Horticulture Innovation Australia

Final Report

New onion protocols to assure viability of European exports.

Dr Jason Dennis
Field Fresh Tasmania

Project Number: VN10001

VN10001

This project has been funded by Horticulture Innovation Australia Limited with co-investment from Field Fresh Tasmania and funds from the Australian Government.

ISBN 0 7341 3603 X

Published and distributed by:
Horticulture Innovation Australia Limited
Level 8, 1 Chifley Square
Sydney NSW 2000
Tel: (02) 8295 2300
Fax: (02) 8295 2399

New onion protocols to assure viability of European exports

HAL Project VN10001

Final Report
31 December 2014

Dennis, JJC *et al*

Field Fresh Tasmania

Auto skinning (photograph by John Congerton)

HAL Project VN10001
New onion protocols to assure viability of European exports

Final Report
31 December 2014

Project Leader

Dr Jason Dennis
Field Fresh Tasmania
ABN 81 078 230 491
349 Forth Road, Devonport, Tasmania 7310
P.O. Box 1283, Devonport, Tasmania 7310
Telephone (03) 64275000
Facsimile (03) 64275001

Project Investigators/Collaborators

Richard Birtill (Field Fresh Tasmania)
John Congerton (Field Fresh Tasmania)
Tim Smallbon (Field Fresh Tasmania)
Melinda Kirkwood (Field Fresh Tasmania)
Dr Alistair Gracie (University of Tasmania)
Dr Mark Boersma (University of Tasmania)

Report Purpose:

The purpose of this report is to detail the outcomes of the four seasons of work carried out to develop an integrated method to measure onion suitability for export to Europe, and to assess new varieties, nutrition programs and curing practices, to restore consistency to field production, regardless of any prevailing unseasonal climatic variations.

Acknowledgements:

This project was funded by voluntary contributions from Field Fresh Tasmania and matched funds from Horticulture Australia Limited. Thanks go to the many Tasmanian Growers that hosted the numerous field trials.

Disclaimer:

Table of Contents

Media Summary

Australian onion exports to Europe are mostly sent in shipping containers fitted with a fan that circulates fresh air through the onions. Exports to Europe depart Australia from late January to early June, arriving from mid March to mid July. The onions have to be robust enough to withstand the wide range of climatic conditions that are experienced during these shipping times from monsoonal downpours in the tropics to 45^{o}C heat in the Middle East.

Most shipments to Europe are re-graded by the customer to remove any onions with skin blemishes or rots, requiring onions to be resilient enough to withstand initial grading in Australia, followed by 2-3 months in the shipping container, then a period of storage in Europe before final grading; it is worth noting that exporters are liable for quality up to this final grading regardless of how customers may store and handle the onions after arrival.

A new approach to variety screening has been developed (involving multiple trials run over multiple years), in combination with a new assessment protocol, to truly understand the strengths and weaknesses of new varieties under the broad range of seasonal growing conditions that industry now faces.

There was an overwhelming failure to detect improvements from fertiliser treatments, suggesting very strongly that the current fertiliser protocols are in almost all cases providing sufficient or even excess nutrients. This poses an interesting research challenge to determine just how much fertiliser application could be reduced without compromising yield or quality.

The influence of field drying practices on skin quality revealed that the greatest impact came from the time field drying was initiated. The time on ground also impacted on skin quality, but to a lesser extent.

This project successfully developed an integrated method to assess new varieties, fertiliser programs and field drying practices, which more accurately measure a crop’s suitability for export to Europe, especially regarding the most important parameter of skin quality. The new assessment method better reflects industry commercial experiences where a crop may appear to be good during the initial grading in Tasmania but upon re-grading in Europe can have a very high level of skin quality issues even to the point of total rejection.

Technical Summary

Australian onion exports to Europe are mostly shipped in ventilated dry shipping containers using a configuration developed by the CSIRO in the 1980's. Exports to Europe depart Australia from late January to early June, arriving from mid March to mid July. A wide range of climatic conditions are experienced during these shipping windows. During shipping the ventilation system is permanently on; drawing in ambient air at the same rate regardless of the ambient conditions; from monsoonal downpours in the tropics to 45^{o}C dry air in the Middle East.

Most shipments to Europe are repacked by the customer, requiring onions to be robust enough to withstand initial packing in Australia, followed by 2-3 months in the ventilated shipping container in transit to Europe, followed by a period of storage in Europe before repacking. The final measure of quality is the customer pack out; it is worth noting that exporters are liable for this final pack out regardless of how customers may store and handle the product after arrival. The pack out measured by customers typically includes: skin colour, skin retention, disease and internal growth. However, skinning is the most common long term issue accounting for the majority of claims apart from sporadic disease or seasonal issues.

A long term challenge facing the export onion industry is being able to adequately assess production protocols and varieties for suitability for European exports. This project successfully developed an integrated method to assess new varieties, fertiliser programs and curing practices, which more accurately measure a crop's suitability for export to Europe especially regarding the most important parameter of skin quality.

Onion samples were put under mechanical pressure at strategic times to replicate standard times commercial onions are exposed to skin pressure; namely 30-40 days post lifting which is representative of standard packing time, and 90-100 days post lifting which is representative of standard repacking time after arrival in Europe. The new assessment method developed in this project better reflects industry commercial experiences, none more so than the introduction of a second skinning assessment which highlights the experience commonly encountered by industry where a variety may pack out well and have very little skinning but upon repacking in Europe can have a very high level of skinning even to the point of total rejection.

Although no varieties were identified that were consistently better than the current industry standards, the cream gold variety trials have successfully identified a number of varieties with potential for export to Europe. The addition of these alternative varieties should help with risk mitigation especially in regard to seed availability. In addition, the reduced growing days identified in some of these new varieties also reduces the risks associated with planting either at the end or towards the end of the current planting windows, as crops are more likely to fully mature and cure normally.

The red variety trials have identified, or confirmed, a fundamental risk with red onions for export with regards to high risk of skinning and limited shelf life. Nonetheless, three red varieties have shown consistent promise for export to Europe.

A new approach to variety screening has been developed, involving multiple trial sites run over multiple years in combination with the new assessment protocol, to truly understand the strengths and weaknesses of new varieties under the broad range of conditions that industry now faces.

During this project there were twenty-four standard replicated block design fertiliser trials run over multiple seasons evaluating multiple fertiliser products, rates and application timings. In total there were 120 treatments applied (all fully replicated) in addition to the controls, but there were only three significant improvements in yield or skin quality recorded from the application of a fertiliser treatment compared to the control: two significant increases in yield and one significant reduction in skinning. However there were 35 significant deteriorations in yield or skin quality recorded from the application of a fertiliser treatment compared to the control: 15 significant reductions in yield and 20 significant increases in skinning. A large scale nutrient benchmark of commercial crops did identify a number of links between nutrient levels and onion skin quality however the link between individual nutrients was only mild to moderate with the exception of sodium.

A number of suggestions have been discussed regarding possible reasons for individual trials not producing significant results, from skinning level being too low to detect differences, to treatment application timing being too late or treatment rate being too low. However, the overwhelming failure to detect consistent significant improvements from fertiliser treatments, suggests very strongly that the current fertiliser protocols are in almost all cases providing sufficient or even excessive nutrients to the crops requirements. This poses an interesting research question regarding just how little fertiliser can be added to grow onions on Tasmanian soils without compromising yield or quality.

The influence of curing practices on skin quality revealed that the greatest impact came from the time of lifting. The time on ground also impacted on skin quality, but to a lesser extent than time of lifting. Soil moisture at the time of lifting and windrow depth had no measurable impact on skin quality. Attempts to try and influence senescence failed to improve skin quality, and in the case of Ethrel decreased skin quality.

Two lifting protocols to reduce the risk of skinning once crops are repacked in Europe are recommended as a result of this research. For crops with standard maturity, as measured by the progression of tops down taking one week or less from <25% tops down to >75% tops down: lift within 1 week of 80% tops down. For crops with delayed maturity, as measured by the progression of tops down taking greater than one week from <25% tops down to >75% tops down: lift within 3 weeks of >25% tops down. These recommendations can be combined in a composite recommendation as follows:

- lift within 1 week of 80% down, or within 3 weeks of 25% tops down, whichever occurs first

In the context of managing risk for exports to Europe, the data supports earlier lifting rather than later lifting. While this reduced the yield potential in some cases and increased skinning risk at packing 30 days post lifting, it reduced the subsequent risk of skinning 90 days post lifting. In order to reduce the risk of incurring a skinning claim with a customer in Europe, earlier lifting is the preferred management strategy.

The second curing factor affecting skin quality was time on ground; however the impact of an extra 30 days on the ground only increased average skinning by 7-16 percentage points. Although not measured in this research project, another factor to be considered with time on ground is skin staining, which may not necessarily result in skinning, but could still result in customer rejections due to unacceptable appearance.

In order to reduce the risk of skinning, especially once crops are repacked in Europe, it is recommended that crops be harvested within 30 days of lifting, which is consistent with current industry practice where May/Jun sown crops are typically harvested 14-21 days after lifting and Jul/Aug or Sep/Oct sown crops are typically harvested 21-28 days after lifting.

Perhaps surprisingly, windrow depth did not have a measureable impact on skinning, although it is worth noting the observation made that onions in the deeper windrows were less well cured, which was also supported by the weight loss data. The temperature and humidity conditions recorded within the windrow depths largely confirmed expectations that temperatures were lower at greater depths while humidity was higher at greater depths, and that coastal windrows were cooler and more humid that inland windrows. The impact of only 5mm of rain on windrow conditions was concerning as humidity remained saturated at all depths for at least 2 days, potentially providing ideal conditions for disease proliferation.

The impact of soil moisture at the time of lifting on skinning has long been questioned by industry; however the trial results indicated that the actual level of soil moisture at the time of lifting did not adversely affect skinning. The relevance of soil moisture at the time of lifting has been challenging to clarify, owing to the difficulty of being able to separate the impact of time of lifting from the impact of soil moisture.

Restoring consistency to European export quality remains an ongoing challenge, but substantial headway has been made in this project by the development of a new assessment method which has been successfully applied to variety, fertiliser and curing trials.

Finally, further work is recommended to better understand the influence of the transit conditions during shipping on onion quality. This area of research by its very nature is complex and will likely require a multi disciplinary approach, but given that the shipping ventilation method is largely unchanged since first developed in the 1980's there may be an opportunity to introduce new technology such as fan controllers that respond to environmental conditions outside the container and also respond to conditions inside the container to improve the final outcome in Europe.

Introduction

Field Fresh Tasmania currently produces 40,000 tonnes of onions per year, about 15% of Australia's total annual production, and currently exports in the order of 30,000 tonnes per year; about 80-90% of Australia's total annual onion exports. Almost all Field Fresh Tasmania's exports are for counter season supply to northern hemisphere countries, with approximately 80% (24,000t) to European countries, where there is strong international competition from other southern hemisphere exporting countries; New Zealand, South Africa and South America.

Australian onion exports to Europe are mostly shipped in ventilated dry shipping containers using a configuration developed by the CSIRO in the 1980's. This ventilation system has a fundamental limitation in that there is only one ventilation configuration, regardless of the export destinations, shipping times, and crop conditions. Exports to Europe depart Australia from late January to early June, arriving from mid March to mid July. A wide range of climatic conditions are experienced during these shipping windows. During shipping the system is permanently on; drawing in ambient air at the same rate regardless of the ambient conditions; from monsoonal downpours in the tropics to 45°C dry air in the Middle East.

Most shipments to Europe are repacked by the customer, requiring onions to be robust enough to withstand initial packing in Australia, followed by 2-3 months in the ventilated shipping container in transit to Europe, followed by a period of storage in Europe before repacking. The final measure of quality is the customer pack out; it is worth noting that exporters are liable for this final pack out regardless of how customers may store and handle the product after arrival. The pack out measured by customers typically includes: skin colour (standard, above/below standard), skin retention (one complete skin after final packing), Penicillium blue mould, staining, disease, breakdown and internal growth. However, skinning is the most common long term issue accounting for the majority of claims apart from sporadic disease or seasonal issues.

Analysis of recent seasonal outcomes highlights a very strong link between seasonal conditions and product outturn quality in Europe. Whilst quality has always been influenced by the climate, in recent years the magnitude of that influence has become more severe as the climatic variations escalate, to the point where proactive measures are needed to counter the impact of unseasonal climatic variations.

