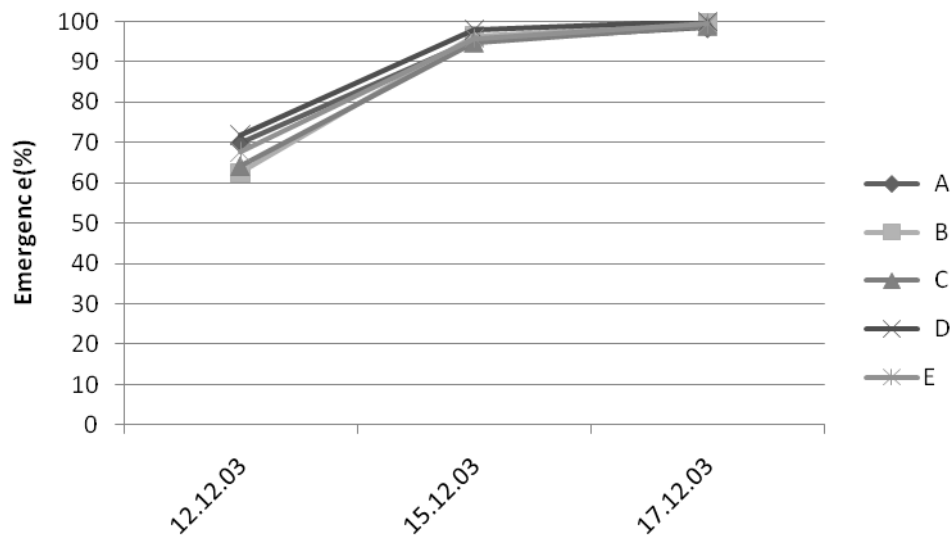
The seed produced across all treatments was more rounded (with some pointed tubers) than the elongated shape normally encountered with **Russet Burbank**. Seed for storage was carefully selected for uniformity and any pointed tuber

was rejected. Stored seed did not show signs of common scab (*Streptomyces scabies*), powdery scab (*Spongospora subterranean*) or rhizoctonia (*Rhizoctonia solani*). Tubers in the size range of 110-150 g were selected for the next season's planting, bagged, and then placed in half ton, slatted wooden bins at a temperature just below 4 °C for the next 133 days. The specific gravity of seed tubers varied between the defoliation treatments with values of 1.080, 1.089, 1.095, 1.094 and 1.094 recorded for seed from the earliest to latest defoliation date respectively.

#### ASSESSMENT OF SEED PERFORMANCE

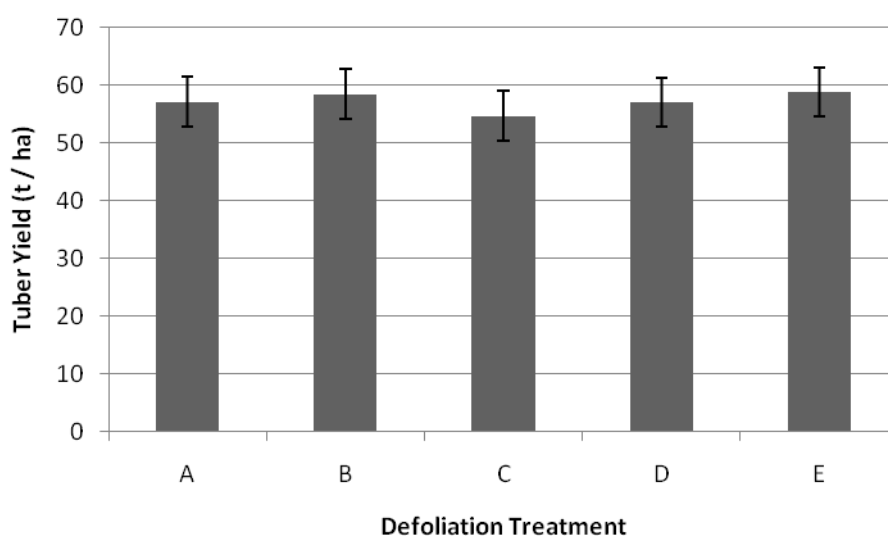
The standard agronomic program of the Forthside Vegetable Research Station for potatoes was applied. The preventative fungicidal program for late blight and target spot was followed on the predetermined farm schedule and only minor target spot infection occurred during senescence. Weeds were controlled by an application of Sprayseed at emergence and by mechanical means at molding. Being based on Bureau of Meteorology evaporation estimates, irrigation was generally adequate, but on two occasions the plants appeared stressed, indicating irrigation was necessary at those times. At harvest, there were no tuber shape anomalies that could be related to these episodes, thus it is assumed the stress events noted were of little consequence. In the period between emergence and senescence, growth was uniform and there were no notable treatment differences. Similarly, there were no measurable differences between treatments during senescence, which was uniform across the whole trial site.

At the final emergence count, 22 days had elapsed from planting (Figure 5). If there were any early differences in emergence, they were missed by the first count. Assessment after senescence confirmed each plot had achieved 100% emergence.



**Figure 5.** Emergence from potato seed harvested from five sequential defoliation dates 74, 81, 90, 96 and 115 days after emergence (A-E) at Staverton 2002-03. Statistical significance is presented as *p* values from the ANOVA analysis. NS = not significant.

Tuber yields were comparable with the late harvested treatments from the Lower Barrington trial, and there were no significant differences between the five seed lots (Figure 6). The lack of treatment effects on crop emergence and yield suggested that there was little variation in seed tuber physiological quality among the five treatments.



**Figure 6.** The effects of seed crop defoliation at 74, 81, 90, 96 and 115 (A-E) days from planting on tuber yield ( $\text{tha}^{-1}$ ) in the subsequent ware crop grown at Forthside Research Station 2004. Bars are the  $\text{LSD} = 4.26$  ( $p=0.05$ ).

Analysis of the number of tubers per plant, tubers per stem and stems per plant revealed no significant treatment effects (Table 9). As plant stand density was constant, these in turn led to no differences in stem and tuber numbers per unit area. Day degrees accumulated by seed from all treatments was calculated at 1212 DD with all seed exposed to the same field conditions, harvested at the same date and stored in the same conditions. Cumulative day degrees were calculated using a base temperature of  $4^{\circ}\text{C}$  commencing from the date of first defoliation (74 days after planting). The results mirrored those of the late harvested tubers from the Lower Barrington trial with defoliation timing having no impact on seed performance, but with lower stem and tuber numbers recorded than from seed in the Lower Barrington trial. While the day degrees were higher for the late harvested seed at Staverton, the data from the 2 sites are not directly comparable as calculations were made over different timeframes.

**Table 9.** *The effects of seed crop defoliation at 74, 81, 90, 96 and 115 (A-E) days from planting on; tubers per plant, stems per plant, tubers per stem, stem m<sup>-2</sup>, and tubers m<sup>-2</sup> on the subsequent ware crop grown at Forthside Research Station 2004.*

Size Class	A	B	C	D	E	Sig. (p)
Tubers / plant	9.5	9.9	9.4	10.6	9.9	NS
Stems / plant	3.3	3.3	3.2	3.5	3.4	NS
Tubers / Stem	2.9	3.0	2.9	3.0	2.9	NS
Stems m <sup>-2</sup>	13.4	13.7	13.3	14.6	14.0	NS
Tuber m <sup>-2</sup>	39.0	40.7	38.5	43.6	40.7	NS

The commercial yield from the five treatments also did not differ significantly. The yield of fry grade tubers was unaffected by the seed production program as was the proportion of waste tubers and those >250g (Table 10). A trend towards increased waste tuber yield with later defoliation dates was noted but no statistically significant differences were found.

**Table 10.** *The effects of seed crop defoliation at 74, 81, 90, 96 and 115 (A-E) days from planting on ware tuber performance when grown out at the Forthside Research Station on tubers in the >250, fry and waste grade size class.*

Class	A	B	C	D	E	Sig (p).
>250g (%)	20.2	21.2	19.2	16.1	18.9	NS
Fry Grade (t / ha)	45.6	45.2	40.2	42.3	44.4	NS
Waste (t / ha)	10.8	12.3	12.7	12.6	13.1	NS

The specific gravities of fry grade tubers from all treatments exceeded the 1.085 that is usually required to manufacture the highest quality French fries produced in Tasmania. Similarly, dry matter content was found to be above commercially acceptable levels for all treatments (Table 11). The percentage of



large tubers with hollow heart and brown centre was relatively high and would have resulted in a downgrading of quality. Although the sets were planted at about 100mm and molded to about 200mm before row closure there, were no periods of low temperature and evapotranspiration events often associated with these physiological conditions.

**Table 11.** *The effects of seed crop defoliation at 74, 81, 90, 96 and 115 (A-E) days from planting on parameters of the following ware crop considered important for processing quality: specific gravity, black spot, hollow heart and brown centre.*

<b>Treatment</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
Specific Gravity	1.094	1.097	1.093	1.093	1.096
Dry Matter %	23.0	23.7	22.7	22.9	23.3
<b>Largest Tuber</b>					
Hollow Heart (%)	28	35	37	45	32
Brown Centre (%)	27	18	23	17	17

## DISCUSSION

The effects of timing of seed crop defoliation on performance of seed in the following ware crop were small, with no significant difference in yield between times of defoliation treatments in the two trials. In one of the two trials, early defoliation times resulted in seed that produced significantly higher numbers of stems per plant and tubers per plant. This occurred when the seed was harvested shortly after defoliation; but the increase in stem and tuber number was lost if the seed tubers were left in the ground after defoliation and harvested at the end of the season. Higher stem numbers per seed tuber may have resulted from seed having a greater number of eyes per tuber but this result is usually associated with physiologically older seed (Iritani and Thornton, 1984), suggesting that significant aging of tubers occurred in response to defoliation and harvest following less than two weeks in ground curing. These results are not inconsistent with those of Grice (1988) who showed in **Russet Burbank**, young seed prior to planting had more stems than

older seed and this was reinforced in crop stem counts. Seed tubers from the early defoliation, early harvest treatments in the first experiment were held in cold storage for longer than the later harvested tubers, and had accumulated fewer day degrees prior to planting. The early defoliated, early harvested seed also displayed faster emergence in the ware crop, again consistent with the seed being physiologically older. While these findings are consistent with the hypothesis that stress late in crop development may age seed tubers, clearly the response may be ameliorated or modified by other factors as it was not present when early defoliation was followed by extended in-ground curing prior to harvest.

While the results demonstrate defoliation effects of seed tuber physiological status may occur when seed is harvested and stored shortly after defoliation, the conclusion was drawn that late planting and midseason defoliation treatments of **Russet Burbank** seed, followed by extended in-ground storage prior to harvest, are unlikely to significantly affect commercial ware crop yield. Results consistent with this conclusion have been reported in previous studies. When seed of the cultivars **Arran Pilot** and **Majestic** were defoliated three weeks prior to senescence the subsequent ware crop showed no yield increases (Holmes and Gray, 1972). A like result was also obtained when Panelo and Caldiz (1989) compared seed desiccated 100 days from planting with seed from the senesced crop and found there was no difference in ware yield. Murphy *et al.* (1967) in three seasons showed that **Katahdin** was unaffected by four different growing periods, however seed storage temperature at 3.3°C produced significantly higher yields than storage temperatures of either 0 or 6.7°C.

While the effect of defoliation date on seed physiological status and performance was small, the effect of harvest date on subsequent seed performance was commercially significant. At the Lower Barrington site, seed plots were harvested 14 days after defoliation or at the end of the growing season. When grown on as a ware crop, early harvested seed was significantly superior and had a 6% (5 tha<sup>-1</sup>) higher fry grade yield of tubers compared to the

late harvested seed. This result was similar to that obtained by Maas (1971) who found that seed of **Netted Gem** harvested early, at 123 days after planting, had significantly higher ware yield compared to seed harvested late at 144 days. In a more detailed study (Chase, 1974), the cultivars **Onaway** (early maturing) and **Sebago** (late maturing) were grown with seed produced by harvesting at 76 days (early season), 96 days (mid-season) and 155 days (end of season). In addition, at the early and midseason harvest, plots were desiccated and later harvested with the full maturity treatment. The results from three years of ware yield comparison indicated the two early harvests significantly out-yielded the desiccated treatments left in the soil for 39 and 19 days respectively. A contrary view was expressed by Rowberry and Johnson (1966), who showed that **Kennebec**, **Netted Gem**, **Sebago** and **Norland** were unaffected by the two seed harvest times, the earlier about 55 days after planting compared with full maturity. This outcome was supported by Wurr (1978b) whose data showed that ware yields from early harvested seed were lower than later harvested seed when crops were grown to full senescence. Further investigations by Wurr *et al.* (2001) showed that four defoliation times in a seed crop trial had no effect on ware crop production. In Rowberry and Johnson's time of harvest studies, two cultivars, **Netted Gem**, a synonym for **Russet Burbank**, and **Sebago**, produced opposing results. An interaction between a number of factors potentially influencing tuber physiological status between late crop development and storage is needed to explain the results of these experiments and previous studies. These factors may include the stage of crop development at which treatments are imposed and the rate of tuber growth at the point of treatment application, both of which will affect the tuber physiological status when treatments are applied.

Significant changes in yield and size grade composition of seed within the desired range of 35-280g were recorded as the seed crops developed, and a 30% and 22% increase in total tuber yield was recorded for the Lower Barrington and Staverton crops respectively. Stem weights declined at both sites over the defoliation treatments and were still decreasing at the final

defoliation. A measure of the difference between the two sites was shown in the respective tuber bulking rates. Lower Barrington commenced at  $2.4 \text{ t ha}^{-1} \text{ day}^{-1}$  and fell to  $1 \text{ t ha}^{-1} \text{ day}^{-1}$  two weeks later, compared to Staverton where in the first week the average increase was  $0.7 \text{ t ha}^{-1} \text{ day}^{-1}$  falling to  $0.4 \text{ t ha}^{-1} \text{ day}^{-1}$  after two weeks. These rates are comparable with those recorded for **King Edward** of  $5 \text{ t ha}^{-1} \text{ day}^{-1}$  to near zero depending on water availability (Hide and Whelam, 1992).

The physiological changes occurring in developing tubers on plants defoliated during periods of high bulking rate are likely to be greater than effects on tubers in slower growing crops. This difference may explain why a significant stem and tuber number response was recorded in the early defoliation treatments in the Lower Barrington trial but there was no effect noted in the Staverton trial. The previously reported effects of stress on seed P-age would also be consistent with external influences during periods of high growth rate, such as the tuber bulking phase of crop development causing rapid changes in tuber physiology and resulting in observed aging responses.

Any physiological differences induced by the treatments imposed during seed crop development were not expressed as morphological differences prior to planting. The seed of both sites was stored in the same commercial cool store at  $4^{\circ}\text{C}$  till required for replanting. When removed to ambient conditions sound seed was selected, with very few eyes exhibiting activity. Yet during the warming period required, and prior to cutting, sprouting started with very few tubers showing apical dominance. This condition would fit the “enforced dormancy” category, where dormancy was complete but the low temperature prevented bud movement (Reust, 1984; Struik and Wiersema, 1999). This situation in a system where seed is cut is advantageous as there is a propensity to equalise the physiological status between sets (Struik and Wiersema, 1999). The absence of obvious differences in sprouting morphology prior to seed cutting in the trials, and evidence of enforced dormancy, indicated that

differences in duration of dormancy were unlikely to explain the physiological aging and stem number response noted in the first trial.

Struik *et al.* (2006) examined accumulation of DD prior to dormancy and showed post dormancy accumulation was more important in explaining physiological aging. In contrast, Knowles and Knowles (2006) prepared seed having DD of 80, 450 and 900 prior to storage at 12, 22 and 32°C and found significant physiological aging responses. However, whilst there were variations in stem numbers and tuber size distribution, there was little effect on total or ware yields. This yield response was consistent with the results of the first trial reported in this chapter, but stem number in the trial did not follow the expected increase. Other studies using **Russet Burbank** have shown few differences in stem number with day degree accumulation during storage. The stem number and growing periods of the cultivars **Russet Burbank**, **Ranger Russet**, **Shepody** and **Umatilla** were assessed under two P-age treatments of 117 and 172 DD, and few significant effects apart from cultivar differences were found (Olsen, 2004). The capacity for treatments such as defoliation prior to harvest to modify the physiological quality of seed tubers independently of day degree accumulation may explain some of the inconsistent results on degree day relationships noted in the literature.

The effect of treatments modifying tuber physiological quality independent of day degree effects may extend beyond plant development pattern and tuber yield. At the Staverton site, and in the late harvest at the Lower Barrington site, all treatments spent an equal time in the soil, and were harvested at season's end and stored under standard conditions. Therefore, there were no differences in day degree accumulation between treatments. However, while no seed production treatment had an effect on ware yield, the incidence of waste mostly from second growth was very high in the Staverton trial. Waste accounted for 20.6 % of total yield and may be compared with the substantially lower incidence from Lower Barrington, where for the early harvested tubers, waste constituted 2.9 % of total yield and 4.8% for late harvested seed. As P-age

increases, the tendency to second growth increases (Struik and Wiersema, 1999). However Struik (personal communication) also believes that “with rather young seed the tendency to show secondary growth is stronger, but diminishes with time, and with older seed the plant becomes more sensitive”. The question arises: does the level of stress in the seed generation create “innate aging” and predispose the following generation to produce poorer quality tubers?

The results obtained from the two experiments presented in this chapter and in previously published work are consistent with crop defoliation, and potentially other seed crop management practices, having a significant influence on the physiological status of seed tubers. Factors such as the duration of in-ground storage prior to harvest and the stage of development or rate of development of tubers at the time of crop defoliation may modify the effect, and calculation of degree days is not able to account for the changes induced by the defoliation treatment and the factors modifying the response. Experimentation within a seed production program at a single site that involves a range of planting, defoliation and harvest times may help to validate these conclusions. This approach may also lead to the elucidation of a more efficient seed production system for the Tasmanian industry.

# CHAPTER 6

## PLANTING PERIOD, DEFOLIATION AND HARVEST TIME EFFECTS ON SEED AND SUBSEQUENT WARE PRODUCTION

### BACKGROUND

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The production practices and growing conditions for seed production have previously been implicated as factors influencing the physiological quality of seed tubers (Struik and Wiersema, 1999), and evidence for an effect of seed crop production practices on seed performance in Tasmania was documented in the previous chapter. In particular, the timing of crop defoliation and tuber harvest were shown to significantly affect the performance of the seed tubers in the subsequent ware crop. This chapter documents a large scale field experiment examining in greater detail the effect of seed crop planting date, defoliation date and harvest date on the performance of seed tubers in the following season.

### INTRODUCTION

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The Tasmanian seed potato industry uses cut seed for propagation purposes and planting is usually planned to occur between mid-spring and early-summer (September- December), although circumstances such as unfavourable weather conditions sometimes result in plantings being made outside these limits. Results from three previous investigations (Chapters 4 and 5) indicated that yield could be influenced by the time between planting and plant death, and also the time of harvest and possibly the time of planting. These findings have particular significance to Tasmanian seed tuber production as the variation in planting dates, haulm kill dates and harvest dates in Tasmania is much greater than in most other major seed production regions in the world. The cool

temperate, maritime climate in the potato growing regions in Tasmania provides a frost free production window that may exceed 160 days. This climate is ideal for production of processing crops, with the main cultivar **Russet Burbank** performing well with a growing period of at least 20 weeks (140 days) and other processing cultivars such as **Kennebec** (16 weeks) and **Shepody** (17 weeks) also producing high yields under long growing seasons. Growers have tended to establish an optimum planting time for their district, based on soil conditions, elevation and temperature. Seed crops require a shorter growing season as, unlike processing crops, large tuber size is not desired and seed crops may therefore be planted over an extended period leading to a broad range of harvest dates in addition to haulm kill dates and durations of in ground storage.

Variable results for time of haulm kill and harvest date treatments were noted in Chapters 4 and 5. As haulm kill and harvest date treatments may affect the physiological status of the tubers, the timing of the treatments relative to the stage or rate of crop development may be expected to determine the nature of the physiological changes induced by the treatments. The range of planting dates used in seed crops in Tasmania, combined with seasonal differences in plant growth rates and crop development patterns, will make it difficult to develop prescriptive recommendations for haulm kill timing if an interaction between crop development stage and haulm kill affects seed tuber physiological quality. Unfortunately, there is a paucity of published data on planting date, haulm kill date and harvest date effects on seed physiological quality from which conclusions on interactions between seed crop management practices can be drawn.

The effect curtailing growing time using haulm destruction treatments for seed crops of a range of cultivars has been examined, with variable results reported. A number of studies have reported no significant differences in seed performance during ware crop yield evaluations (Murphy *et al.* 1967; Caldiz *et al.*, 1985; Panelo and Caldiz, 1989), while other researchers have demonstrated significant yield responses from time of haulm destruction treatments (Maas,



1971, Wurr, 1973, Chase, 1974). When these studies are summarized, early defoliation has been shown to increase, decrease or have no effect on yield in the subsequent ware crop. While the range of cultivars examined and production environments used in the studies precludes drawing broad conclusions, the variability in responses is consistent with interactions between crop development stage and timing of haulm destruction affecting seed physiological status.

In a seed production program, Wurr (1980) showed that when ware yield was recorded sequentially, seed from early defoliation treatments resulted in higher early harvest yields, but by crop senescence, late harvested seed gave the highest yield across four later maturing cultivars. This finding highlights the importance of the relationship between seed physiological status at planting and ware crop production factors on ware crop yield, and adds a further complication to assessing effects of seed crop haulm destruction treatments on ware crop yield.

The productivity of potatoes is essentially determined by crop light interception which is strongly influenced by leaf area index, which in turn is affected by planting time and nitrogen nutrition (Allen and Scott, 1980). Furthermore tuber bulking rates fall as plants age and daylength, light intensity and temperature decline in the late summer and autumn periods. Jefferies *et al.* (1989) showed dry matter accumulation was best described by a linear function of DD based on 0°C and soil moisture deficit, which accounted for some 79% of the variance. When Hide and Wehlam (1992) examined 11 years of data for three UK cultivars, bulking rates fell from 5 to 1 t ha<sup>-1</sup> week<sup>-1</sup> over the growing season. Most tubers were initiated between weeks 9 and 11 and the maximum number was established by week 11. Out of these populations the ware tubers developed. The complex of tuber size variability was reported by Wurr *et al.* (1993) to be affected by nutrition, seed size and included P-age and other field factors. Tuber physiological state is likely to vary not only with stage of crop

development but also to be affected by the range of field factors that have been shown to influence tuber number and bulking rate.

While tools to assess aspects of tuber physiological state have not been developed for seed production, research has been published on the assessment of tuber physiology at harvest and subsequent propensity to decline in quality for processing. A seasonal effect of importance in French fry production is the development of SG, an estimate of dry matter content, and the relationship with premium grade fries. A quadratic regression equation best described the change in SG in **Russet Burbank** tubers late in the season (Werner *et al.*, 1998). The accumulation of starch depends on the conversion of sugar to starch. Sucrose concentration is high in tubers during rapid bulking, reflecting the rapid translocation of photosynthate to the tubers during growth, but declines as tuber bulking rate decreases and the rate of conversion of sucrose to starch exceeds the translocation rate. Sowokinos (1973) examined two groups of cultivars, those suitable or unsuitable for processing, and at maturity found the sucrose levels differed from 1.91mg g<sup>-1</sup> of tuber tissue for the processing lines and 4.53mg g<sup>-1</sup> for fresh market types. Following harvest, sucrose concentrations continue to decline, but glucose concentration increases and tubers with a higher sucrose concentration at harvest tend to display higher glucose concentrations during storage making them less suitable for processing (Pritchard, 2002). These responses have led processors to monitor sugar concentrations to predict processing quality, and to use sucrose concentration at harvest as a measure of the chemical maturity of a crop.

Exploration of some of these concepts may provide an explanation of the impact of early defoliation and harvest date effects on **Russet Burbank** grown for seed purposes in Tasmania. The only previous seasonal study of this cultivar in Tasmania did not document incremental yield changes nor SG data (Grice, 1988), focusing on the effect of temperature on tuber physiological state and concluding that DD accumulation wherever it occurs in seed production needs to be evaluated.

The experiment documented in this chapter examined the impact of the timing of planting on seed quality; duration of the crop as determined by timing of crop defoliation; and duration of in-ground storage. Each seed lot produced may be affected by the treatments, which may be viewed as stresses encountered prior to harvest, and these may affect the tuber physiological state prior to standard cool store at 4°C. The experiment was designed to occur in two phases, firstly to produce seed and secondly, growing out the progeny from each of the treatments in the following season.