The significant difference between supplying Europe and supplying Australia is that onions exported to Europe must be robust enough for 6-8 weeks shipping in ambient conditions with modest ventilation and then be able to be regraded and repacked in Europe. This contrasts strongly with the Australian supply chain where onions need only be graded and packed once, and can reach the end customer in only a few days, so any inherent quality issues can be effectively graded out before supplying to the market, which minimises quality issues in the market. For European exports, an inherent quality issue may manifest itself during the long transit and in some instances onions are stored for lengthy periods of time after arrival in Europe before regrading and repacking, as it is expected that southern hemisphere new season onions will be suitable for long storage.

One of the long term challenges facing the export onion industry is being able to adequately assess production protocols and varieties for suitability for export to Europe. This project aimed to develop an integrated method to assess new varieties, nutrition programs and curing practices, and to restore consistency to field production, regardless of any prevailing unseasonal climatic variations. This represented a significant R&D challenge and was reflected in the duration and magnitude of this project.

The key attributes for European exports of firmness, skins and shelf life can be influenced by variety, nutrition and curing practices (Brewster 2008, Dennis et al. 2005, Field Fresh Tasmania 20 years commercial production and export experience).

Skins were put under mechanical pressure using a method adapted from Hole et al. (2002). Our system used a 200L drum with two rubber ribs attached to the inside of the drum as per Gracie et al. (2006), rotating at 40rpm, to tumble the onions for a given period of time. Skinning was defined to be representative of European customer standards as splits, cracks or shelling, where scale was visible. Onion samples were put under mechanical pressure in the drum at strategic times to replicate standard times commercial onions are exposed to skin pressure; namely 30-40 days post lifting which is representative of standard packing time, and 90-100 days post lifting which is representative of standard repacking time after arrival in Europe. This project used a controlled atmosphere storage facility to provide a more rigorous test of shelf life by creating diurnal fluctuation in temperature and humidity; 6am to 6pm 21°C and 60% RH, 6pm to 6am 11°C and 80% RH. These daily changes in conditions were designed to put onions under both skinning and sprouting pressure.

Onions exported to Europe experience fluctuations in temperatures which generally get warmer rather than colder, and this provides conditions conducive to reducing shelf life, by triggering the onions to begin to break dormancy due to the fluctuating and warming conditions (Brewster 2008). Shelf life and skins are also adversely affected by handling, so the new protocol is designed to better mimic commercial conditions. Impacts during handling elevate respiration rate and contribute to reducing shelf life (Brewster 2008). Skins are also affected adversely by impacts as they can be cracked or split. The new assessment method includes two separate tumbling steps to provide a representation of commercial handling conditions so that varieties and treatments can be more accurately assessed for suitability for European exports.

New varieties were evaluated for suitability for European exports, utilising the assessment method developed in this project. Recent studies (Dennis et al. 2005) attempted to screen new varieties for suitability for export, but in this project pilot commercial scale crops were the only real way to evaluate suitability and they carried huge cost and risk. To date there have been no comprehensive evaluations regarding the practical suitability of new varieties for European exports, so the use of new varieties in commercial production carries tremendous risk. The lack of detailed data is compounded by the method traditionally used for variety evaluation where varieties are typically hand harvested and then stored at ambient conditions in Tasmania without incurring any mechanical forces or damage. This method provides a very poor representation of conditions experienced by onions exported to Europe. Ambient conditions in Tasmania favour long term storage as temperatures progressively get colder.

All variety trials included internal standards or controls appropriate for the planting window. The control variety for all May planted trials was early cream gold which is an open pollinated line. During the Jul/Aug planted trials, the control variety was regular cream gold which is an open pollinated line. The variety Canterbury (Seminis) is a late season hybrid cream gold control variety and was the control for all Sep/Oct planted trials. “Red Shipper” (Clause) is a hybrid red variety used as the control for all the red onion trials.

Tasmanian onion fertiliser programs are heavily influenced by nutrient budgeting, where the estimated amount of nutrients to be removed by the crop are applied to the crop on the basis that the soil will be left with the same nutrient level after the crop as before planting. It is considered poor practice to “mine” the soil for nutrients however it is well recognised that it is definitely poor practice to apply excessive fertiliser to a crop and potentially create the risk of excess fertiliser contaminating waterways, not to mention the potential wasted expense involved. Onions require excess amounts of nutrients to be added to the soil to achieve maximum yield potential owing to the relatively low density root system (Brewster, 2008). This leaves residual fertiliser in the soil after the onion crop has been harvested, creating a dilemma for designing fertiliser programs.

In the UK, nitrogen is applied earlier in the crop life than in Tasmania, specifically to try and counter the negative effects of late season nitrogen application which results in reduced firmness and reduced shelf life. However, nitrogen is important for skins as well as achieving yield potential. There is also an additional source of nitrogen in the soil itself, namely nitrogen that is released from the breakdown of soil organic matter, especially in spring when soil temperatures increase. Managing nitrogen across the range of planting windows in Tasmania may require different approaches depending on the planting season.

Skins can be improved with increasing sulphur and copper. Recent studies (Gracie et al. 2006) examined the influence of salt forms of sulphur and copper but not chelated forms which are reportedly far more available for uptake by plants. Shelf life can be improved by increasing phosphorus, potassium and calcium, although they are typically increased to offset the negative effects of high nitrogen applications rates (Charron et al. 2001, Coolong et al. 2008).

This project evaluated the influence of chelated nutrients, silica, post bulbing nitrogen, post bulbing boron, early post emergence nitrogen and silica, growth manipulation, planting phosphorous and nitrogen interaction, sulphur, nitrogen and molybdenum interaction, plus a major benchmark of nutrient levels across all the onion growth stages.

The Tasmanian practice of lifting at maturity, windrowing and then leaving the onions in the field until stage 1 curing is completed is effective, but it does also expose crops to risk. Skins can be adversely affected by the process of dehydration and then rehydration which can stretch them to breaking point. Onions that are not firm are more vulnerable to sun burn and translucent scale when cured in the field, and onions that develop translucent scale have dramatically reduced shelf life (Compendium of Onion and Garlic Diseases and Pests. 2nd Ed, 2008; Field Fresh Tasmania commercial experience 2009). Although field curing is very cost-effective, the current protocol used in Tasmania does expose the crop to risks and in the current era of increased unseasonal climatic variations, those risks may become unmanageable.

This project re-evaluated curing practices to alleviating some of the current risks. Steps investigated include time of lifting, time on ground, windrow depth, soil moisture at lifting and senescence.

“If successful, the outcome of this project will be the continuation of European onion exports at current levels, assuming there are no unprecedented changes in trading conditions that would render exports unviable.” (HAL grant application summary, November 2009). The table below details the exchange rate between the Euro and the Australian dollar throughout the project, and it is probably fair to say that the exchange rate changes since the project was first developed constitutes an "unprecedented" change in trading conditions; however it has made the project even more relevant, as it has become even more critical to assure continuity of supply of quality product to Europe regardless of seasonal influences during the growing seasons.

EURO exchange rates from project concept to completion

Year	Month	EURO to $1AUD	Project Stage
2008	November	0.5091	Project concept developed
2009	November	0.6092	Grant application submitted
2010	November	0.7348	First season of project
2011	November	0.7516	Second season of project
2012	November	0.8025	Third season of project
2013	November	0.6699	Fourth season of project
2014	November	0.6884	Final report submission

Due to the size of this project, the main part of the report is divided into four chapters:

1. Assessment Method
2. Variety Evaluation
3. Fertiliser Program
4. Curing Strategies

Each chapter has its own Materials & Methods, Results, Discussion and Recommendations sections to make accessing the information more efficient. There is some minor repetition in the Materials & Methods sections, so that each chapter can be read in isolation without having to refer to other chapters.

1. Assessment Method

Materials & Methods

Standard Onion Assessment Protocol (SOAP)
Purpose: To develop a standard method to assess onion suitability for export to Europe, with particular emphasis on the assessment of skinning

SOAP - Skinning
In order to better replicate commercial practices where onions are mechanically handled which potentially exposes any skin weaknesses, trials were implemented to determine the duration and timing of simulated mechanical damage to provide a repeatable measure of skinning.

Four factorial trials with 5 replicates were implemented using mature bulbs from 3 cream gold crops and one red crop from the 2010/11 season, to assess the impact of timing and duration of mechanical tumbling to express skinning.

- 1st tumble applied 30-40 days post lifting
- 2nd tumble applied 90-100 days post lifting
- Cream gold onions tumbled 0, 5, 10 or 15 minutes, at each timing
- Red onions tumbled for 0, 5 or 10 minutes at each timing

Skins were put under mechanical pressure using a method adapted from Hole et al. (2002). Our system used a 200L drum with two rubber ribs attached to the inside of the drum as per Gracie et al. (2006), rotating at 40rpm, to tumble the onions for a given period of time. The standard onion sample size collected from the field was 20L (10-11kg). Samples were placed in 20kg bags which provided plenty of room for the onions to move within the bag, and two bags were placed in the drum at a time. The measurement of skinning was defined to be representative of European customer standards where any amount of visible scale is classified as skinning, regardless of the cause (includes splits, cracks or shelling). Onion samples were put under mechanical pressure in the drum at strategic times to replicate the standard times commercial onions are typically exposed to skin pressure; namely 30-40 days post lifting which is representative of standard packing time, and 90-100 days post lifting which is representative of standard repacking time after arrival in Europe. Onions that were skinned after the first tumble were removed from the sample after the first assessment.

Onions were harvested from the field once fully cured; typically 14-21 days after lifting if May/Jun sown and 21-28 days after lifting if Jul/Aug or Sep/Oct sown. Samples were collected from one section of the paddock from 5 adjacent beds.

The samples were placed in the controlled atmosphere storage facility for post harvest evaluation of skins, weight loss and sprouting, where the following conditions were maintained: 6am to 6pm 21^{o}C and 60% RH, 6pm to 6am: 11^{o}C and 80% RH.

Weight loss was recorded at 90-100 days and 160-170 days post lifting, taking into account any losses due to disease.

Sprout development was measured at 160-170 days post lifting by cutting all onions in half and recording whether a sprout was visible beyond the shoulder of the bulb.

The data presented in the results tables is the average of the replicates plus the outcome of the analysis of variance, using Genstat 13.

SOAP - Bulb Firmness
Bulb firmness was measured by recording the pressure (PSI) required for an 11mm diameter flat end round probe, from a penetrometer mounted in a drill press, to be inserted 8mm into the mid section of a bulb at 30 days, 90 days and 160 days post lifting. At 90 days post lifting an additional pressure measurement was taken, this time only inserting the probe 1.5mm into the mid section of the bulb. Ten unskinned bulbs were taken at random at each sampling time; bulbs were sampled post tumbling.

Bulbs were collected from 3 variety trials from the 2010/11 season to provide a range of material for testing; two trials had 12 varieties and one trial had 14 varieties, all included cream gold and red onions. The variety trials were all randomised block designs with 4 replicates; all 4 replicates were sampled. Onions were harvested from the field once fully cured; typically 14-21 days after lifting if May/Jun sown and 21-28 days after lifting if Jul/Aug or Sep/Oct sown. Samples were placed in the controlled atmosphere storage facility, where the following conditions were maintained: 6am to 6pm 21^{o}C and 60% RH, 6pm to 6am: 11^{o}C and 80% RH.

During the 2010/11 season, this method of measuring bulb firmness was also applied to the commercial crop survey conducted during that season (refer later section “SOAP - Crop Surveys”).

The data presented in the results tables is the average of the replicates plus the outcome of the analysis of variance, using Genstat 13.

SOAP - Skin Strength & Scale Texture

Skin strength and scale texture were measured using a Mecmesin FTA 2.5-i Food Texture Analyser. Skin strength was calculated as the peak in load between the skin surface and 10mm into the bulb, measured in newtons; using a 3mm diameter flat end round probe. Scale texture was calculated as the area under the load curve from 6mm to 11mm, measured in millijoules; using a 3mm diameter flat end round probe. Ten unskinned bulbs were sampled from each replicate prior to tumbling, 30-40days post lifting.