## **MATERIALS AND METHODS**

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The investigation was conducted on a ferrosol soil at Forthside Research Station 145°W, 42°S. The two previous crops grown on the trial site were poppies and barley and respectively. Ploughing had taken place in the autumn and the soil left fallow. Fertiliser, 1000kg ha<sup>-1</sup> of N:P:K, 11:12:19, was pre-placed in two bands 100mm apart when the drills were opened prior to planting. The seed crop trials and ware crop assessments were grown according to the current agronomic practices.

### **SEED PRODUCTION**

Prior to the commencement of the experiment, certified seed (generation 3) was harvested three weeks after full crop senescence and subsequently graded to the current commercial seed specifications. Seed was held under ambient conditions to allow for wound healing prior to placement in a commercial cool store at 4°C from June until required in early November. Seed for each planting was removed from storage two weeks prior to the planned planting date and hand cut into sets of 50g or greater by a single experienced operator. Cut tuber pieces (sets) were dusted with a mixture of Tato Dust and powdered pine bark two days prior to planting. The seeding operation was carried out with a Faun twin row cup planter modified to place compound fertiliser (11:12:19, N:P:K) in bands 50 mm to the side of the set at 1200 kg ha<sup>-1</sup>.

A clod free seedbed was prepared for planting on November 15 and the subsequent plantings of December 15 and January 15. Sets were approximately 210 mm apart and 200 mm below the top of the finished ridge. Weighing the residual sets after each planting was used to cross check the set population which was approximately 6 sets m<sup>-2</sup>. The trial was implemented as a split-split plot design in two blocks. The main plots were allocated to three planting times and each of these divided into three sub plots to which defoliation times (top pulling) were randomly allocated. Defoliation (top pulling) was undertaken by hand. Within each defoliation time the plots were halved and a harvest time (sub-sub plot) was randomly assigned. Each harvest plot contained 4 rows and was 5m long. Defoliation for seed production commenced 100 days after planting. The first harvest took place three weeks after defoliation and the second at the end of the season when senescence in all plantings had occurred. The table 7.1 shows the time schedule for the production of the 18 different lots of seed and includes planting, defoliation, harvest, grading and cool storing times relative to planting or post harvest.

**Table 1.** *The time schedule of planting, defoliation, and days to harvest, grading and cool storage (and days between respective activities) for the seed 'crops' treatments at the FVRS in November 2003.*

<b>Planting 1</b>	<b>22 November 2003</b>		
	<b>Defoliation No.</b>		
<i>Days to event</i>	<b>1 (26.02.04)</b>	<b>2 (11.03.04)</b>	<b>3 (25.03.04)</b>
Planting to defoliation	98	112	126
Planting to 1 <sup>st</sup> harvest	119	133	147
In-ground curing	21	21	21
<i>Days after 1<sup>st</sup> Harvest</i>			
Grading	7	7	7
Cool store	7	7	7
Planting to 2 <sup>nd</sup> harvest	196	196	196
In-ground curing	98	84	70
<i>Days after 2<sup>nd</sup> Harvest</i>			
Grading	7	7	7
Cool store	15	15	15
<b>Planting 2</b>	<b>15 December 2003</b>		
	<b>1 (25.03.04)</b>	<b>2 (08.04.04)</b>	<b>3 (22.04.04)</b>
Planting to defoliation	101	115	129
Planting to 1 <sup>st</sup> harvest	122	136	150
In-ground curing	21	21	21
<i>Days after 1<sup>st</sup> Harvest</i>			
Grading	7	7	7
Cool store	7	7	7
Planting to 2 <sup>nd</sup> harvest	171	171	171
In-ground curing	70	56	31
<i>Days after 2<sup>nd</sup> Harvest</i>			
Grading	21	21	21
Cool store	7	7	7
<b>Planting 3</b>	<b>9 January 2004</b>		
	<b>1 (15.04.04)</b>	<b>2 (29.04.04)</b>	<b>3 (13.05.04)</b>
Planting to defoliation	97	111	125
Planting to 1 <sup>st</sup> harvest	118	132	146
In-ground curing	21	21	21
<i>Days after 1<sup>st</sup> Harvest</i>			
Grading Delay	7	7	7
Cool store	7	7	7
Planting to 2 <sup>nd</sup> harvest	146	146	146
In-ground curing	49	35	0
<i>Days after 2<sup>nd</sup> Harvest</i>			
Grading	25	25	25
Cool store	3	3	3

Data from an automatic meteorological station about 500m from the experimental site was collected. The solar radiation ( $\text{MJ m}^{-2}$ ) was summed from the collected data over the growing period when foliage was present. Temperature detectors (Tiny-tags) were installed at set depth in plantings one and three to obtain a measure of soil temperature fluctuations during the growing periods. The planting one detector was removed at the first tuber harvest 119 days after planting. The second detector remained in the soil till the final harvest of all the Harvest 2 treatments. Both detectors registered the temperature hourly allowing the recording of the maximum and minimum temperature for each day. This data was used to calculate the DD based on the daily mean and using either a 0 or 4°C base temperature over the whole growing and storage period.

Within each planting, an area was set aside for the weekly harvest of three plants commencing two weeks prior to the first defoliation and concluded with the final defoliation of each planting. The following attributes were recorded: stem number, stem weight, stem length, stem node number, green and dead leaf number and weight, and below soil level: stem length and node number, and finally the number and weight of individual tubers.

#### ASSESSMENT OF TUBER SUGAR CONTENT

Ten tubers from each treatment at each sampling date were randomly sampled from the total harvested population and immediately frozen. These tubers were used for assessment of tuber sugar content for tuber chemical maturity monitoring (Pritchard, 2002). Soluble sugars were extracted using 80% ethanol from pooled tissue of 10 tuber samples for each treatment and sample date. Tissue samples were taken from as close to the centre of the potato tuber as practical. Samples were either taken using a cylindrical coring tool approximately 1cm in diameter or using a central chip cut using a lever action chip cutting grid (T336), cutting in the longitudinal direction. Roughly 4cm of the centre most tissue was then placed in an individually labeled plastic tube and weighed. The tubes were then placed in a Dynavac FD16 Vacuum freeze-

drying dehydrator unit for 3 days. Once dehydrated, the sample and plastic tube masses were recorded to determine tissue dry weight and moisture content. Samples were then stored with lids on at -20°C until further processing.

Dehydrated potato tissue samples were ground using a blunt metal rod, inside the plastic tubes, to break down the cellular structure. The extraction of sugars was based on the method of Lambrechts *et al.* (1994) with minor modifications. 0.1g of each sample was weighed out into individually labeled plastic tubes with the exact weight recorded to 4 decimal places. 2 ml of 80% ethanol was then pipetted into each tube and the tubes placed in a water bath at 60°C for 1 hour. Samples were then centrifuged at 3000rpm in a Beckman Coulter Avanti™ J-30I centrifuge for 10 minutes at 18-22°C. The supernatant was then decanted into glass vials. A further 2 ml of 80% ethanol was then added to the sample and the procedure repeated twice more to yield approximately 6 ml of decanted supernatant. The extract was then stored in the refrigerator until further processing.

The extract solutions were dried down (ethanol evaporated) using a speed vac concentrator (SVC200H Savant). Solutions were then pushed gradually through 45µm nylon filters and Sep-Pak plus CM silica based weak cation exchange cartridges (Waters Wat020550) in order to separate sugars from other compounds in the samples. The solutions were then made up to 2ml with deionised water and trehalose added as an internal standard.

Samples were analysed at the School of Pharmacy, University of Tasmania using HPLC to determine sucrose, glucose and fructose concentrations. Samples were injected into the Waters Alliance 2690 HPLC, equipped with a CarboPac PA1 column (4 x 250mm) and an Alltech C18 guard column preceding the previous one. Sugars were eluted as described in Lambrechts *et al.* (1994), monitored by pulsed amperometry and identified and quantified by comparison with elution profiles of metabolite standards. The sample sugar concentrations in ppm were then converted back to grams per kilogram fresh weight.

#### ASSESSMENT OF TUBER SPROUTING INDEX DURING STORAGE

Following harvest and curing of the seed crop treatments, tubers were size graded and stored. Seed tubers in the 40-65g size class were used to assess changes in sprouting capacity during the storage period. At monthly intervals, 10 tubers from each treatment were taken from cold storage, placed in polystyrene boxes and covered with moistened sand. The tubers were incubated at 15°C for 4 weeks and then assessed for sprout development. The number of sprouts, weight of the largest sprout, total weight of sprouts and weight of the tubers were recorded. Sprouting index was calculated as the percentage by weight of total sprout weight to tuber weight.

#### EVALUATION OF SEED PERFORMANCE

The seed evaluation of this experiment was conducted in the 2004-2005 season at Forthside Vegetable Research Station (41°11'S, 146°20'E) on a Ferrosol soil type (pH 6.2) following pasture and poppies and in the previous two seasons. The trial area was ploughed in the autumn and left fallow prior to planting. Fertiliser (N:P:K, 11:12:19) at 1000 kg ha<sup>-1</sup> was pre-placed in two bands 100mm apart into the open drills prior to planting. The crop was grown according to the current Research Station agronomic practices.

The eighteen seed lots were removed from the cool store for preparation of the sets and allowed to warm from the 4°C storage temperature to ambient conditions prior to handling. An assessment of sprouting was carried out on ten tubers from each treatment and the number of sprouts on each tuber, and tuber and sprout weights were recorded.

Three days before planting tubers from each treatment were closely graded and 200 uniform tubers within the range 110 to 150g were selected. Each tuber was cut along a longitudinal dorso-ventral axis and a mixture of Tato Dust and pine bark applied as a protectant and drying agent. Twenty eight sets were weighed, bagged and tagged for the respective treatments.



Plots consisted of two rows 810 mm apart and 14 sets long at a 300mm spacing (3.9m long) and were separated with three sets of a red-skinned cultivar. Each set was planted flesh side (cut surface) down and covered with about 100mm of soil. A completely randomized block design was used and the planting of each block was allocated to one person. Planting was completed on November 10.

As emergence commenced, Sprayseed (contact herbicide) was applied for weed control. The emergence sequence was recorded for all plots, and the plant population was verified at senescence. Plant height was recorded twice in each row prior to scarifying and, molding was completed just before row closure.

After molding the trial was observed at frequent intervals throughout the growing period. Following senescence and prior to harvest, stem counts were taken either as single plants for replicates one, two, four and five; or as a plot total for blocks three and six. Single plant assessments allowed variability in stem number per plant to be examined, but were time consuming to complete, while the combination of stem number and plant number per plot provided the mean stem number per plant data needed to determine tuber yields per plant and per stem.

Plots were machine harvested, hand bagged and taken to the grading station where tuber number and yields were determined for the following tuber size classes: <80, 81-250, 251-450 and >450g and reject tubers. The twenty largest tubers were cut longitudinally to assess the incidence of hollow heart and brown centre.

## RESULTS

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### SEED PRODUCTION

Planting 1 emerged at 22 DAP, planting 2 at 20 DAP and planting 3 at 21 DAP. At the end of January there was an unseasonable deluge that washed soil from an adjoining property onto Replicate 1, this causing some scouring of the valleys of Replicate 2. The soil drained rapidly and no burst lenticels were found in the following weekly sample harvest area that was at the lowest section of the experiment.

At the final defoliation of the third planting there was no effective remaining foliage, only green/yellow stems of the haulm. The second harvest in all three plantings occurred on the same day. This was necessary because the land was required for the subsequent crop and as a consequence an entire harvest of the second harvest of all of the plants from the third planting date treatment was not possible, but a small area of the plot was set aside and representative samples obtained.

In order to describe the development of the seed crop a series of measurements were taken during production of the seed tubers. The assessment of seed crop development was not statistically analysed as the plots were designed to produce the seed for the main experiment in the following season rather than to analyse the patterns of seed crop growth and development. Seed was produced in two replicate blocks in order to ameliorate any unobserved soil variation, thereby reducing the inherent variability in seed quality. Differences in stem density and fresh weight were observed between planting date and defoliation date treatments.