Bulbs were collected from 4 variety trials from the 2011/12 season to provide a range of material for testing; trials had either 10, 12, 13 or 15 varieties, and all included cream gold and red onions. The variety trials were all randomised block designs with 4 replicates; all 4 replicates were sampled. Onions were harvested from the field once fully cured; typically 14-21 days after lifting if May/Jun sown and 21-28 days after lifting if Jul/Aug or Sep/Oct sown. The samples were placed in the controlled atmosphere storage facility, where the following conditions were maintained: 6am to 6pm 21°C and 60% RH, 6pm to 6am: 11°C and 80% RH.

During the 2011/12 season, this method of measuring skin strength and scale texture was also applied to the commercial crop survey conducted during that season (refer later section “SOAP - Crop Surveys”).

The data presented in the results tables is the average of the replicates plus the outcome of the analysis of variance, using Genstat 13.

SOAP - Sprout Development

During the 2010/11, 2011/12 and 2012/13 seasons, sprout development was measured at 160-170 days post lifting by cutting all onions in half from base to neck and recording the relative sprout height within the bulb from the bulb base to the top of the bulb shoulder as follows:

- 0 to ¼
- ¼ to ½
- ½ to ¾
- ¾ to 1
- >1 (spout higher than bulb shoulder and often visible before cutting)

During the 2013/14 season a minor variation on sprout measurement was introduced to provide a more easily repeatable method. Sprout development was measured 160-170 days post lifting by cutting all onions in half from side to side at the midpoint of the bulb. If a coloured sprout was visible, then the onion was cut vertically along the coloured sprout to determine the full extent of the sprout as follows:

- <½
- ½ to ¾
- ¾ to 1
- >1

The measurement of sprout development was applied to all trials in Chapters 2, 3 and 4 in order to provide a wide range of material for assessment, and results are reported in those chapters.

The data presented in the results tables is the average of the replicates plus the outcome of the analysis of variance, using Genstat 13.

SOAP - Crop Surveys

In each of the four onion cropping seasons during this project, surveys were undertaken of commercial crops to develop a profile of skinning risk. A single 20L (10-11kg) sample was harvested from each commercial crop once fully cured; typically 14-21 days after lifting if May/Jun sown and 21-28 days after lifting if Jul/Aug or Sep/Oct sown.

The samples were placed in the controlled atmosphere storage facility for post harvest evaluation, where the following conditions were maintained: 6am to 6pm 21°C and 60% RH, 6pm to 6am: 11°C and 80% RH.

Skins were put under mechanical pressure by tumbling cream gold onions for 10 minutes and red onions for 5 minutes, at 30-40 days post lifting and 90-100 days post lifting. In the 2011/12, 2012/13 and 2013/14 seasons, onions were tumbled for a third time and skinning evaluated at 160-170 days after lifting representative of long term storage and multiple handling of onions that occurs in difficult market seasons

A total of 317 commercial crops were surveyed over the life of the project:

- 2010/11 season, 93 crops
- 2011/12 season, 87 crops
- 2012/13 season, 73 crops
- 2013/14 season, 64 crops

Crops were grouped into 5 locations and given a 3 digit location number according to the following schedule:

- 100-199 = Devonport
- 200-249 = Deloraine to Westbury/Hagley
- 250-299 = Longford
- 300-349 = Wynyard
- 350-399 = Forest/Smithton

Fast Track
Purpose: To evaluate a fast track version of the standard onion assessment protocol (SOAP), to generate a crop skinning risk profile shortly after harvest, for evaluating crops prior to packing

During the 2012/13 and 2013/14 seasons an additional 20L (10-11kg) sample was collected from each crop included in the commercial crop survey. The first stage of the Fast Track assessment was exactly the same as the commercial crop survey where cream gold onions were tumbled for 10 minutes and red onions for 5 minutes. After the skin assessment, the unskinned onions from the Fast Track sample were placed in an incubator for 24 hours at 34°C and 40-50% RH. After this incubation period the samples were placed in the controlled atmosphere storage facility for a further 24 hours. The samples were then tumbled for a second time and assessed for skinning.

Auto Skinning
Purpose: To evaluate a range of conditions that may be able cause auto skinning; confined to temperature and humidity ranges that may be experienced in commercial conditions

Auto skinning was first observed during the 2011/12 season when onions were exposed to a rapid drop in temperature; the skins on some bulbs split and in the most extreme case the skins began to peel away from the bulb giving the appearance of a partially peeled onion (refer photograph on front cover). This process occurred within half an hour of the temperature drop and in some instances the onions could be heard cracking as the skins were splitting.

Twenty-three trials were conducted, each using one 20L (10-11kg) sample of cream gold onions collected from commercial crops post harvest. Samples were tumbled for 10 minutes 24 hours before the trial start and skinned onions were discarded to provide a more uniform sample at least in terms of skinning. The samples were placed in the controlled atmosphere storage facility, where the following conditions were maintained: 6am to 6pm 21°C and 60% RH, 6pm to 6am: 11°C and 80% RH.

Samples were placed in an incubator where a range of conditions were evaluated including:

- 34°C for 6hrs, at 60-80%RH
  - 4 trials, 1 variety
- 34°C for 18hrs, at 60-80%RH
  - 1 trial, 1 variety
- 34°C for 18hrs, at 40-60%RH
  - 2 trials, 1 variety
- 34°C for 24hrs, at 40-60%RH
  - 16 trials, 4 varieties

Once removed from the incubator, samples were placed on the assessment table where they were exposed to air at 21°C & 60-65%RH, and a gentle air current from the ventilation system. It was observed that the number and width of splits did not change after 30 mins after removal from the incubator; samples were assessed at this point.

The diameters of an additional 10 bulbs were measured in 6 of the incubator trials. Onions were pre marked with two spots on the middle of each bulb and the diameter recorded before and immediately after incubation.

Results
Information regarding observations from the statistical analysis is located beneath each table, for ease and efficiency of reference.

SOAP – Skinning
Skinning 30 days post lifting was significantly increased by 5 minutes of tumbling in 2 of the 3 cream gold trials (Tables 1.1, 1.3) and was significantly increased by 10 minutes of tumbling in all 3 cream gold trials compared to the control which had no tumbling (Tables 1.1-1.3). Skinning 90 days post lifting was significantly increased by 5 minutes of tumbling in 2 of the 3 cream gold trials (Tables 1.2, 1.3) and was significantly increased by 10 minutes of tumbling in all 3 trials compared to the control which had no tumbling (Tables 1.1-1.3). Skinning 30 and 90 days post lifting was significantly increased by 5 minutes of tumbling in the red onion trial compared to the control which had no tumbling (Table 1.4).

In 1/3 of the cream gold onion trials and the red onion trial the level of skinning 90 days post lifting was significantly increased by increasing duration of tumbling 30 days post lifting, P=0.003 and P=0.005 respectively. In the other 2 cream gold onion trials the level of skinning 90 days post lifting was not significantly affected by the duration of tumbling 30 days post lifting. Tumbling timing or duration had no significant effect on weight loss and had no consistent effect on sprout development (Tables 1.1-1.4).

It is proposed that a SOAP skinning level of 20% or greater at 90 days post lifting would likely result in a skinning related claim in Europe. This proposal is based on a number of observations made during the first season of the project, and subsequently confirmed in later seasons, where the SOAP skinning level predicted a number of crops that ultimately did result in skin related claims.

In order to validate the proposed threshold a number of analyses were undertaken, however results were inconsistent. In some cases the 20% threshold was supported but in other cases the correlation was poor, suggesting that other factors would need to be taken in to account, such as storage and handling conditions or conditions during shipping.

SOAP - Bulb Firmness
There were no significant differences in firmness between any of the varieties in any of the 3 trials (Tables 1.5-1.7). The pressure required to insert the probe 8mm into the bulb ranged from 10.7-11.1psi at 30 days post lifting, 10.5-11.0psi at 90 days post lifting and 10.6-11.1psi at 160 days post lifting. The range recorded for inserting the probe 1.5mm into the bulb at 90 days post lifting was 2.49-2.85psi. Despite the penetrometer being mounted in a drill press with pre set mechanical stops for either 1.5mm or 8mm, it was observed that the pressure applied to the lever to insert the probe into the bulb could influence the final pressure reading.

There were no correlations between bulb firmness measured at 30 days post lifting and 30d skinning (R^2 =0.12) or bulb firmness measured at 90 days post lifting and 90d skinning (R^2 =0.01) in the crop survey of 93 sites from the 2010/11 season.

SOAP - Skin Strength & Scale Texture
Skin strength and scale texture were significantly different between some varieties in all 4 variety trials, with cream gold onions mostly having stronger skins and firmer scale textures than red onions (Tables 1.8-1.11).

Correlation (R^2) analysis was used to test for any relationship between skin strength or scale texture and skinning 90 days post lifting. For the purposes of discussion correlations are grouped as follows:

- R^2 <0.3 no relationship
- R^2 >0.3-0.5 mild relationship
- R^2 >0.5-0.7 moderate relationship
- R^2 >0.7-1.0 strong relationship

Three trials had a strong negative correlation between average skin strength and skinning 90 days post lifting (Tables 1.9-1.11); the fourth trial had a mild negative correlation between average skin strength and skinning 90 days post lifting (Table 1.8). Similar correlations were obtained when the skin strength data was grouped into the proportion of samples <40N, <50N and <60N (Tables 1.8-1.11). When all the skin strength data from all 4 variety trials is aggregated there was a moderate negative correlation between average skin strength and skinning 90 days post lifting with an R^2 of 0.60 (Figure 1.1).

There was only a mild negative correlation between average skin strength and skinning 90 days post lifting (R^2 =0.43) in the crop survey of 45 regular sites from the 2011/12 season (Figure 1.2).

There were no trials with a strong correlation between average scale texture and skinning 90 days post lifting (Tables 1.9-1.11); 3 trials had a moderate correlation between average scale texture and skinning 90 days post lifting (Tables 1.9-1.11) while the fourth trial site had a mild correlation between average scale texture and skinning 90 days post lifting (Table 1.8). The correlations were generally similar or weaker when the scale texture data was grouped into the proportion of samples <40mJ, <50mJ and <60mJ (Tables 1.8-1.11).

It was observed during the assessments that the position of the probe on different sides of some bulbs resulted in very different measurements of both skin strength and scale texture. Cutting these bulbs revealed internal differences, which appeared to be linked to which side of the bulb may have been exposed to the sun, possibly whilst curing in the windrows in the field. Some of this side to side variation may also have been due to bruises that occurred during mechanical lifting of the crop.

SOAP - Sprout Development
It was observed that identifying the sprout is very difficult unless it is coloured. The time needed to accurately distinguish between a non coloured sprout and a bladeless scale is too long for the method to be practical for routine use in trials. It was also noted that cutting the onions from base to tip did not always line up with the actual sprout, especially as many of the varieties are at least somewhat multi centred. It was more practical to first cut the onions in half across the middle and then cut vertically along any coloured sprout to determine its full length.

SOAP - Crop Survey
Season results for skinning 30 days, 90 days and 160 days post lifting have been graphed against the commercial crop planting sequence for each of the 4 seasons, with R^2 values for each correlation analysis located below each graph for ease and efficiency of reference.

Analysis of the 2010/11 season commercial crop survey revealed no relationships (R^2) between skinning 30 days post lifting and skinning 90 days post lifting (Figure 1.3).

The 2011/12 season commercial crop survey revealed a single mild relationships ($R^2 = 0.48$) between skinning 90 days post lifting and skinning 160 days post lifting (Figure 1.4). There were no relationships (R^2) between skinning 30 days post lifting and skinning 90 or 160 days post lifting (Figure 1.4).

Results from the 2012/13 season commercial crop survey revealed a moderate correlation between skinning 30 and 90 days post lifting ($R^2 = 0.58$) and a strong relationship between skinning 90 and 160 days post lifting ($R^2 = 0.75$) and a mild correlation ($R^2 = 0.34$) between skinning 30 and 160 days post lifting (Figure 1.5).

The 2013/14 season commercial crop survey identified a single moderate relationship ($R^2 = 0.48$) between skinning 90 days post lifting and skinning 160 days post lifting (Figure 1.6). There were no relationships (R^2) between skinning 30 days post lifting and skinning 90 or 160 days post lifting (Figure 1.6).

During the 2010/11 season there were 23 crops with skinning >20% 90 days post lifting (Figures 1.3); the causes of this elevated skinning can be split into the following categories:

- 8 crops – Lifting delayed by an extreme rain event between 12th -15th January 2011 (25.2mm 12th , 115.6mm 13th , 35.2mm 14th , 10.8mm 15th). Crops lifted prior to the rain event in this area did not have elevated levels of skinning, nor did the first 2 crops lifted immediately after the rain event, however all subsequent early crops in this area recorded elevated skinning levels 90 days post lifting.
- 2 crops - Red onions crops; higher level expected (refer Chapter 2)
- 13 crops - Planted outside optimum planting window. Maturity may have been disrupted; possible delay in reaching tops down (refer Chapter 4)

During the 2011/12 season there were 24 crops with skinning >20% 90 days post lifting (Figures 1.4); the causes of this elevated skinning can be split into the following categories:

- 10 crops – Lifting delayed by three separate rain events; 27.4mm of rain on 19th December 2011 (2 crops affected), 35mm rain on 8th-11th January 2012 (7 crops affected) and 19.4mm rain 6th February 2012 (1 crop affected). Crops in the same area lifted prior to the rain events were not affected.
- 5 crops - Red onions crops; higher level expected (refer Chapter 2)
- 6 crops – Disrupted maturity; crops maturing during an unusual cool period that occurred in late January to early February; delays in reaching tops down were observed (refer Chapter 4)
- 1 crop - Downy Mildew
- 2 crops – Maturity disrupted; delays in reaching tops down were observed (refer Chapter 4)

During the 2012/13 season there were 29 crops with skinning >20% at 90 days post lifting (Figure 1.5); the causes of this elevated skinning can be split into the following categories:

- 8 crops - Downy Mildew
- 2 crops - Lifting more than 10days after 80% tops down (note that there were another 7 crops lifted more than 10days after 80% tops down where skinning 90 days post lifting was <20%)
- 3 crops - Lifting 7-10days after 80% tops down (note that there were another 5 crops lifted 7-10 days after 80% tops down where skinning 90 days post lifting was <20%)

- 7 crops - Red onions crops; higher level expected (refer Chapter 2)
- 2 crops - Elevated disease levels; Botrytis or onion white rot
- 7 crops - Unknown causes; not associated with disease or late lifting, or late planting (delay in reaching maturity cannot be ruled out)

During the 2013/14 season there were 11 crops with skinning >20% skinning 90 days post lifting (Figure 1.6); the causes of this elevated skinning can be split into the following categories:

- 5 crops - Red onions crops; higher level expected (refer Chapter 2)
- 3 crops - Planted outside optimum planting window. Maturity may have been disrupted; possible delay in reaching tops down (refer Chapter 4)
- 1 crop - Severe wet conditions and freeze damage
- 1 crop - Prolonged wet conditions and downy mildew
- 1 crop – Possibly downy mildew, although level was low and disease was well controlled; cool area possibly disrupted maturity; possible delay in reaching tops down (refer Chapter 4)

Fast Track

During the 2012/13 season there was a single strong relationships (R^2 =0.761) between the level of skinning detected by the Fast Track 2nd skin assessment and the level of skinning detected by the standard onion assessment protocol (SOAP) method 90 days post lifting (Figure 1.7). The graph of this data reveals a broad range of skinning data from 0% to over 80% skinning recorded by both Fast Track and SOAP, with considerable data points between 20-70% for both (Figure 1.7).

There was a strong relationship (R^2= 0.85) between the level of skinning detected by the Fast Track 1st skin assessment and the level of skinning detected by the SOAP method 30 days post lifting (Figure 1.8). This correlation (R^2) was expected to be much higher as at this point the methodology and assessments are identical, as both samples were assessed 30 days post lifting and prior to assessment both samples were collected and stored identically. Any differences may be due to the inherent variability within the samples, the methodology of sample collection or perhaps variability in conditions inside the storage facility or the tumbling barrel.

Closer analysis of the data revealed a potential improvement in the sample collection methodology. Two of the crops, labelled as 211 & 251 in Figure 1.8, were sampled by two people instead of one. This resulted in the samples for Fast Track and SOAP being collected separately, rather than pooled and then sub sampled which was the standard procedure applied to most of the sample collection. When the data is reanalysed without these two crops, the correlation between the level of skinning detected by the Fast Track 1st skin assessment and the level of skinning detected by the SOAP method 30 days post lifting is improved, R^2 = 0.906 (Figure 1.9). This suggests a change to the sample collection methodology may be able to improve the accuracy of the Fast Track method to predict suitability for export to Europe. To this end the sample collection criteria in the field has been designed to only exclude onions on a basis that will not be open to interpretation; these include onions <40mm, >80mm, misshapen, damaged, diseased and bolters. Subsequent trial work has also revealed another potential improvement to the methodology regarding the conditions that cause "auto skinning" (refer later section). Standardising the temperature exposure when transferring the fast track onions from the incubator to the laboratory should further help reduce variability in the results.

During the 2013/14 season there was only a mild relationship (R^2 = 0.32) between the level of skinning detected by the Fast Track 2nd skin assessment and the level of skinning detected by the standard onion assessment protocol (SOAP) method 90 days post lifting (Figure 1.10). The graph of this data reveals a much narrower range of skinning data compared to the previous season, from 0% to 40% recorded by both Fast Track and SOAP with only one data point above 40% (Figure 1.10).

There was a moderate relationship (R^2= 0.59) between the level of skinning detected by the Fast Track 1st skin assessment and the level of skinning detected by the standard assessment method 30 days post lifting during 2013/14, although as per the 2012/13 season this correlation was expected to be much higher given that the samples should be the same at this point in time. However, during 2013/14 the Fast Track and SOAP samples were not always processed on the same day and it was observed that ambient conditions on the day of tumbling and assessment were potentially influencing the level of skinning (refer auto skinning section).

Auto Skinning

Although auto skinning was successfully induced in all the trials (Table 1.12), it was never to the extent first observed in the 2011/12 season. During the 2012/13 season trials, bulbs were occasionally heard splitting but the level of skin splitting was relatively minor compared to the 2011/12 season.

A large number of trials were assessed involving a range of conditions and varieties, and while there was variation between results, auto skinning was repeatedly induced when bulbs were exposed to 21°C at 75-80% RH after 24 hrs incubation at 34°C and 40-60% RH. There is evidence of varietal differences in susceptibility to auto skinning (Table 1.12), although all varieties did develop auto skinning in all trials.

The proportion of bulbs that split in the large sample trials ranged from 58.3-90%, while the proportion of bulbs with a split width >1mm ranged from 41.7-85.7% and the average split width ranged from 1.6-5.3mm (Table 1.12). Not all of these would be classified as skinning as some had more skins below the split skin**.** Occasionally, a skin in the second layer split underneath a surface layer skin that did not split**.** No "auto" peeling back of the skins occurred during the 2012/13 season trials**.**

Results from the 10 individual bulbs showed that the average diameter of the bulbs did increase when incubated for 24hrs at 34°C and 40-60% RH by 0.5% to 0.8%, but did not change when only incubated for 6 hours at 34°C and 60-80% RH (Table 1.12). The proportion of bulbs that split ranged from 60-90%, while the proportion of bulbs with a split width >1mm ranged from 40-70% and the average split width ranged from 1.9-4.2mm (Table 1.12).

Discussion

SOAP - Skinning

Ten minutes of tumbling was the minimum amount of tumbling that resulted in significant differences in the level of skinning compared to no tumbling in all three cream gold trials at both tumbling times (30 & 90 days post lifting). Five minutes of tumbling resulted in significant differences in the level of skinning compared to no tumbling in the red crop at both tumbling times. Based on these results, the duration of tumbling used in the standard onion assessment protocol (SOAP) was 10 minutes for cream gold onions and 5 minutes for red onions at both 30 days and 90 days post lifting.

The level of skinning was consistently higher after the second tumble, even though onions that were skinned after the first tumble were removed from the sample after the first assessment. This is consistent with previous commercial experiences where some crops show no sign of skin issues at initial packing, but have substantial skin issues by the time they are repacked in Europe.

The level of skinning produced by this tumbling method is much greater than that normally seen in commercial crops. The tumbling process appears to greatly amplify the level of skinning by successfully revealing even very small skin weaknesses present. The level is further exaggerated by the very harsh definition of skinning used throughout this project, however the skin assessment method is very easily repeatable requiring little if any interpretation during assessments. The definition of skinning used in the standard onion assessment protocol (SOAP) is "any amount of visible scale is classified as skinning, regardless of the cause (includes splits, cracks or shelling).

It is not clear why in some trials the duration of tumbling at 30 days post lifting affected the level of skinning at 90 days post lifting; it should be noted that skinned onions were removed from the sample after the 30 day assessment, so did not add to the 90 day assessment total. This result suggests that some of the crops used in the trials may have been more vulnerable or sensitive to the damage caused by the initial tumbling, but the deterioration in skin quality did not become evident or did not develop until the second tumbling.

Calibration between the exaggerated skinning level achieved in SOAP and commercial outcomes proved to be a substantial challenge, potentially influenced by many factors such as conditions during shipping and customer storage and handling procedures. However, another unforeseen factor was the market condition itself. It was observed that in strong markets with a shortage of new season imported onions, quality standards became quite relaxed in Europe, whereas in the opposite market conditions, quality standards became extremely rigid. This dramatically altered the level of skinning related claims in each season; however personal inspection of selected crops in Europe by staff from Tasmania confirmed that crops with skinning levels above 20% in the SOAP typically resulted in skinning levels high enough in Europe to warrant a claim.

Based on this observation a threshold level of 20% skinning in the SOAP has been used throughout the project as the level of skinning in trials likely to indicate a potential skinning issue in a commercial situation.

In chapters 2, 3 and 4 the following colour key has been applied to all the trial analysis tables, to assist with identification of positive skinning results:

	Skinning <20% at both 30d post and 90d post lifting

In chapters 3 and 4 an additional colour key has been applied to all the trial analysis tables, to assist with identification of negative skinning results:

	Skinning >20% at either 30d post or 90d post lifting

SOAP - Bulb Firmness

The range of values recorded using a penetrometer to measure bulb firmness were too narrow to detect any differences between varieties and the absence of any correlation between bulb firmness and skinning in the commercial crop survey, suggests that the method lacked sensitivity. Noting also that the amount of force the operator applied to the drill press lever could influence the measurements; it was decided not to continue with this approach to measuring bulb firmness.

SOAP - Skin Strength & Scale Texture

The correlations between skin strength or scale texture measured 30 days post lifting were encouraging in the variety trials, however when the method was applied to the commercial crop survey the correlation was insufficient to be able to use skin strength or texture measured 30 days post lifting to accurately forecast the level of skinning risk when rehandled 90 days post lifting in commercial crops. However, there was a potential limitation in the accuracy of the data due to the sample size of 10 bulbs per replicate, given the observation that the position of the probe on different sides of some bulbs resulted in very different measurements of both skin strength and scale texture. To overcome this source of variation much larger sample sizes would be needed.

Unlike the bulb firmness measurement using the penetrometer, this method of measuring skin strength and scale texture was very successful, at least on an individual onion basis. The data generated for each bulb was literally like looking at any x-ray of the onion; the peaks in force coincided with the number of skins and scales, while the distance between the peaks corresponded with the skin and scale thickness. As a method to measure individual bulb skin strength and scale texture the Mecmesin FTA 2.5-i Food Texture Analyser was very successful.

However, the variation in readings depending on the location of the probe on each bulb limits the application of this method to more detailed studies, rather than commercial application in large scale crop surveys where speed of processing samples is an imperative. While it is likely that the variation detected could be compensated for by taking much larger sample sizes, the time involved in processing these extra samples would most likely be prohibitive in a production environment, especially in this instance where the readings were taken during a very narrow window of opportunity, namely 30 days post lifting.

Nonetheless, the Mecmesin FTA 2.5-i Food Texture Analyser is a very valuable research tool, but probably best used for smaller more detailed studies of specific components of skin research.

SOAP - Sprout Development

Owing to the difficulty of distinguishing between a non coloured sprout and a bladeless scale, a more practical sprout assessment method has been included in the SOAP, where the onions are first cut in half across the middle and then cut vertically along any coloured sprout to determine its full length. This provides a practical easily repeatable measure of sprouting, and perhaps more importantly in the context of this project, is representative of how many European customers assess sprouting.