**Table 2.** *The effects of time of planting and the timing of defoliation on stem density (stems m<sup>-2</sup>) and haulm fresh weight yield (t ha<sup>-1</sup>).*

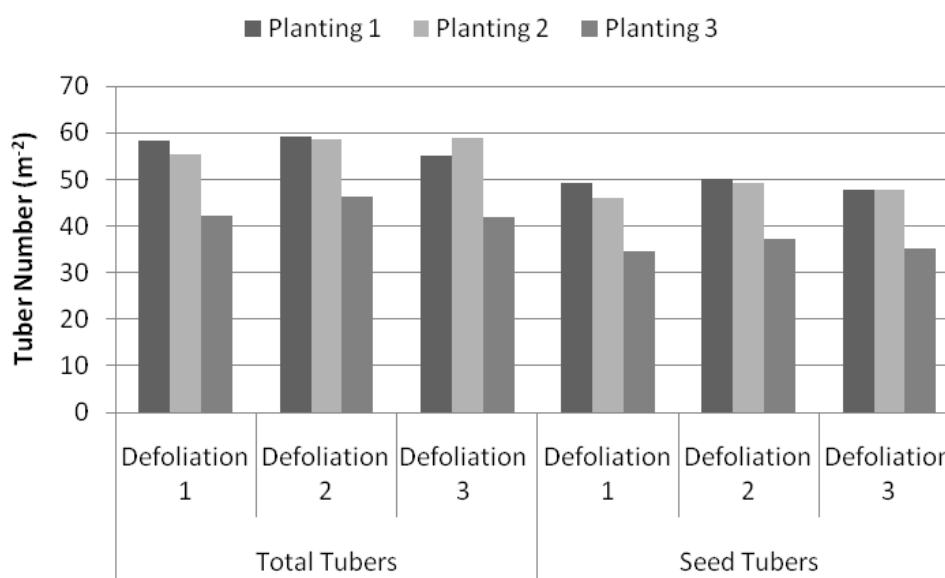
	Stem Number m <sup>-2</sup> and Haulm Yield (t ha <sup>-1</sup> )		
	Planting 1 (20.11.03)	Planting 2 (15.12.03)	Planting 3 (9.01.04)
Stems No. (m <sup>-2</sup> )			
Defoliation 1	18.8	29.6	29.6
Defoliation 2	19.6	28.8	29.8
Defoliation 3	19.1	28.0	31.0
Haulm Fresh Weight (t.ha <sup>-1</sup> )			
Defoliation 1	30.6	29.6	31.5
Defoliation 2	26.3	7.6 <sup>#</sup>	9.7 <sup>#</sup>
Defoliation 3	15.2	4.1 <sup>*</sup>	2.1 <sup>*</sup>

<sup>#</sup> leaves senescing; <sup>\*</sup>senescent stems

Planting one had a lower stem number than the two later plantings that had a similar population and may be associated with the increased age of the seed as planting time was delayed.

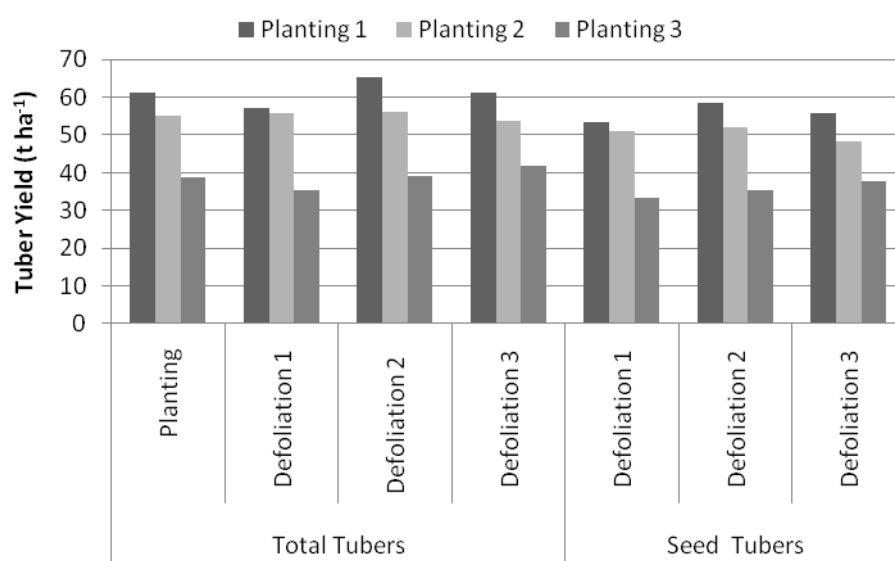
The haulm yield at the initial defoliation was similar for the three planting times despite the stem number differences, indicating higher individual stem weights from the first planting. The haulm senescence was slower in planting one compared to the two later plantings and may have been related to the longer growing season expected from younger seed or the declining day length and temperature conditions experienced by the later planted plots towards the end of the growing season..

Similar tuber numbers were produced in plantings 1 and 2 despite the differences noted in stem density, indicating a higher number of tubers per stem was produced in planting 1. Delaying planting to early January resulted in a 25 per cent reduction in tuber numbers (Figure 1).



**Figure 1.** Seed crop tuber number (m<sup>-2</sup>) for the main effect (three times of planting); Planting 1 (20 November 2003), Planting 2 (15 December 2003) and Planting 3 (9 January 2004) and; the three times of defoliation (split effect) within each planting. Yield is broken down into the total harvest of sound tubers and seed grade tubers.

Plantings 2 and 3 produced lower yields than planting 1 (Figure 2), demonstrating the effect of declining solar radiation levels on crop biomass production in the associated growing periods (Table 3). This was also associated with reduced yield capacity from the lower number of tubers initiated for planting 3.



**Figure 2.** Seed crop tuber yield ( $\text{t ha}^{-1}$ ) for the main effect (three times of planting; 20 November 2003, 15 December 2003 and 9 January 2004), and the three times of defoliation (split effect) within each planting. Yield is broken down into the total harvest of sound tubers and seed grade tubers. Differences were found between the planting time at  $p \leq 0.001$ .

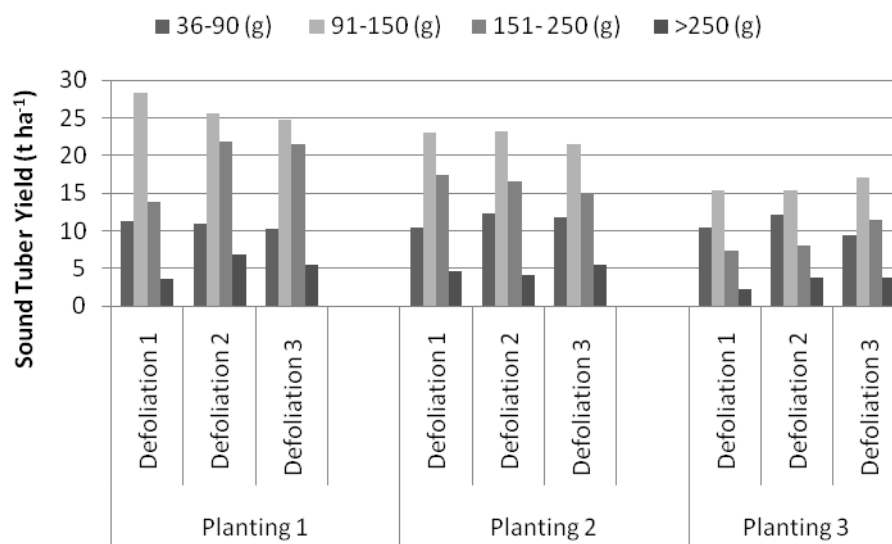
**Table 3.** The accumulated solar radiation ( $\text{MJ m}^{-2}$ ) for the time of defoliation treatments within each of three planting dates (20 November 2003, 15 December 2003 and 9 January 2004) summed from planting to defoliation date of the seed crop.

	Planting 1	Planting 2	Planting 3
Defoliation 1	2767	2528	1919
Defoliation 2	3003	2706	2157
Defoliation 3	3205	2904	2306

Tuber size distribution changed over time, with large changes between defoliation dates observed for planting 1. Few differences were noted between defoliation dates for plantings 2 and 3, reflecting the onset of crop senescence during the defoliation treatments. The seed tuber size grade is shown in Figure 3.

## Figure

3



**Figure 3.** The proportion of tuber yield across tuber size classes for the three times of planting (main effect); 20 November 2003, 15 December 2003 and 9 January 2004), and the three times of defoliation (split effect) within each seed crop planting.

Degree day accumulation differed between the seed production treatments. When calculated from seed crop emergence to ware crop planting date, degree day accumulation based on a 0°C base temperature varied from 2691 for seed from the third planting date, first defoliation and early harvest, to 3500 for all late harvested seed from the first planting date (Table 4).

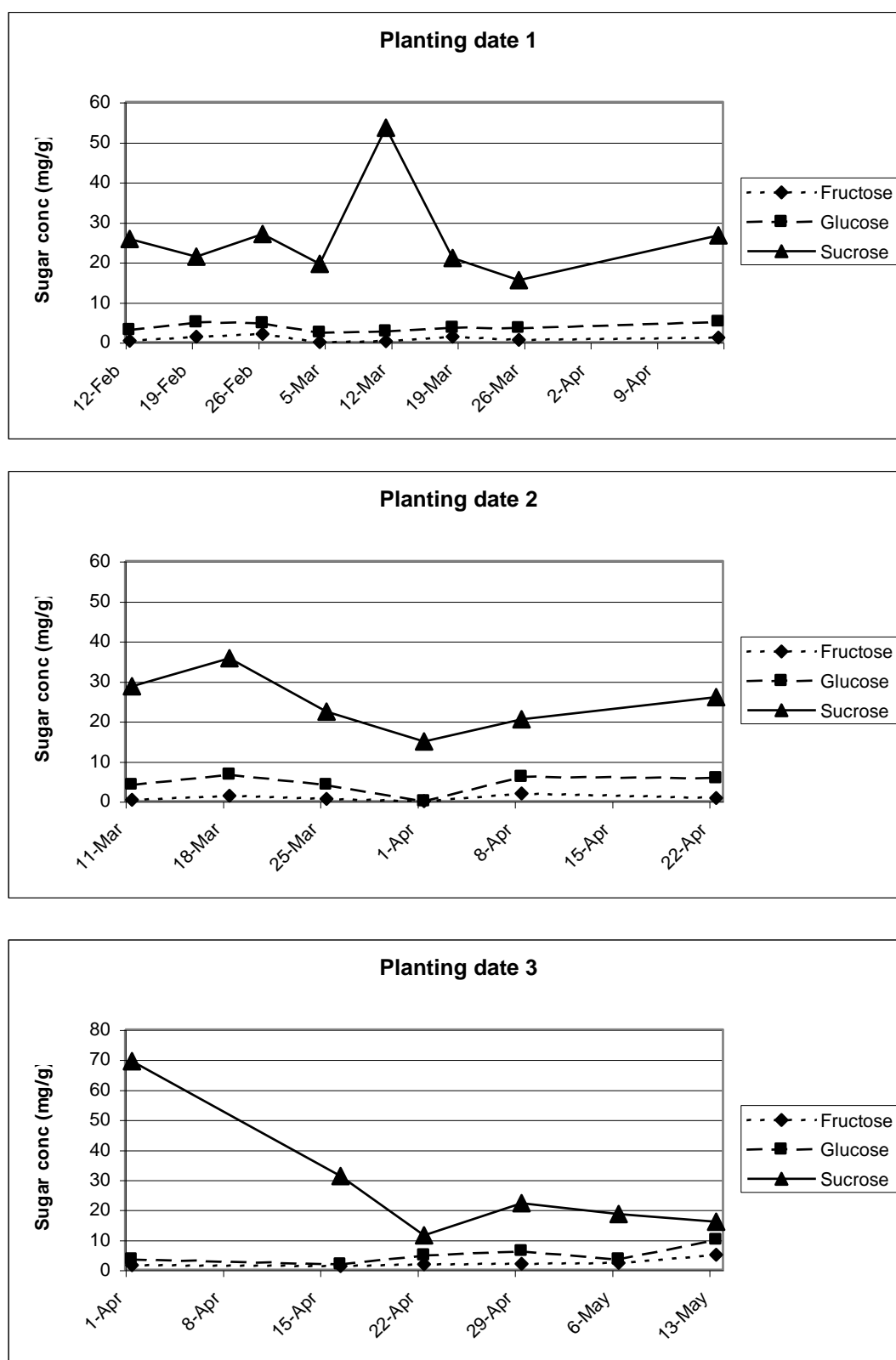
**Table 4.** Seed crop Degree Day accumulation calculated for time of harvest and defoliation treatments within each of three planting times (20 November 2003, 15 December 2003 and 9 January 2004) from planting through to cool storage. Day degrees were calculated using base temperatures of 0 degrees Celsius, and summed using soil temperature from planting to harvest and ambient air temperatures from grading to cool storage.