SOAP - Crop Survey

In the three seasons where skinning was assessed at the third time of 160 days post lifting in addition to the first two assessment times, there was a correlation between skinning 90 days post lifting and skinning 160 days post lifting, albeit inconsistent between the seasons; 2011/12 had a mild relationship, 2012/13 had a strong relationship and 2013/14 had a moderate relationship. Although the 90 day assessment is largely too late to be of commercial benefit to help determine crop suitability for export to Europe as most crops would have already been sent by that time, the relationship is useful to help prioritise crops in storage not yet packed for domestic or shorter transit late season export markets, such as Asia. Even though the correlations were not always strong, any information to help assess which crops may be at increased risk of developing skinning issues after extended storage would be a value to industry, so that those crops at greatest risk can be packed first.

Over the four cropping seasons of the commercial crop survey a number of consistent trends emerged regarding high skinning levels, as defined by the SOAP threshold of 20% skinning.

In two of the seasons rain events caused delays in lifting some of the crops which led to increased skinning levels in the delayed crops (2010/11, 2011/12). At the time it was unclear whether the increased skinning was caused by the delay in lifting or the increase in soil moisture. Subsequent trials have determined that the most likely cause is the delay in lifting as this has been shown conclusively to be a major contributor to increased skinning (Chapter 4), whereas trials have been unable to demonstrate any link between soil moisture at the time of lifting and skinning (Chapter 4).

The commercial crop surveys also identified consistent high skinning levels in many red onion crops in all four cropping seasons, which has also been demonstrated in the variety trials (refer Chapter 2). The elevated skinning levels in red onions occurred despite the red onion SOAP only tumbling red onions for 5 minutes instead of 10 minutes as for cream gold onions.

In two of the surveys increased skinning levels were associated with late planting of some crops (2010/11, 2013/14). In these instances the crops affected were not only planted outside the accepted commercial planting windows but many were in locations with cool microclimates that would potentially have delayed or even disrupted normal crop maturity processes. Similarly, in two seasons (2011/12, 2013/14) and possibly in a third season (2012/13) a number of crops did not mature normally when there was a cold event close to the expected time of reaching tops down. This appears to have delayed the normal maturity process, which has been observed in other trials to lead to increased skinning (Chapter 4). It was also noted in the 2011/12 season that two crops were observed with a delay in reaching tops down independent of any weather related event, but ended up with elevated skinning levels.

Several crops in two seasons (2011/12, 2012/13) that were adversely affected by downy mildew had increased skinning levels not associated with any other cause. Downy mildew has already been established as a cause of increased skinning (Gracie et al. 2006), however the severity and perhaps more importantly the timing of initial onset appear to be key factors as many crops experience low levels of infection without incurring elevated skinning levels.

In the only season where the date of tops down progression was recorded routinely (2012/13), a number of crops lifted more than one week after 80% tops down was reached had elevated skinning levels, although it was noted that there were many more crops also lifted more than one week after 80% tops down that did not have elevated skinning levels.

Overall, the commercial crop surveys have reflected a number of findings made in trials from other chapters, and have revealed a number of commercial indicators that can be used to identify crops at risk of developing skinning upon repacking in Europe, namely

- Delayed lifting
- Late planting
- Cool conditions at maturity
- Downy mildew
- Red onions

Fast Track & Auto Skinning

It became apparent during the development of Fast Track that auto skinning is inextricably linked, and in fact in all likelihood auto skinning is the key component of Fast Track and may also be an important element of the concerning variation detected in the Fast Track results, especially between the two years.

Auto skinning is potentially a new onion disorder or at least a newly reported onion disorder. It is suspected that a much broader range of conditions may be able to induce auto skinning than was evaluated in this project. All of the conditions tested in this project could occur during shipping and handling.

Although the mechanism of auto skinning is unknown it is suspected that it occurs due to a sudden change in pressure within the onion tissue caused by the sudden change in external temperature, although this would require verification. The auto skinning trials did demonstrate that during the high temperature incubation the diameter of the bulbs did increase, indicating that the skins would be stretched and potentially under increased pressure.

Regardless of the mechanism of auto skinning, the results have shown how sensitive onion skinning can be to changes in environmental conditions such as temperature, and that skinning can occur even in the absence of mechanical pressure. This presents a major challenge for implementing the SOAP and also for improving the accuracy and consistency of Fast Track.

The finding has an even greater implication for commercial onion packing and shipping operations, potentially identifying a new source of risk for onion quality. Although not verified as the cause, there have been occasional arrivals in Europe in recent years where the onions appear to have been skinned at packing. Until the identification of auto skinning in this project, it was never understood how onions could be sent in such poor condition, but it is now apparent that the affected containers may have experienced conditions that caused auto skinning of the crop post packing whilst the container was in transit to Europe. In our trials auto skinning was repeatedly induced when bulbs were exposed to 21^{o}C at 75-80% RH after incubation at 34^{o}C and 40-60% RH; conditions that commercial shipments could easily experience when a cool change arrives at the end of a hot dry day.

Fast Track requires further work before it can be fully adopted into commercial operations. The key areas that require further research include sample size and collection methodology, and most importantly the conditions under which samples are stored and moved, including the conditions of the assessment area. Most likely, the entire process will need to be done inside a controlled atmosphere facility with strict adherence to protocol conditions and timings, however the potential reward if successful would be of great value to the Australian onion industry, as it would mean an accurate prediction of skinning risk could be generated within 30 days of lifting, which is typically within one to two weeks of packing in the case of exports to Europe.

Recommendations - SOAP (Standard Onion Assessment Protocol)

It is recommended that all trials associated with determining suitability of onions for export to Europe are assessed using the new standard onion assessment protocol (SOAP) developed in this project, as follows:

Lift

Lift
- Machine or hand lift within 1 week 80% tops down

Cure
- Standard commercial field windrow curing

↓

Harvest

Harvest
- By hand when dry; typically 14-21 days after lifting if May/Jun sown, & 21-28 days after lifting if Jul/Aug or Sep/Oct sown
- Measure gross yield = weight of un topped onions (all sizes) in 2m^2 of windrow
- Top: by hand, leaving 5cm neck (Botrytis prevention strategy: if necks not fully dried - sterilise secateurs)
- Fill 20L bucket lined with onion net bag with topped onions (exclude <40mm, >80mm, misshapen, damaged, diseased and bolters)
    - Do not harvest plot/treatment if less than half bucket of suitable bulbs (refer bulbs to be excluded)
- Store in controlled conditions, with air flow

↓

30-40 days after lifting

30d Skin Assessment
- Tumble 10 minutes (Red Onions 5 minutes), 2 bags at a time
- Record weight of onions with complete skin, & weight of onions with flesh showing (exclude diseased bulbs)
- Replace bulbs that are not skinned in bag
- Store in controlled conditions, with air flow

↓

90-100 days after lifting

90d Skin Assessment
- Tumble 10 minutes (Red Onions 5 minutes), 2 bags at a time
- Record weight of onions with complete skin, & weight of onions with flesh showing (exclude diseased bulbs)
- Replace bulbs that are not skinned in bag
- Store in controlled conditions, with air flow

↓

160-170 days after lifting

160d Skin Assessment
- Tumble 10 minutes (Red Onions 5 minutes), 2 bags at a time
- Record weight of onions with complete skin, & weight of onions with flesh showing (exclude diseased bulbs)

160d sprout assessment (option to separate skinned from un skinned bulbs, depending on trial objectives)
- Cut bulbs from side to side at the mid point
    - If no coloured sprout visible, record bulb weight in sprout grade <0.5
    - If coloured sprout visible, cut bulb along colouration to determine extent of sprout, then record bulb weight in the following grades
        - 0.5-0.75
        - 0.75-1
        - >1
    - exclude diseased bulbs

Controlled storage conditions (vary to suit the trial/assessment objectives):
- 6am to 6pm 21^{o}C and 60% RH
- 6pm to 6am: 11^{o}C and 80% RH

Note: the above storage conditions may not be optimum for encouraging sprout development; lower minimum temperatures may be needed to help break bulb dormancy in order to increase the pressure on sprout development if this is a priority in trials.

Note: owing to the limitations identified in this research regarding the measurement of bulb firmness, skin strength and scale texture, these are not included in the SOAP.

Table 1.1 Results of skin quality trial 1011 T 106 factorial analysis
Variety: 10-SP-211
Planted: 26 May 2010
Lifted: 9 Jan 2011

1st Tumble Duration Mins	2nd Tumble Duration Mins	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Shoot ¼	Shoot ½	Shoot ¾	Shoot 1	Shoot >1
0	0, 5, 10, 15	1.3	4.2	2.2	5.1	0.1	4.5	30.0	65.2	0
5	0, 5, 10, 15	6.7	6.1	2.5	5.6	0.2	4.6	31.8	63.3	0
10	0, 5, 10, 15	4.5	7.4	2.4	5.3	0	3.0	30.1	66.8	0
15	0, 5, 10, 15	9.3	9.2	2.6	5.8	0	2.8	33.3	63.8	0
P		<.001	<.001	NS	NS	NS	NS	NS	NS	-
LSD 5%		2.58	2.23							
0, 5, 10, 15	0	5.3	2.0	2.4	5.3	0.2	4.4	30.9	64.3	0
0, 5, 10, 15	5	5.6	4.0	2.5	5.5	0.1	4.2	32.8	62.8	0
0, 5, 10, 15	10	4.8	8.0	2.4	5.4	0	3.1	30.6	66.2	0
0, 5, 10, 15	15	6.1	13.0	2.3	5.6	0	3.3	30.9	65.8	0
P		NS	<.001	NS	NS	NS	NS	NS	NS	-
LSD 5%			2.23							

- Skinning 30d post lifting was significantly increased by 5, 10 or 15 minutes of tumbling compared to the control
- Skinning 90d post lifting was significantly increased by 10 or 15 minutes of tumbling compared to the control
- Tumbling timing or duration had no significant affect on weight loss or sprout development

Table 1.2 Results of skin quality trial 1011 T 223 factorial analysis
Variety: 10-DR-161
Planted: 18 Sep 2010
Lifted: 10 Mar 2011

1st Tumble Duration Mins	2nd Tumble Duration Mins	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Shoot ¼	Shoot ½	Shoot ¾	Shoot 1	Shoot >1
0	0, 5, 10, 15	0.1	8.0	2.4	6.1	0.06	2.9	27.5	67.3	1.7
5	0, 5, 10, 15	0.3	19.3	2.4	6.1	0	1.7	28.3	66.8	2.0
10	0, 5, 10, 15	2.9	19.1	2.6	6.5	0	1.2	26.6	69.4	1.5
15	0, 5, 10, 15	5.1	23.9	2.4	6.2	0	1.1	27.2	68.6	1.1
P		<.001	<.001	NS	NS	NS	.025	NS	NS	NS
LSD 5%		0.76	4.10				1.26			
0, 5, 10, 15	0	2.3	0.1	2.3	5.8	0	2.8	30.1	64.2	1.9
0, 5, 10, 15	5	2.1	18.0	2.5	6.3	0	0.1	29.6	68.6	1.1
0, 5, 10, 15	10	2.1	21.5	2.4	6.3	0.06	3.0	25.6	69.1	1.1
0, 5, 10, 15	15	1.8	31.4	2.5	6.5	0	0.9	24.2	70.2	2.1
P		NS	<.001	NS	.024	NS	<.001	NS	NS	NS
LSD 5%			4.10		0.47		1.26			

- Skinning 30d post lifting was significantly increased by 10 or 15 minutes of tumbling compared to the control
- Skinning 90d post lifting was significantly increased by 5, 10 or 15 minutes of tumbling compared to the control
- Tumbling timing or duration had no significant affect on weight loss or consistent affect on sprout development

Table 1.3 Results of skin quality trial 1011 T 252 factorial analysis
Variety: 10-SP-181A
Planted: 25 Sep 2010
Lifted: 27 Feb 2011

1st Tumble Duration Mins	2nd Tumble Duration Mins	30d Skin %	90d Skin %	30-90d Weight Loss %	90-150d Weight Loss %	Shoot ¼	Shoot ½	Shoot ¾	Shoot 1	Shoot >1
0	0, 5, 10, 15	0	9.2	2.2	5.7	0	2.5	37.0	59.9	0.4
5	0, 5, 10, 15	1.5	11.0	2.5	6.3	0	1.3	35.8	62.6	0.2
10	0, 5, 10, 15	4.4	14.0	2.5	6.4	0	1.8	33.8	63.9	0.3
15	0, 5, 10, 15	6.8	16.7	2.4	6.2	0	2.8	36.1	60.3	0.7
P		<.001	<.001	.019	.004	-	NS	NS	NS	NS
LSD 5%		0.88	2.98	0.26	0.39					
0, 5, 10, 15	0	3.2	0.6	2.1	5.8	0	1.5	37.2	60.6	0.6
0, 5, 10, 15	5	3.2	8.4	2.5	6.1	0	2.2	34.8	62.5	0.5
0, 5, 10, 15	10	3.1	15.7	2.4	6.3	0	2.2	37.8	59.4	0.5
0, 5, 10, 15	15	3.2	26.3	2.5	6.5	0	2.6	33.0	64.2	0.2
P		NS	<.001	.010	.005	-	NS	NS	NS	NS
LSD 5%			2.98	0.26	0.39					

- Skinning 30d post lifting was significantly increased by 5, 10 or 15 minutes of tumbling compared to the control
- Skinning 90d post lifting was significantly increased by 5, 10 or 15 minutes of tumbling compared to the control
- Tumbling timing or duration had no significant affect on weight loss or sprout development

Table 1.4 Results of skin quality trial 1011 T 236 factorial analysis
Variety: 10-SP-317A (no MH30) – red OP
Planted: 14 Sep 2010
Lifted: 14 Feb 2011

1st Tumble Duration Mins	2nd Tumble Duration Mins	30d Skin %	90d Skin %	30-90d Weight Loss %	90-150d Weight Loss %	Shoot ¼	Shoot ½	Shoot ¾	Shoot 1	Shoot >1
0	0, 5, 10	1.3	13.3	2.2	5.6	0	0.4	24.5	64.1	11.0
5	0, 5, 10	7.4	18.0	2.0	5.3	0	2.0	23.5	62.9	11.5
10	0, 5, 10	13.3	28.5	2.0	5.2	0	1.0	18.7	68.3	11.9
P		<.001	<.001	NS	NS	-	NS	NS	NS	NS
LSD 5%		1.77	4.57							
0, 5, 10	0	7.8	3.1	2.2	5.4	0	0.6	23.6	62.9	12.9
0, 5, 10	5	7.9	18.5	2.0	5.3	0	1.3	22.9	65.4	10.4
0, 5, 10	10	6.4	38.1	2.0	5.5	0	1.6	20.2	67.0	11.2
P		NS	<.001	NS	NS	-	NS	NS	NS	NS
LSD 5%			4.57							

- Skinning 30d post lifting was significantly increased by 5 or 10 minutes of tumbling compared to the control
- Skinning 90d post lifting was significantly increased by 5 or 10 minutes of tumbling compared to the control
- Tumbling timing or duration had no significant affect on weight loss or sprout development

Table 1.5 Results of onion firmness trial 1011 V 253
Variety: Canterbury
Planted: 26 Sep 2010
Lifted: 9 Feb 2011

Variety	30d Firm @ 8mm PSI	90d Firm @ 8mm PSI	90d Firm @ 1.5mm PSI	160d Firm @ 8mm PSI
10-DR-161	10.7	10.8	2.68	11.0
10-SP-181	10.9	10.8	2.68	10.9
Arnie	11.0	10.8	2.59	11.0
Cabernet	10.8	10.7	2.76	10.8
Canterbury	11.0	10.9	2.67	11.0
Conan	10.9	10.7	2.54	10.9
Countach	10.9	10.8	2.58	10.8
Cricket	11.0	11.0	2.62	10.9
E 72.T 6001	10.9	10.9	2.67	11.1
E 72.T 6004	11.1	10.9	2.66	11.1
E 72.T 6074	11.0	10.9	2.76	11.0
Manuka	10.9	10.9	2.67	10.9
Red Shipper	10.7	10.7	2.68	10.7
Rugby	10.9	11.0	2.49	11.0
P	NS	NS	NS	NS
LSD 5%				

- Firmness of the bulbs did not differ significantly between varieties in either test method

Table 1.6 Results of onion firmness trial 1011 V 235
Variety: Canterbury
Planted: 9 Oct 2010
Lifted: 5 Mar 2011

Variety	30d Firm @ 8mm PSI	90d Firm @ 8mm PSI	90d Firm @ 1.5mm PSI	160d Firm @ 8mm PSI
10-DR-161	10.8	10.8	2.70	10.6
10-SP-211	10.8	10.8	2.78	10.6
Arnie	10.9	10.5	2.61	10.6
Cabernet	11.0	10.7	2.77	10.7
Canterbury	10.9	10.9	2.81	10.8
Conan	10.9	10.7	2.80	10.6
E 72.T 6001	11.0	10.8	2.74	10.8
E 72.T 6004	10.9	10.7	2.70	10.6
E 72.T 6074	10.8	10.8	2.69	10.7
Manuka	11.0	10.7	2.79	10.7
Red Shipper	10.8	10.6	2.82	10.7
Rugby	11.0	10.8	2.80	10.8
P	NS	NS	NS	NS
LSD 5%				

- Firmness of the bulbs did not differ significantly between varieties in either test method

Table 1.7 Results of onion firmness trial 1011 V 333
Variety: Canterbury
Planted: 29 Sep 2010
Lifted: 28 Feb 2011

Variety	30d Firm @ 8mm PSI	90d Firm @ 8mm PSI	90d Firm @ 1.5mm PSI	160d Firm @ 8mm PSI
10-DR-161	10.8	10.5	2.76	10.8
10-SP-211	10.9	10.8	2.74	10.8
Arnie	10.8	10.8	2.78	10.7
Cabernet	10.8	10.8	2.69	10.6
Canterbury	11.0	10.8	2.83	10.8
Conan	10.7	10.7	2.78	10.8
E 72.T 6001	11.0	10.7	2.85	10.7
E 72.T 6004	10.9	10.9	2.84	10.6
E 72.T 6074	10.9	10.5	2.66	10.9
Manuka	11.0	10.8	2.74	10.7
Red Shipper	10.9	10.9	2.73	10.6
Rugby	10.8	10.8	2.80	10.6
P	NS	NS	NS	NS
LSD 5%				

- Firmness of the bulbs did not differ significantly between varieties in either test method

Table 1.8 Results of onion skin strength and scale texture variety trial 1112 V 109
Variety: Baron
Planted: 17 July 2011
Commercial Crop Lifted: 20 Jan 2012

Variety (Bag ID)	Skin Strength Average N	% samples SS <40N	% samples SS <50N	% samples SS <60N	% samples SS <70N	Scale Texture Average mJ	% samples ST <40mJ	% samples ST <50mJ	% samples ST <60mJ	% samples ST <70mJ
11-DR-211	84.7	0	2.5	12.5	20	72.1	0	0	17.5	40
11-SP-162	71.4	7.5	17.5	32.5	45	67.9	0	5	20	57.5
Baron	91.2	0	7.5	10	15	78.9	0	0	2.5	17.5
Cabernet	48.4	40	55	80	87.5	63.3	0	2.5	35	87.5
Cowboy	67.4	0	10	35	60	62.4	0	5	40	80
Perez	77.8	2.5	5	17.5	25	75.3	0	0	5	25
Pinotage	45.8	35	62.5	87.5	100	56.5	2.5	15	75	95
Python	74.3	0	2.5	12.5	45	73.4	0	2.5	10	37.5
Red Shipper	48.9	17.5	60	82.5	95	70.2	0	0	12.5	55
Rugby	57.6	5	35	60	82.5	63.9	2.5	5	32.5	80
T6074	74.1	0	2.5	15	40	67.2	0	2.5	17.5	60
Thesis	50.3	17.5	52.5	77.5	92.5	77.5	0	0	0	25
P	<.001	<.001	<.001	<.001	<.001	<.001	NS	.005	<.001	<.001
LSD 5%	9.37	14.9	21.4	24.8	23.3	5.78		7.70	18.9	25.5
R^2 with 90d % Skinning	.37	.14	.30	.39	.44	.38	.36	.16	.34	.47

- Skin Strength/SS = Peak in load between skin surface and 10mm into bulb, measured in newtons (N), 3mm diameter flat end round probe
- Scale Texture/ST = Area under load from 6mm to 11mm, measured in millijoules (mJ), 3mm diameter flat end round probe
- 10 bulbs were sampled from each replicate prior to tumbling, 30-40days post lifting
- Skin strength and skin texture were significantly different between some varieties
    - The 3 red varieties all had an average skin strength significantly lower than all bar 2 of the brown onions; Rugby & Thesis
- The proportion of samples below each threshold for skin strength was significantly different between some varieties
- The proportion of samples below 3 of the thresholds for scale texture was significantly different between some varieties
    - 2 of the 3 red varieties are easily identified in the "% samples SS<40N" column, as they are the only varieties with a high proportion of samples with skin strength below 40N
    - Red Shipper had a skin profile more like a brown onion than a red onion at 90 days post lifting
- There were no moderate or strong correlations between any of the measures of skin strength or skin texture and skinning 90 days post lifting

Table 1.9 Results of onion skin strength and scale texture variety trial 1112 V 219
Variety: 10-SP-181A
Planted: 25 August 2011
Commercial Crop Lifted: 11 Feb 2012

Variety (Bag ID)	Skin Strength Average N	% samples SS <40N	% samples SS <50N	% samples SS <60N	% samples SS <70N	Scale Texture Average mJ	% samples ST <40mJ	% samples ST <50mJ	% samples ST <60mJ	% samples ST <70mJ
10-SP-161A	77.7	5	10	15	30	71.4	0	5	15	42.5
10-SP-317A	40.5	45	82.5	92.5	95	60.6	5	17.5	50	87.5
Cabernet	33.1	80	87.5	100	100	56.4	0	20	70	97.5
Canterbury	66.3	2.5	15	37.5	62.5	67.5	0	5	17.5	65
Cricket	68.4	7.5	20	35	45	69.0	0	0	7.5	65
Kauri	60.8	7.5	32.5	52.5	72.5	73.4	0	0	12.5	40
Manuka	63.4	7.5	27.5	60	67.5	71.3	0	0	7.5	42.5
Pinotage	36.9	65	85	97.5	97.5	54.1	0	27.5	77.5	100
Plutonus	67.1	7.5	20	47.5	60	72.9	0	0	2.5	35
Red Shipper	42.0	47.5	72.5	90	97.5	65.8	0	5	30	70
Rhinestone	62.7	2.5	15	50	75	67.9	0	0	17.5	60
SA Brown	80.9	0	10	20	32.5	76.7	0	0	10	35
T6074	52.7	17.5	45	80	92.5	62.0	0	5	45	80
P	<.001	<.001	<.001	<.001	<.001	<.001	.005	<.001	<.001	<.001
LSD 5%	10.22	16.67	20.71	25.89	22.47	6.08	2.29	7.76	23.05	29.60
R^2 with 90d % Skinning	.77	.75	.84	.73	.56	.54	.10	.49	.53	.51

- Skin Strength/SS = Peak in load between skin surface and 10mm into bulb, measured in newtons (N), 3mm diameter flat end round probe
- Scale Texture/ST = Area under load from 6mm to 11mm, measured in millijoules (mJ), 3mm diameter flat end round probe
- 10 bulbs were sampled from each replicate prior to tumbling, 30-40days post lifting
- Skin strength and skin texture were significantly different between some varieties
    - The 4 red varieties all have an average skin strength significantly lower than all of the brown onions
- The proportion of samples below each threshold for skin strength was significantly different between some varieties
- The proportion of samples below each threshold for scale texture was significantly different between some varieties
    - The 4 red varieties are easily identified in the "% samples SS<40N" column, as they are the only varieties with a high proportion of samples with skin strength below 40N
- There were moderate to strong correlations between all of the measures of skin strength and skinning 90 days post lifting
- There were marginally moderate correlations between 3 of the measures of skin texture and skinning 90 days post lifting