	Planting 1		Planting 2		Planting 3	
	Har 1	Har 2	Har 1	Har 2	Har 1	Har 2
Defoliation 1	2936	3500	2723	3155	2691	2934
Defoliation 2	3109	3500	2802	3155	2831	2934
Defoliation 3	3183	3500	2886	3155	2860	2934

#### ASSESSMENT OF TUBER SUGAR CONTENT

Tuber sugar concentrations displayed similar trends to those reported in US and Canadian studies (Pritchard, 2002), but the rate of decrease in concentration of sucrose in tubers during later stages of crop development was less than previously reported. There were small differences between planting dates, with later planted material displaying a more pronounced decline in sucrose concentration during late tuber development than crops planted in November and December (Figure 4). The concentration of sugars in tubers varied across the range of defoliation dates used in each of the three planting date treatments, providing tubers at different chemical maturity levels prior to storage and subsequent assessment of seed performance in the following season.

Sucrose concentrations were higher in tubers harvested 10 days after haulm killing compared to tubers from the same haulm killing treatment stored for up to 50 days in the ground prior to harvest. The decrease in tuber sucrose concentration during in-ground storage was matched by an increase in tuber glucose and fructose concentration.



**Figure 4.** Changes in tuber sugar concentrations (mg sugar/g tuber dry weight) during crop development for planting dates 1 (20 Nov 03), 2 (15 Dec 03) and 3 (9 Jan 04).



## PREPLANTING ASSESSMENTS

***Degree of Sprouting***

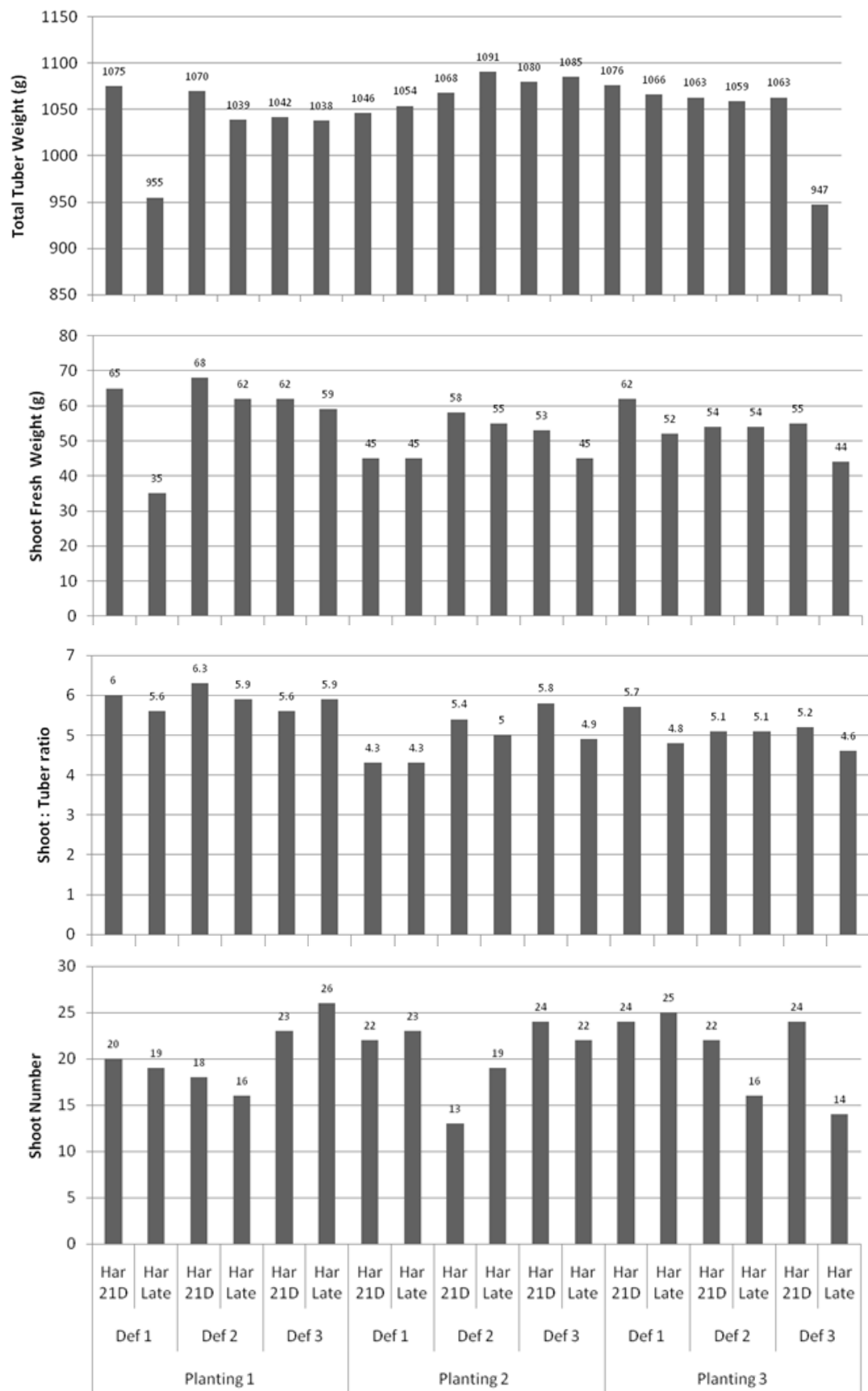
Tubers were taken for assessment 10 days after removal from the cool store. Generally most tubers had broken dormancy and sprout initials were present over the whole tuber. Some tubers had one larger sprout, up to 20mm and rarely were they terminal. The absence and presence of apical dominance is shown in *Figure 5*.



**Figure 5.** *Typical pattern of sprout growth (left) and apically dominant growth (right).*

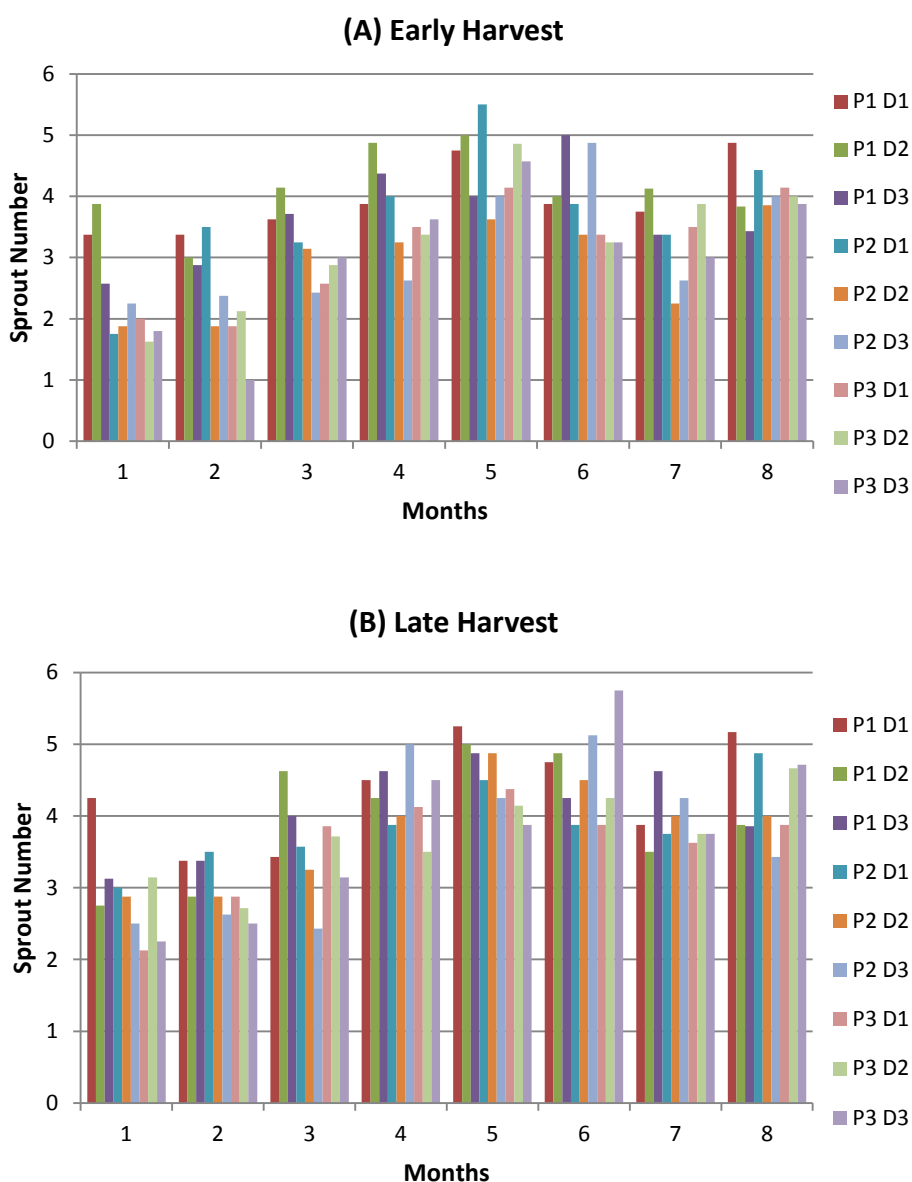
Sprout growth prior to planting was assessed on a subsample of tubers from each seed production treatment (Figure 6). Tuber weight was recorded and sprouts were removed from each individual tuber and sprout number and weight recorded. The sprouting index (ratio between sprout weight and tuber weight, expressed as a percentage) was calculated for all treatments and ranged from 4.3 to 6.3; no consistent trends with planting date, defoliation date or harvest date treatments were noted.

**Figure 6** [next page]. *Seed sprouting assessments after storage and prior to ware crop planting as measured by (a) Tuber weight (g), (b) shoot fresh weight (g), (c) shoot to tuber ratio(% wet wt) and (d) shoot number for all treatment combinations of planting time (main effect), time of defoliation (split effect) and harvest time (split-split effect).*



### SPROUTING INDEX

Assessment of sprouting capacity of small, whole tubers from all treatments during storage produced results demonstrating the characteristic sprouting patterns associated with tuber physiological aging. Sprout number per tuber increased during storage before declining after extended storage time (Figure 7A&B).