Table 1.10 Results of onion skin strength and scale texture variety trial 1112 V 223
Variety: 09-DR-180
Planted: 2 September 2011
Commercial Crop Lifted: 14 Feb 2012

Variety (Bag ID)	Skin Strength Average N	% samples SS <40N	% samples SS <50N	% samples SS <60N	% samples SS <70N	Scale Texture Average mJ	% samples ST <40mJ	% samples ST <50mJ	% samples ST <60mJ	% samples ST <70mJ
Cabernet	42.0	55	75	82.5	92.5	59.0	0	15	55	85
Canterbury	77.9	2.5	10	20	32.5	75.1	0	0	7.5	27.5
Cricket	81.6	0	5	15	27.5	63.6	0	0	32.5	80
Kauri	76.1	2.5	17.5	20	40	75.5	0	0	10	30
Pinotage	36.2	57.5	90	100	100	57.4	0	10	57.5	97.5
Plutonus	89.3	2.5	5	20	25	75.0	0	0	10	37.5
Red Shipper	45.9	37.5	65	82.5	90	74.5	0	0	5	27.5
Rhinestone	74.4	0	7.5	17.5	37.5	71.6	0	0	5	27.5
SA Brown	81.6	0	7.5	12.5	37.5	73.6	0	5	17.5	35
T6074	56.5	22.5	45	57.5	77.5	67.1	0	0	25	57.5
P	<.001	<.001	<.001	<.001	<.001	<.001	-	.005	<.001	<.001
LSD 5%	10.17	16.15	16.09	17.24	14.80	5.18		8.33	15.60	19.46
R^2 with 90d % Skinning	.70	.82	.79	.79	.70	.56	-	.38	.57	.57

- Skin Strength/SS = Peak in load between skin surface and 10mm into bulb, measured in newtons (N), 3mm diameter flat end round probe
- Scale Texture/ST = Area under load from 6mm to 11mm, measured in millijoules (mJ), 3mm diameter flat end round probe
- 10 bulbs were sampled from each replicate prior to tumbling, 30-40days post lifting
- Skin strength and skin texture were significantly different between some varieties
    - The 3 red varieties all have an average skin strength significantly lower than all bar 1 of the brown onions; T6074
    - Red Shipper had amongst the highest value for scale texture, indicating that it was as firm or firmer than all the brown onions
- The proportion of samples below each threshold for skin strength was significantly different between some varieties
- The proportion of samples below 3 of the thresholds for scale texture was significantly different between some varieties
    - The 3 red varieties are easily identified in the "% samples SS<40N" column, as they are the only varieties with a high proportion of samples with skin strength below 40N
- There were strong correlations between all of the measures of skin strength and skinning 90 days post lifting
- There were marginally moderate correlations between 3 of the measures of skin texture and skinning 90 days post lifting

Table 1.11 Results of onion skin strength and scale texture variety trial 1112 V 255
Variety: Canterbury
Planted: 13 September 2011
Commercial Crop Lifted: 20 Feb 2012

Variety (Bag ID)	Skin Strength Average N	% samples SS <40N	% samples SS <50N	% samples SS <60N	% samples SS <70N	Scale Texture Average mJ	% samples ST <40mJ	% samples ST <50mJ	% samples ST <60mJ	% samples ST <70mJ
10-SP-181A	73.8	5	15	25	42.5	69.0	0	2.5	15	55
10-SP-317A	37.9	67.5	90	95	95	59.2	0	15	57.5	87.5
Cabernet	39.9	50	82.5	97.5	100	61.4	0	0	52.5	87.5
Canterbury	74.5	2.5	12.5	17.5	45	71.8	0	0	5	47.5
Cricket	70.5	7.5	25	37.5	50	62.0	0	5	45	87.5
Kauri	73.0	0	10	27.5	45	71.8	0	0	10	47.5
Manuka	66.1	10	20	42.5	57.5	72.7	0	0	7.5	32.5
Murray Brown	87.1	0	7.5	12.5	22.5	72.5	0	0	15	52.5
Patterson	67.1	0	22.5	32.5	60	64.6	0	2.5	27.5	77.5
Pinotage	37.2	50	72.5	80	90	57.6	0	7.5	52.5	87.5
Plutonus	80.0	0	7.5	17.5	40	71.6	0	0	10	47.5
Red Shipper	42.1	42.5	72.5	87.5	95	72.4	0	0	10	42.5
Rhinestone	70.3	0	12.5	30	55	71.8	0	0	12.5	35
SA Brown	81.7	0	5	17.5	30	72.4	0	0	10	32.5
T6074	62.5	7.5	30	50	67.5	70.4	0	0	10	52.5
P	<.001	<.001	<.001	<.001	<.001	<.001	-	<.001	<.001	<.001
LSD 5%	11.66	24.20	23.74	27.01	25.51	4.93		9.10	22.68	18.94
R^2 with 90d % Skinning	.84	.77	.86	.81	.79	.50	-	.26	.46	.42

- Skin Strength/SS = Peak in load between skin surface and 10mm into bulb, measured in newtons (N), 3mm diameter flat end round probe
- Scale Texture/ST = Area under load from 6mm to 11mm, measured in millijoules (mJ), 3mm diameter flat end round probe
- 10 bulbs were sampled from each replicate prior to tumbling, 30-40days post lifting
- Skin strength and skin texture were significantly different between some varieties
  - The 4 red varieties all have an average skin strength significantly lower than all of the brown onions
  - Red Shipper had amongst the highest value for scale texture, indicating that it was as firm or firmer than all the brown onions
- The proportion of samples below each threshold for skin strength was significantly different between some varieties
- The proportion of samples below 3 of the thresholds for scale texture was significantly different between some varieties
  - The 4 red varieties are easily identified in the "% samples SS<40N" column, as they are the only varieties with a high proportion of samples with skin strength below 40N
- There were strong correlations between all of the measures of skin strength and skinning 90 days post lifting
- There were marginally moderate correlations between 1 of the measures of skin texture and skinning 90 days post lifting

Figure 1.1 Correlation between average skin strength (N) from all variety data combined from Tables 1.8-1.11, measured 30 days post lifting and skinning 90 days post lifting

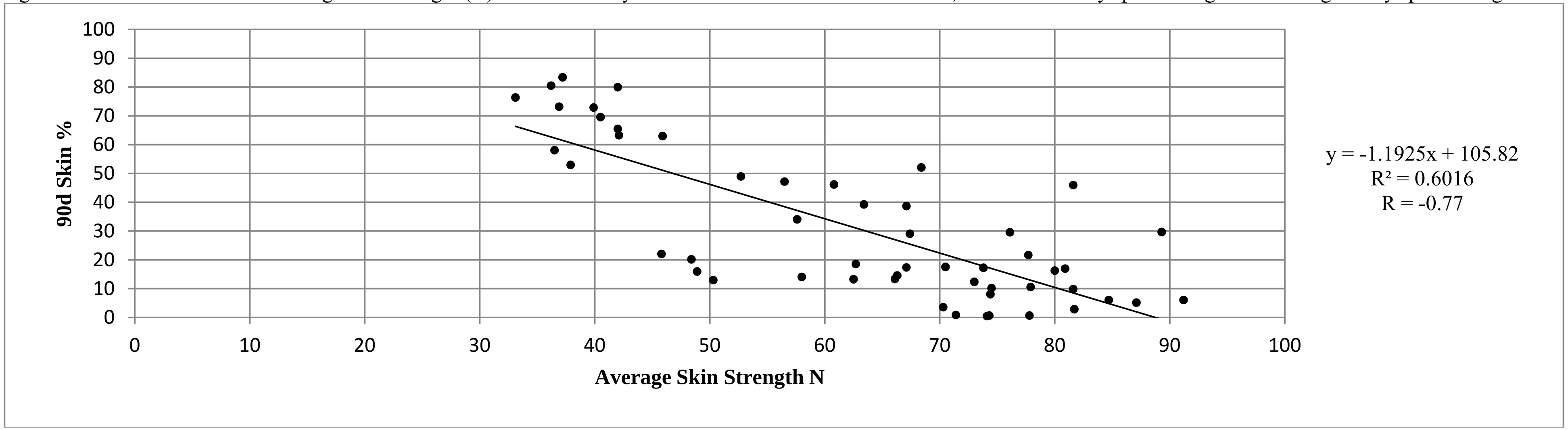


Figure 1.2 Correlation between average skin strength (N) measured 30 days post lifting and skinning 90 days post lifting, from 45 crops sown Jul-Sep, surveyed during 2011/12

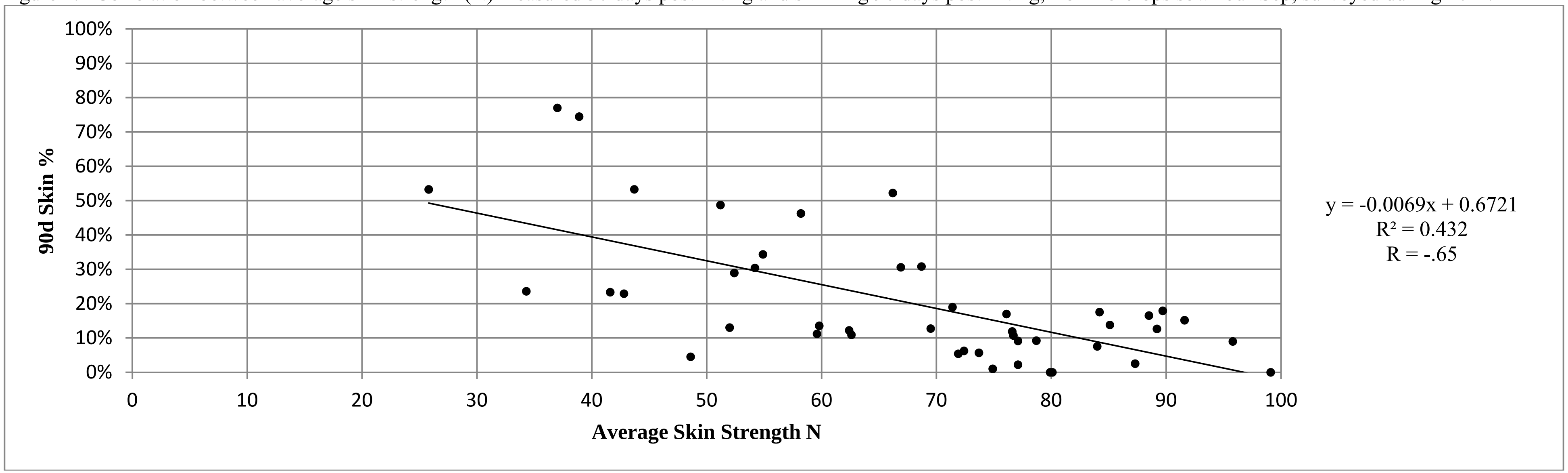
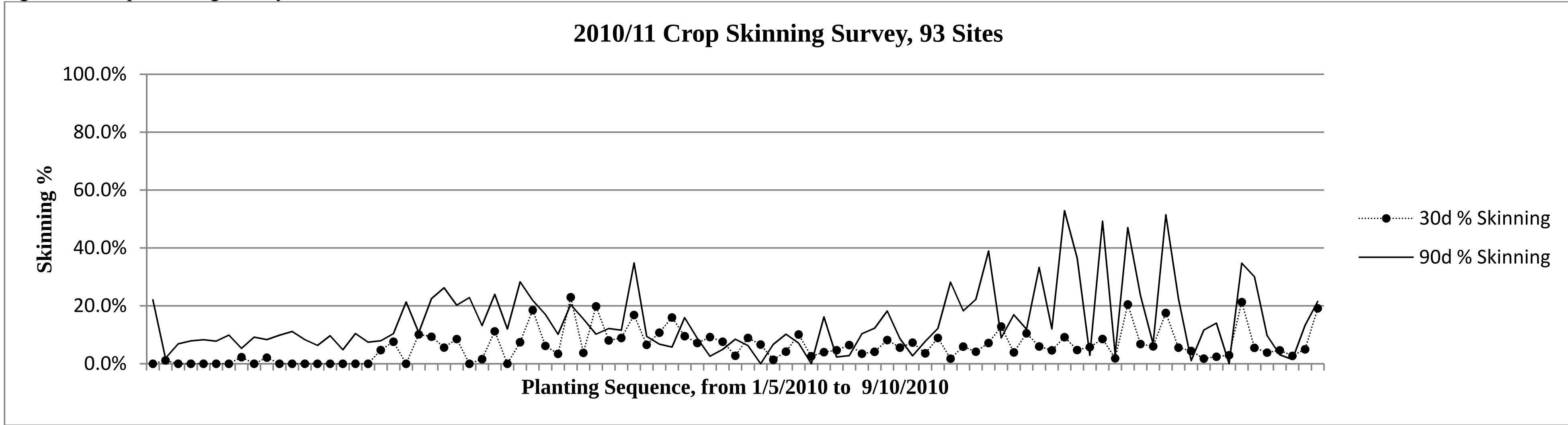
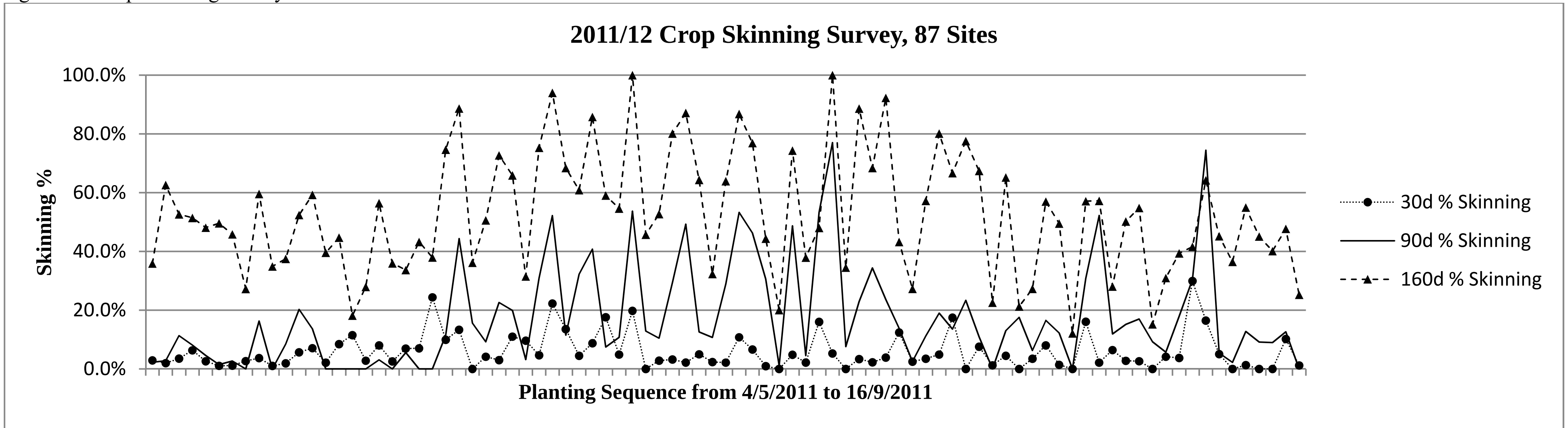