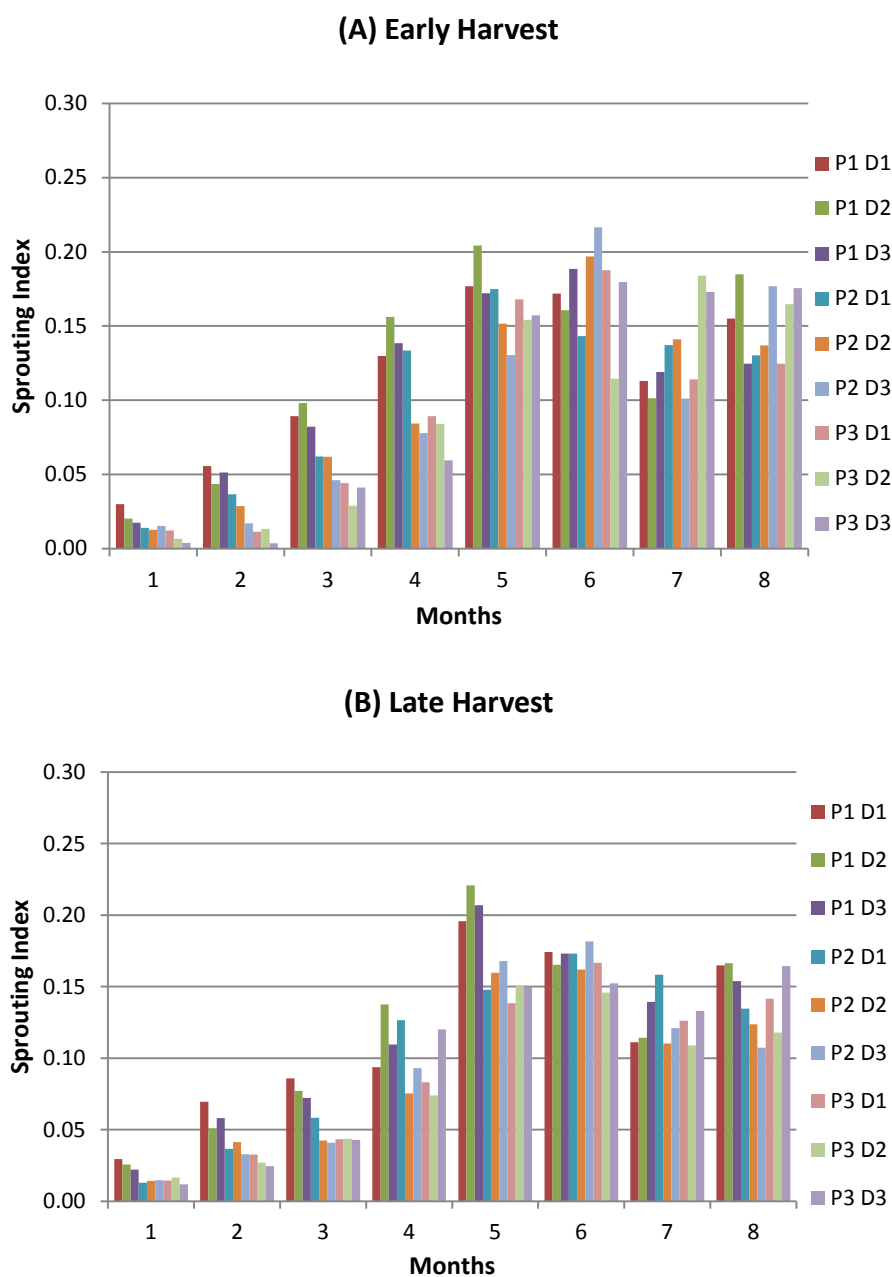


**Figure 7 (A&B).** Mean sprout number per tuber ( $n=10$ ) for all planting date (P1, P2, P3) and defoliation date (D1, D2, D3) treatments for (A) early, and (B) late harvested seed. Assessment commenced on 1 August 2004 and proceeded on a monthly basis.

A trend towards higher sprout numbers in seed from the first planting date and from the late harvest treatments was noted. Seed from planting date 1 consistently produced higher sprout numbers than seed from the later planting dates and the peak in sprout numbers coincided for all treatments at the fifth or sixth sampling date. This suggests that the higher sprout number for seed from the first planting date was not simply a reflection of the older age of these tubers in comparison to those from the later planting dates.

The tuber sprouting capacity, calculated by sprout weight as a proportion of tuber weight, displayed a similar pattern of increase, peak and decline (Figure 8). No clear defoliate date treatment trends were evident in the sprouting index data. Again, seed produced from the first planting date had the highest sprouting index at most sampling dates for both early and late harvested seed.

Sampling date 4 corresponded approximately to the field planting date of the seed performance assessment trial. Seed from the first planting date was displaying the highest sprouting index at the point, and early harvested seed from the first planting date tended to have a higher sprouting index than late harvested seed. This trend was similar to that observed in the assessment of sprout growth on tubers prior to planting of the trial (Figure 6).



**Figure 8.** Mean ( $n=10$ ) sprouting index (sprout wt/tuber wt) for all planting date (P1, P2, P3) and defoliation date (D1, D2, D3) treatments for (A) early and, (B) late harvested seed. Assessment commenced on 1 August 2004 and proceeded on a monthly basis.

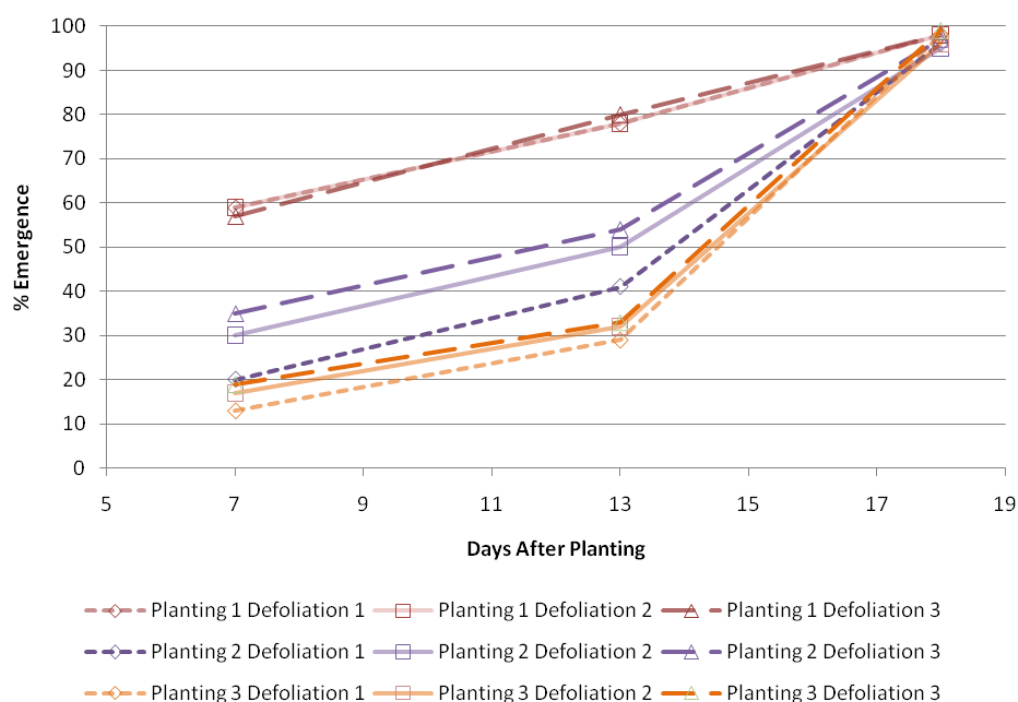
### SET SIZE

The mean set weight varied between treatments from 59.6 to 62.7g and the overall mean set weight was 61.9g. Variability in set weight within treatments was small, with the coefficient of variation ranging from 1-12%. Uniformity in set weight within and between treatments was sufficient to avoid any seed size effects confounding the seed performance assessment.

## **SEED PERFORMANCE IN THE FOLLOWING WARE CROP**

### EMERGENCE

Significant differences in emergence rate were noted between treatments. No significant differences between early and late harvested seed were found, so data from the two harvest time treatments were pooled in analysis of defoliation time and planting date effects. Seed from Planting 1 emerged earlier than the two later plantings (Figure 9). The process was well advanced by the following day and essentially completed six days later, 13 days after planting. When stems were counted at full senescence, 28 plants were present in all but two plots of the whole experiment. In four of the six replicates individual plant stems were recorded.



**Figure 9.** Emergence (%) from the same day planting of the ware crop using seed produced under different planting and defoliation date treatment combinations. Planting times are distinguished by colour, while line patterns indicate the timing of seed crop defoliation prior to harvest.

#### STEMS PER PLANT

Mean stem number from seed generated from the first planting date (20 Nov 03) treatment the previous season was significantly ( $p < 0.01$ ) higher than stem number produced by seed for the two later planting dates (Table 5). Early harvest tended to result in seed that produced higher stem numbers than late harvest for each planting date, and the difference across all defoliation date treatments for the harvest time effect was significant ( $p < 0.05$ ). Differences in stem number with defoliation date treatments were noted but these were not statistically significant and no consistent trends across the three planting dates were found.

**Table 5.** Stem production (stems plant<sup>-1</sup>) from a ware crop planting using tubers using seed sets produced under a factorial treatment combination of three planting times (20 November 2003, 15 December 2003 and 9 January 2004), two times of harvest and three times of defoliation. Data is presented as treatment and factor means to allow for interpretation of the split-split plot statistics. Statistical significance from the ANOVA is presented at the bottom of the table; \* $p=0.05$ , \*\* $p=0.01$ , \*\*\* $p=0.001$ , NS=not significant.

Planting Time		P1		P2		P3	
Defoliation Time		Harvest Time					
		1	2	1	2	1	2
	D1	3.43	3.20	2.95	2.74	2.83	2.53
	D2	3.68	3.32	2.81	2.75	2.70	2.81
	D3	3.27	3.10	2.91	2.73	2.78	2.71

Factor Means						
Planting	P1	3.33	P2	2.81	P3	2.73
Defoliation	D1	2.95	D2	3.01	D3	2.92
Harvest	H1	3.04	H 2	2.88		

ANOVA	Sig. (p)		Sig. (p)		Sig. (p)
Planting	***	Planting x Defoliation	NS	Planting x Defoliation x Harvest	NS
Defoliation	NS	Planting x Harvest	NS		
Harvest	**	Defoliation x Harvest	NS		

As stem number per plant was higher, the stem population per unit area was significantly higher for seed produced from planting date 1 compared to seed from planting dates 2 and 3. Stem density across all treatments varied from 11 to 14.4 stems m<sup>-2</sup>, which placed all treatments in the zone of 9 to 15 stems m<sup>-2</sup> considered ideal for processing crops.

#### EFFECTS ON TUBER NUMBER

Small but significant differences in the number of tubers per plant were found between treatments (Table 6). Seed produced from the first planting date (20 Nov 03) resulted in plants that produced a higher number of tubers



than seed produced from the second and third planting dates ( $p < 0.01$ ). The planting date effect was particularly obvious for seed harvested from the first defoliation date treatment, and was not present for seed harvested from the final defoliation treatment. Harvest time had no significant effect on tubers per plant.

**Table 6.** Tuber production  $\text{plant}^{-1}$  from a ware crop planting using tubers using seed sets produced under a factorial treatment combination of three planting times (20 November 2003, 15 December 2003 and 9 January 2004), two times of harvest and three times of defoliation. Data is presented as treatment interaction and factor means to allow for interpretation of the split-split plot statistics. Statistical significance from the ANOVA is presented at the bottom of the table; \* $p = 0.05$ , \*\* $p = 0.01$ , \*\*\* $p = 0.001$ , NS=not significant.

Planting Time x Defoliation time Interaction						
		Planting Time				
		P1	P2	P3		
Defoliation Time	D1	11.13	10.37	9.85		
	D2	10.92	10.06	10.30		
	D3	10.24	10.21	10.36		
Factor Means						
Planting	P1	10.8	P2	10.2	P3	10.2
Defoliation	D1	10.5	D2	10.4	D3	10.3
Harvest	H1	10.5	H 2	10.3		

ANOVA	Sig. (p)		Sig. (p)		Sig. (p)
Planting	**	Planting x Defoliation	*	Planting x Defoliation x Harvest	NS
Defoliation	NS	Planting x Harvest	NS		
Harvest	NS	Defoliation x Harvest	NS		

Significant ( $p < 0.01$ ) differences in tuber number ( $\text{tubers m}^{-2}$ ) were found between seed produced from the three planting dates. The multiplier effect at a constant set number combined with the tubers per plant produced results similar to those in Table 7; and consequently the total number of tubers  $\text{m}^{-2}$ ,

followed the pattern of tuber per set interaction. The earliest planting had the highest number of tubers. As with stem number, tuber number, was highest for the first planting date and decreased in crops grown from the two later planting dates.

The increase in tuber yield from seed produced from the first planting date treatment was due to the increase in stem number per plant, with significantly ( $p < 0.001$ ) fewer tubers per stem produced in crops grown from seed from the first planting date (Table 7). No significant defoliation date or harvest date effects were found.

**Table 7.** Tuber  $\text{stem}^{-1}$  from a ware crop planting using seed sets produced under a factorial treatment combination of three planting times (20 November 2003, 15 December 2003 and 9 January 2004), two times of harvest and three times of defoliation. Data is presented as treatment interaction and factor means to allow for interpretation of the split-split plot statistics. Statistical significance from the ANOVA is presented at the bottom of the table; \* $p=0.05$ , \*\* $p=0.01$ , \*\*\* $p=0.001$ , NS=not significant.

Planting Time x Defoliation time Interaction						
		Planting Time				
		P1	P2	P3		
Defoliation Time	D1	3.43	3.65	3.72		
	D2	3.15	3.65	3.76		
	D3	3.25	3.63	3.79		
Factor Means						
Planting	P1	3.28	P2	3.64	P3	3.76
Defoliation	D1	3.60	D2	3.52	D3	3.55
Harvest	H1	3.50	H2	3.61		
ANOVA	Sig. (p)			Sig. (p)		
Planting	***	Planting x Defoliation	*	Planting x Defoliation x Harvest	NS	
Defoliation	NS	Planting x Harvest	NS			
Harvest	NS	Defoliation x Harvest	NS			

## TUBER YIELDS

The yield response was similar to stem number and tuber number responses to the treatments. Significant ( $p < 0.001$ ) differences in total tuber yields were found between the seed planting date treatments. No significant defoliation date or harvest date effects were found.

**Table 8.** Ware crop yield ( $t\ ha^{-1}$ ) using seed sets produced under a factorial treatment combination of three planting times (20 November 2003, 15 December 2003 and 9 January 2004), two times of harvest and three times of defoliation. Data is presented as treatment and factor means to allow for interpretation of the split-split plot statistics. Statistical significance from the ANOVA is presented at the bottom of the table; \* $p=0.05$ , \*\* $p=0.01$ , \*\*\* $p=0.001$ , NS=not significant.

Planting Time		P1		P2		P3	
Defoliation Time		Harvest Time					
		1	2	1	2	1	2
	D1	75.6	76.7	73.9	74.0	70.0	68.1
	D2	73.0	74.6	73.0	71.3	69.1	71.2
	D3	74.6	72.1	73.2	70.4	68.8	72.0

Factor Means						
Planting	P1	74.42	P2	72.62	P3	69.95
Defoliation	D1	73.22	D2	72.13	D3	71.83
Harvest	H1	72.33	H 2	72.33		

ANOVA	Sig. (p)		Sig. (p)		Sig. (p)
Planting	***	Planting x Defoliation	NS	Planting x Defoliation x Harvest	NS
Defoliation	NS	Planting x Harvest	NS		
Harvest	NS	Defoliation x Harvest	NS		

The commercial yields are affected by the quantity of discard tubers and in this evaluation composed of under-size, waste (predominantly second growth) and cracked tubers. In this instance, under size, tubers constituted 4.5% of the total yield. The yield of ware (processable) tubers (Table 9) was significantly higher ( $p < 0.01$ ) from the first planting date seed production treatment. A significant

( $p < 0.01$ ) harvest date effect on processing yield was also found, with a higher yield from seed produced from earlier compared to later harvested treatments. No significant defoliation date effect was found.

**Table 9.** Processable ware crop yield ( $t\ ha^{-1}$ ) using seed sets produced under a factorial treatment combination of three planting times (20 November 2003, 15 December 2003 and 9 January 2004), two times of harvest and three times of defoliation. Data is presented as treatment and factor means to allow for interpretation of the split-split plot statistics. Statistical significance from the ANOVA is presented at the bottom of the table; \* $p=0.05$ , \*\* $p=0.01$ , \*\*\* $p=0.001$ , NS=not significant.

Planting Time		P1		P2		P3	
		Harvest Time					
		1	2	1	2	1	2
Defoliation Time	D1	63.9	66.4	60.5	50.3	53.9	52.0
	D2	63.4	59.07	58.5	53.8	55.4	52.7
	D3	60.4	58.09	56.1	53.9	56.3	54.1

Factor Means						
Planting	P1	61.9	P2	55.53	P3	54.0
Defoliation	D1	57.8	D2	57.2	D3	56.5
Harvest	H1	58.72	H 2	55.61		

ANOVA	Sig. (p)		Sig. (p)		Sig. (p)
Planting	***	Planting x Defoliation	NS	Planting x Defoliation x Harvest	NS
Defoliation	NS	Planting x Harvest	NS		
Harvest	**	Defoliation x Harvest	NS		

The yield of waste tubers was significantly ( $p < 0.001$ ) higher from seed produced from the later two planting dates compared to the first date (Table 10). A significant ( $p < 0.001$ ) harvest date effect was also found, but no significant defoliation treatment effect.

**Table 10.** Yield of waste material ( $t\ ha^{-1}$ ) using seed sets produced under a factorial treatment combination of three planting times (20 November 2003, 15 December 2003 and 9 January 2004), two times of harvest and three times of defoliation. Data is presented as treatment and factor means to allow for interpretation of the split-split plot statistics. Statistical significance from the ANOVA is presented at the bottom of the table; \* $p=0.05$ , \*\* $p=0.01$ , \*\*\* $p=0.001$ , NS=not significant.

Planting Time		P1		P2		P3	
Defoliation Time		Harvest Time					
		1	2	1	2	1	2
	D1	7.4	7.3	9.7	20.2	12.7	13.1
	D2	5.8	12.0	11.2	14.5	10.6	15.7
	D3	11.2	10.9	13.5	12.7	9.3	14.6

$P=0.05$ , LSD = 5.69 t/ha

Factor Means						
Planting	P1	9.1	P2	13.8	P3	12.7
Defoliation	D1	11.8	D2	11.6	D3	12.2
Harvest	H1	10.2	H 2	13.5		

ANOVA	Sig. (p)		Sig. (p)		Sig. (p)
Planting	**	Planting x Defoliation	NS	Planting x Defoliation x Harvest	NS
Defoliation	NS	Planting x Harvest	NS		
Harvest	***	Defoliation x Harvest	NS		

The occurrence of waste tubers for **Russet Burbank** is frequently associated with a range of second growth conditions that is often attributed to high temperatures and/or soil water deficits. The problem has been observed frequently in production of processing crops in Tasmania. Whilst the stress conditions may be causal on some occasions, there have been situations where this is not so and no plausible explanation has been forthcoming. In this experiment there were highly significant increases in discard tuber associated with seed produced from the delayed planting and harvest time treatments, suggesting that seed production factors may play a role in predisposing plants

grown from that seed to tuber second growth development in the following season.

### **INDICATORS OF SEED PERFORMANCE**

Analysis of relationships between measures of seed performance and potential indicators of seed physiological quality revealed that none of the indicators adequately reflected actual measures of seed performance. Sprouting index of seed at the time of field planting was a reasonably good indicator of stem number per plant, but not the other seed performance characteristics (Table 11). Degree days, calculated from the date of first defoliation in the seed production trial, was not a useful indicator of seed performance in the following ware crop.

Correlative analysis revealed no relationships between sugar concentrations in the tubers at the point of harvest and performance of the seed the following season. The range of yield between treatments was low, but larger variation in stem number per plant between treatments was recorded. There was an overall trend of increased stem number per plant with early harvest compared to late harvest (in-ground storage), and for higher sucrose concentrations and lower glucose and fructose concentrations with early compared to late harvest, but the relationship was not statistically significant when analysed over all data. It was therefore concluded that, while the sugar profiles at harvest may influence the subsequent rate of aging during storage and potential for sprouting the following season, the relationship was not strong enough to make chemical maturity monitoring a reliable indicator of potential seed performance.

**Table 11.** A summary seed performance characteristics against the potential indicators of seed quality measured in this study. The seed used was produced under a factorial treatment combination of three planting times (20 November 2003, 15 December 2003 and 9 January 2004), two times of harvest and three times of defoliation. DAP = days after planting.

Treatments			Seed Performance				Indicators				
Planting date	Defoliation date (DAP)	Harvest (DAP)	Yield (t/ha)	Tubers Plant <sup>-1</sup>	Stems Plant <sup>-1</sup>	% Emerged (13 DAP)	Degree days	Sprouting index	Sucrose	Glucose	Fructose
30 Nov	98	119	75.63	11.29	3.43	73	2936	0.177	53.6	0.2	2.7
30 Nov	98	196	76.67	10.98	3.20	80	3500	0.196	12	11.3	20.7
30 Nov	112	133	72.99	11.11	3.68	84	3109	0.204	15.5	0.6	3.5
30 Nov	112	196	74.63	10.73	3.32	76	3500	0.221	4.7	6.9	11.5
30 Nov	126	147	74.55	10.21	3.27	79	3183	0.172	26.7	1.1	5.1
30 Nov	126	196	72.06	10.26	3.10	80	3500	0.207	13.9	7.5	14.7
15 Dec	101	122	73.88	10.94	2.95	43	2723	0.175	17.2	2.6	5.6
15 Dec	101	171	73.95	9.79	2.74	40	3155	0.148	12.5	6.8	13.9
15 Dec	115	136	72.96	9.88	2.81	51	2802	0.152	10.7	0.8	3.3
15 Dec	115	171	71.32	10.23	2.75	48	3155	0.160	13.5	6.2	11.7
15 Dec	129	150	73.20	10.64	2.91	51	2886	0.130	14.1	0.6	2.4
15 Dec	129	171	70.42	9.78	2.73	56	3155	0.168	14.8	0.8	3.7
9 Jan	97	118	69.86	9.85	2.83	35	2691	0.168	54.2	0.8	6.4
9 Jan	97	146	68.14	9.86	2.53	24	2934	0.138	6.1	7.6	16.1
9 Jan	111	132	69.11	10.02	2.70	29	2831	0.154	28.5	2.4	8.4
9 Jan	111	146	71.79	10.58	2.81	33	2934	0.151	4.6	7.9	15.2
9 Jan	125	146	68.80	10.26	2.78	39	2934	0.150	12.1	9.3	16.7
9 Jan	125	146	71.97	10.46	2.71	24	2934	0.150	12.1	9.3	16.7

## DISCUSSION

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The potential for seed production practices to influence the performance of seed tubers is widely acknowledged, but the complexity of interactions between internal physiological processes and external climatic and management factors has prevented consistent demonstration of climatic or management factor effects. Variable results have previously been reported in trials examining the effect of timing of haulm destruction (Murphy *et al.* 1967; Maas 1971; Chase, 1974; Wurr 1978b; Caldiz *et al.*, 1985; Panelo and Caldiz, 1989) and planting and harvest date (Perenec and Madec, 1980; Jones and Allen, 1983; Allen *et al.*, 1991). The results of the experiment presented in this chapter further highlight the difficulty in demonstrating effects of crop management practices on seed performance. Time of planting was shown to have a significant effect on seed performance, while defoliation date and harvest time treatments in the first planting date influenced seed performance but these treatments had no effect in later planting dates. In contrast, Caldiz *et al.* (1985) found no significant differences for ware yields produced from two seed-planting dates over three successive seasons, suggesting that any planting date effect may be influenced by production region and/or cultivar.

The seed performance results obtained from the experiment presented in this chapter confirmed that seed crop management practices may have a significant influence on the physiological status and therefore performance of seed tubers, but unlike the experiments presented in the previous chapter, the timing of defoliation treatments had no significant effect on most aspects of seed performance. No differences between defoliation dates were found in stem number and tubers per stem for the early harvested treatments, but significant differences in commercial yield were identified. This finding supported the conclusion that small but commercially significant increases in processing yield could be generated by using seed from early to mid-season planted seed crops that had been defoliated and harvested prior to full crop senescence. Extended periods of in-ground storage prior to harvest eliminated this effect, and late



planting of the seed crop also produced lower quality seed irrespective of the defoliation or harvest-date treatments.

The effect of harvest date of seed following defoliation on stem number per seed tuber in the following season was similar to that noted in the previous trials: there were greater stem numbers from seed harvested and placed in cold storage shortly after defoliation than for seed exposed to extended durations of in ground storage prior to cold storage. Differences in tuber physiology associated with harvesting without in-ground curing compared to in-ground storage after haulm senescence have previously been noted (Knowles, *et al.* 2002) and linked to storage performance for processing, but the effect on seed performance in this project has not been documented previously.

The performance of the seed tubers generated from the planting date, defoliation date and harvest date treatments could not be adequately explained by differences in day degrees accumulated during or after crop harvest. Similarly, the sprouting index, assessed under controlled environment conditions, did not adequately describe the sprouting pattern and seed performance observed under field conditions. Tuber chemical maturity when measured as sugar concentrations was also not a useful indicator of seed performance. Differences in the patterns of sugar metabolism in tubers were noted between planting date treatments, demonstrating that physiology of tubers varies with production conditions and may therefore be influenced to different degrees by management practices according to the status of the tuber at the time of application.

Early defoliation tended to produce tubers that produced higher stem numbers and emerged more rapidly, developmental patterns consistent with the behavior of physiologically older tubers. The effect was, however, not observed when tubers received an extended period of in-ground storage prior to harvest and cold storage despite the accumulation of higher degree days. Stress late in crop development has been proposed to age seed tubers, so the behaviour of in ground stored seed following stress suggests that recovery from stress may be

possible during seed development even when stems are removed.

The capacity for crop management treatments to modify tuber physiological quality independent of day degree effects was consistent with the findings of the previous chapters. While temperature has a significant effect on the rate of physiological changes occurring in tubers during storage, more complex changes are occurring prior to harvest. These changes determine the physiological status at harvest and may predispose the tubers to variations in the pattern of aging after harvest. The physiological basis for the effects of preharvest treatments on aging remains an area requiring further investigation.

# CHAPTER 7

## GENERAL DISCUSSION

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The theme of the studies reported in this thesis was to provide a further insight into the intergenerational effects created in seed potato tubers by various agronomic aspects of seed production. Treatments in the study included: varying times of planting, defoliation, harvest, the effects of nitrogen, phosphorus nutrition, seed tuber origin and the effect of seed dressings. The response to each variously prepared seed lot was evaluated in the subsequent ware crop environment at a single site. Seed production practices were shown to significantly affect seed performance, but no single treatment produced a consistent, significant seed performance response. It was concluded that the physiological status of tubers varies with production conditions and crop stage of development, with the potential for treatments to modify the physiological status determined by the actual status at the time of treatment application as well as the nature of the treatment.

Certified seed is expected to meet prescribed pathological and physical attributes, with crop management practices including, location and timing of production in many cases specified for seed crop production (Struik and Weirsema, 1999). The physiological quality aspects of seed production associated with these crop management practices would appear to have been considered of lesser importance than the prescribed pathological and physical attributes associated with certification. Prior to this study, little published scientific evidence of the impact of seed crop management practices on seed performance in the following season existed. This was despite the widespread belief that cultural conditions under which seed tubers are produced will influence seed performance (Burton, 1966; Wurr, 1978a; Struik and Weirsema,

1999). Time of planting and harvest may be prescribed for seed production to manage the risk of virus infection (Panelo and Caldiz, 1989) and were also shown in this study to have effects on the prospective ware crop yield. In addition, tuber number of the ware crop was affected by various defoliation treatments, even when those treatments did not alter the total yield.

Management of crops to achieve prescribed tuber pathological and physical attributes for certification may therefore also have previously unrecognized impacts on seed tuber physiological quality. Varying the rates of nitrogen and phosphorus, although important in seed production *per se*, did not affect the performance in the ensuing ware crop. Similarly, the selection of tubers from a diverse or uniform size grade population had no effect on the performance of the ware crop. To explain the almost mythological status of seed quality or productiveness each of the variables investigated is often included in lists incorporating a range of disparate factors. Generally, in the potato industry awareness of seed quality, often measured or referred to as P-age, and the potential to alter seed performance exists. However to consistently manipulate seed quality, apart from storage temperature and duration, the knowledge of factors affecting physiological quality is insufficient to formulate effective crop management strategies.

The study demonstrated the difficulty in developing seed crop management strategies to consistently produce seed tubers of the highest physiological quality or productivity potential. It showed this was due to the lack of consistency in responses obtained from planting time, defoliation timing and harvest date treatments. In most but not all experiments time of planting was shown to have a significant effect on seed performance, while defoliation date and harvest time treatments produced significant seed performance effects in some but not all experiments. This finding was consistent with previous reports of the effect of timing of haulm destruction (Murphy *et al.*, 1967; Maas 1971; Chase, 1974; Wurr, 1978b; Caldiz *et al.*, 1985; Panelo and Caldiz, 1989); and planting and harvest date (Perenec and Madec, 1980; Jones and Allen, 1983; Allen *et al.*, 1991) on seed productivity. Sufficient evidence was generated to

support the conclusion that, under Tasmanian production conditions, planting seed crops early in the season and defoliating prior to full crop maturity, along with harvesting shortly after defoliation, will increase the likelihood of producing seed tubers with higher productivity in the following season.

While the variation in seed performance with different planting date treatments obtained within individual experiments may be explained by differences in either chronological or thermal (physiological) age, the differences in response between experiments, as well as the variable responses noted in the defoliation date and harvest date treatments, cannot be explained so easily. Previous studies of specific seed crop management practices, such as the effect of early haulm destruction (Hutchinson, 1978a; Panelo and Caldiz, 1989), have also documented either no treatment effect or an improvement in seed performance. Differences in cultivars used, as well as climatic and cultural conditions under which trials were conducted, may account for variability in responses. Storage temperature requirements have been shown to vary between cultivars and weather conditions prevailing during production of tubers influences storage temperature requirements for different cultivars (Fischnich and Krug, 1963). An alternative hypothesis to explain the variation in responses is that the combination of the stage of development or physiological status of the plant at the time of treatment application and the nature of the treatment determines the effect on seed physiological status at harvest. Further work testing this theory is required before reliable strategies to produce highest physiological quality seed tubers can be confidently recommended.

Changes in the physiological status of seed tubers were documented in the period between haulm death (defoliation) and harvest. These changes were not consistent with the view of physiological aging as a sequential process, with tubers harvested shortly after defoliation performing in the following season as physiologically older (higher stem number, faster emergence) than tubers harvested from plants defoliated at the same time but left in the ground for an extended period prior to harvest. Harvesting soon after defoliation has

previously been shown to reduce the duration of the dormancy period compared to delayed harvesting after defoliation in the early season cultivar **Arran Banner** (Hutchinson, 1978). It should be noted that this study is the first documented evidence of a significant effect on the key seed performance attributes of emergence speed and stem number in the long season processing cultivar **Russet Burbank**. Stress late in crop development has been proposed to age seed tubers (Bohl *et al.*, 1995) and the aging response noted following early defoliation in this and Hutchinson's (1978a) study, but not others (Murphy *et al.*, 1967; Caldiz, *et al.*, 1985; Panelo and Caldiz, 1989), could be attributed to stress imposed by mechanical removal of haulms during the period of active tuber growth. The behaviour of in-ground stored seed following stress therefore suggests that recovery from stress may be possible during seed development, even when stems are removed. This capacity for recovery may explain differences in seed tuber responses between studies examining effects of early defoliation treatments.

Few studies have examined the biochemical changes occurring in seed tubers during late crop development, particularly under the range of crop management treatments examined in this study; so it is difficult to identify potential physiological processes regulating the growth responses noted in the study. Changes in carbohydrate metabolism have been the most widely studied in tubers as these changes impact on processing quality in French fry and crisp production. Tuber sucrose concentration declines during tuber maturation (Pritchard, 2002), and tubers harvested from newly defoliated plants have been shown to contain significantly higher sucrose concentrations than tubers allowed to cure in the ground between defoliation and harvest (Knowles *et al.*, 2001). These results demonstrate that significant physiological changes can occur during the relatively short period between haulm removal and harvest, consistent with the possibility of recovery from stress responses associated with defoliation. It is interesting to note that in the study of Knowles *et al.* (2001) it was concluded, based on sugar concentrations and respiration rates, that, following two months' storage, tubers harvested at defoliation appeared

physiologically younger than tubers left in the soil to cure prior to harvest. This conclusion varies from the conclusion drawn from direct assessment of tuber performance in the current study, and highlights again the variability in responses documented in the literature.

In this study differences in the patterns of sugar metabolism in tubers were noted, between planting date treatments, demonstrating that physiology of tubers varies with production conditions and may therefore be influenced to different degrees by management practices, according to the status of the tuber at the time of application. However tuber chemical maturity, when measured as sugar concentrations, was not found to be a useful indicator of seed performance. Similarly, the performance of the seed tubers generated from the planting date, defoliation date and harvest date treatments could not be adequately explained by differences in day degrees accumulated during or after crop harvest. While this conclusion appears counter to those of many previous P-age studies documenting the relationship between thermal time and seed performance (e.g. O'Brien *et al.*, 1983), few previous studies have examined the relationship across varying seed production environments and crop management practices. Thermal time appears an adequate indicator of tuber P-age when used in a single seed lot exposed to a range of postharvest storage treatments (Van Loon, 1987; Struik and Wiersema, 1999), but appears inadequate to describe variation in seed performance between production sites or seasons. As an example, in a two season study of physiological aging in eight cultivars, significant year-to-year variation in the rate of aging under standard conditions was noted (Moll, 1994). The apparent capacity of tubers to recover from stress responses associated with defoliation suggests that, prior to storage, changes in the physiological status of tubers may involve processes that are not as temperature dependant as those involved in aging during storage.

As most seed tubers are stored for extended periods of time between seed crop harvest and planting of the ware crop, storage temperature and duration have the greatest influence on the physiological quality of the seed at planting (Struik

and Wiersema, 1999). Temperature is regarded as the most important factor influencing the rate of physiological aging, with the term P-age (indicating status of tuber internal processes, which are influenced by temperature) being used to separate the response from chronological age (time from tuber set or harvest to planting). Temperature management in storage, along with time in storage, is therefore the major method of managing tuber P age. As variability in seed tuber physiological status at harvest has been demonstrated, it is likely that the rate or pattern of aging during storage may be predisposed by the status of the tubers at harvest. Seed quality management strategies based solely on storage management are therefore unlikely to produce consistent results unless seed production practices and environment can deliver tubers of consistent physiological status at harvest. Prediction of seed performance based on assessment of storage factors, such as degree day calculations after harvest, will be inaccurate if variability in seed tuber physiological status at harvest exists.

Indicators of P-age based on seed tuber status prior to planting have been suggested as alternatives to overcome the deficiency in degree day predictions due to variability in tuber physiological status associated with seed production conditions. A range of biochemical indicators (e.g. Van Es and Hartmans, 1987; Caldiz *et al.*, 1996) and pre-planting sprout assessments (e.g. Krijthe, 1962) have been proposed and more recently a practical quantitative measure, the P-age index, combining chronological age and sprouting performance under standardized conditions prior to planting (Caldiz *et al.*, 2001). Incorporation of pre-plant assessment provides a summation of seed crop production and storage effects on seed tuber physiological quality, and therefore an indication of the potential productivity of the seed. Numerous ware crop production environment and management practice factors affect the capacity of the seed to achieve its potential productivity, meaning that strong correlations between pre-plant P-age indicators and ware crop yield are difficult to attain.



Stem number per set, a seed performance attribute expressed early in ware crop development, was found to be affected by the physiological status (sprouting index) of the tubers at planting, while yield was poorly explained by seed status. Stem number has been shown to vary with tuber P-age (Knowles and Botar, 1991); so the response noted in the project is consistent with physiological aging of tubers during production and storage. Tuber number per plant and tuber size distribution are linked to stem density in the crop (Struik and Wiersema, 1999) and variations in these measures of seed performance that would be consistent with differences in seed physiological status were observed. This view of seed performance may, however, be overly simplistic as published evidence (Brown, 2005) suggests that the physiological status of the seed tuber at planting may interact with the planting environment to determine emergence rate and the number of stems per set. Seed performance may therefore be viewed as a function of the biological characteristics of the seed, including physiological status, and the environment in which it is planted.

One aspect of seed performance that has received little research attention but in this study was noted to vary between the seed crop production treatments was the propensity of the ware crops to produce tubers unsuitable for processing. Tubers displaying, in particular, second growth or cracking were more prevalent in ware crops grown from seed produced from the delayed planting and harvest time treatments. It has been noted previously that as P-age increases through increased storage time, the tendency to produce second growth tubers increases (Struik and Wiersema, 1999). The highly significant increases in discard tubers associated with later planted and harvested seed production treatments was consistent with this conclusion, and suggests that seed production factors may play a role in predisposing plants grown from that seed to tuber second growth development in the following season.

The evidence for reduced predisposition to waste tuber production and increased likelihood of producing seed tubers with higher productivity in the following season leads to a recommendation for planting seed crops in

Tasmania early in the season, defoliating prior to full crop maturity and harvesting shortly after defoliation. Based on the results of the study it is, however, not possible to recommend new management practices for seed production in other regions. It was concluded that the effect of seed crop management treatments, such as timing of haulm removal, was influenced by the tuber developmental status at the time of application, and that significant changes in physiological status may occur between imposition of treatments and harvest. Prediction of treatment effects under varying production environments is therefore difficult without further understanding of the physiological basis of the changes in tuber status. This study provides valuable insights into areas where these changes occur, particularly associated with haulm removal and between haulm removal and harvest. The effect of seed production practices on seed physiological quality has been shown to be a complex area that has received little research attention. Clearly with increasing importance being placed on consistently attaining high yields of tubers in narrow size ranges, the capacity to manage seed physiological quality is highly important to the potato industry.

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