Figure 1.3 Crop Skinning Survey 2010/11



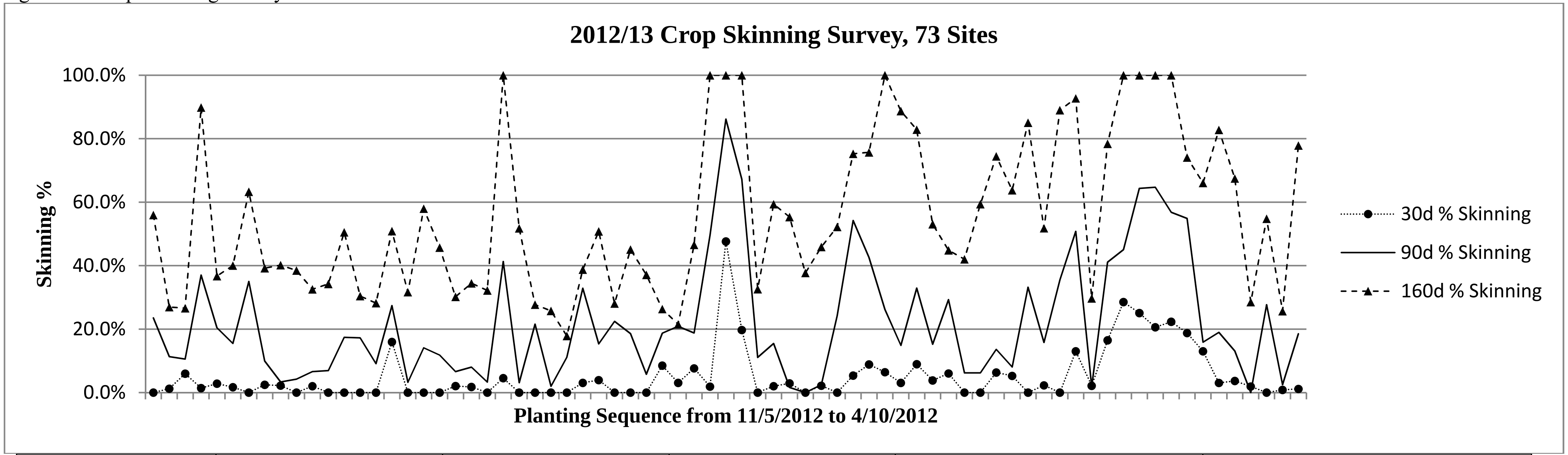
Correlation Factors	30d skin & 90d skin	30d skin & 160d skin	90d skin & 160d skin	90d skin & 30-90d Weight Loss	160d skin & 90-160d Weight Loss
2010/11 R^2	.17	-	-	.25	-

Figure 1.4 Crop Skinning Survey 2011/12



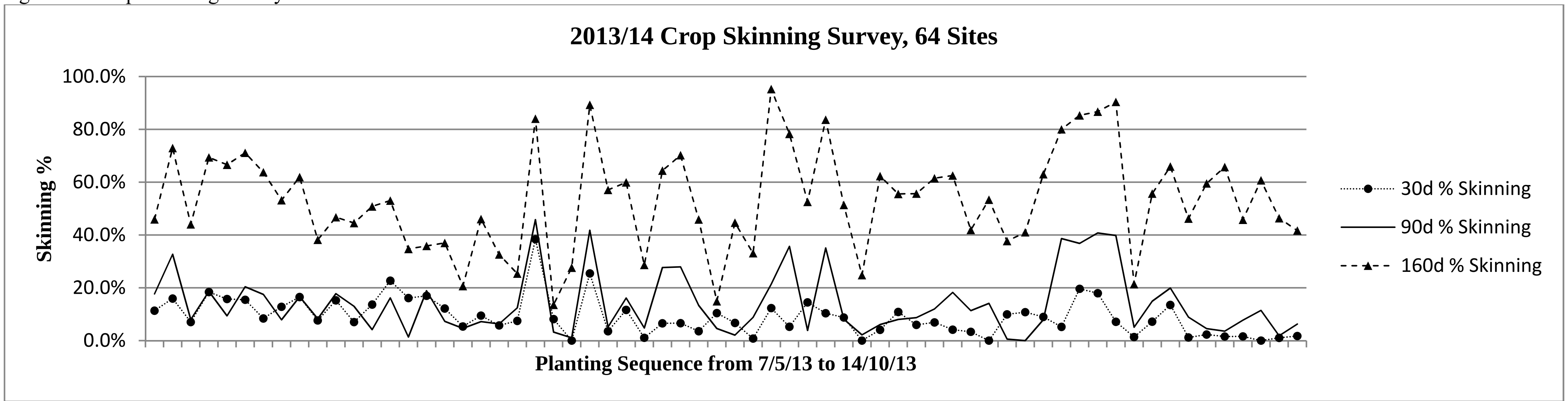
Correlation Factors	30d skin & 90d skin	30d skin & 160d skin	90d skin & 160d skin	90d skin & 30-90d Weight Loss	160d skin & 90-160d Weight Loss
2011/12 R^2	.12	.09	.48	.02	.31

Figure 1.5 Crop Skinning Survey 2012/13



Correlation Factors	30d skin & 90d skin	30d skin & 160d skin	90d skin & 160d skin	90d skin & 30-90d Weight Loss	160d skin & 90-160d Weight Loss
2012/13 R^2	.58	.34	.57	.08	.13

Figure 1.6 Crop Skinning Survey 2013/14



Correlation Factors	30d skin & 90d skin	30d skin & 160d skin	90d skin & 160d skin	90d skin & 30-90d Weight Loss	160d skin & 90-160d Weight Loss
2013/14 R^2	.26	.16	.59	.04	.02

Figure 1.7 Correlation between fast track 2nd skin assessment and 90 day SOAP from the 2012/13 crop survey

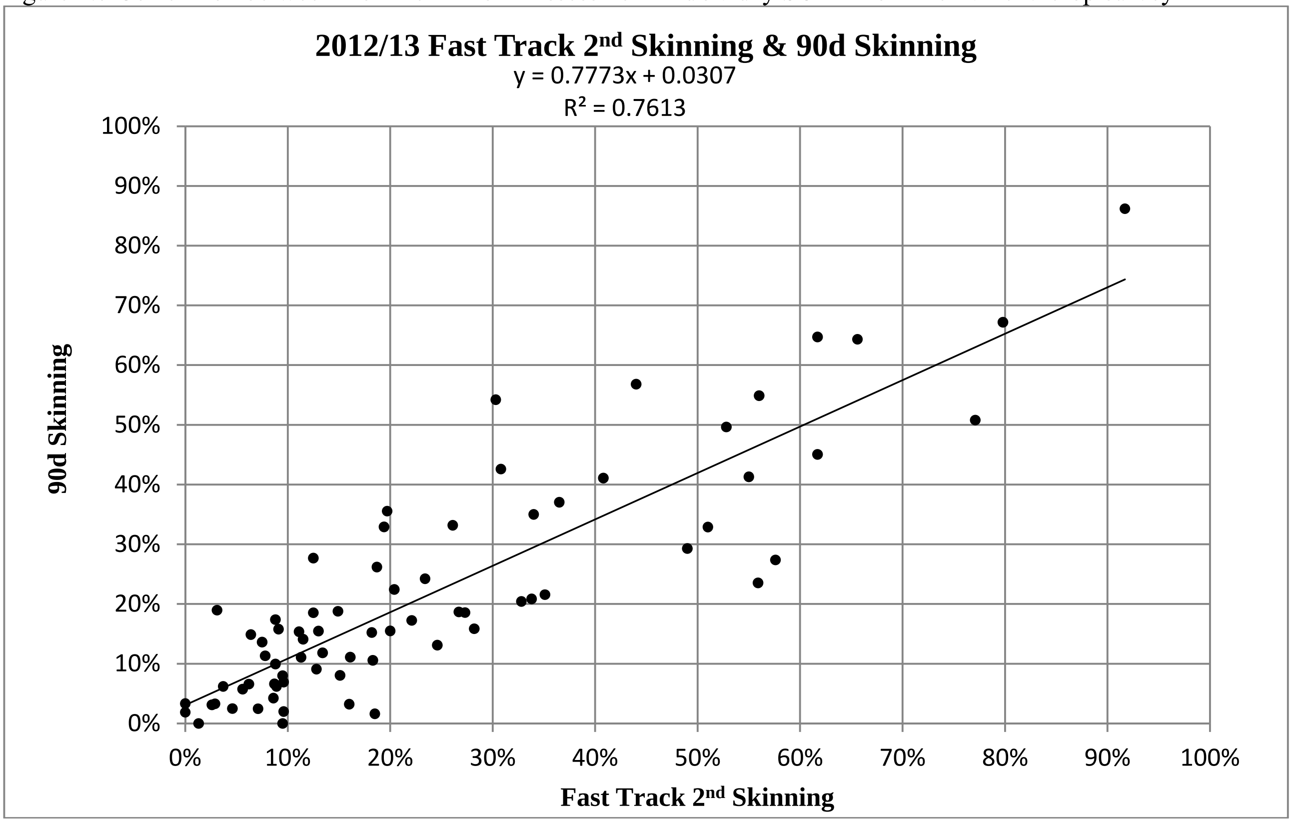


Figure 1.8 Correlation between fast track 1st skin assessment and 30 day SOAP from the 2012/13 crop survey

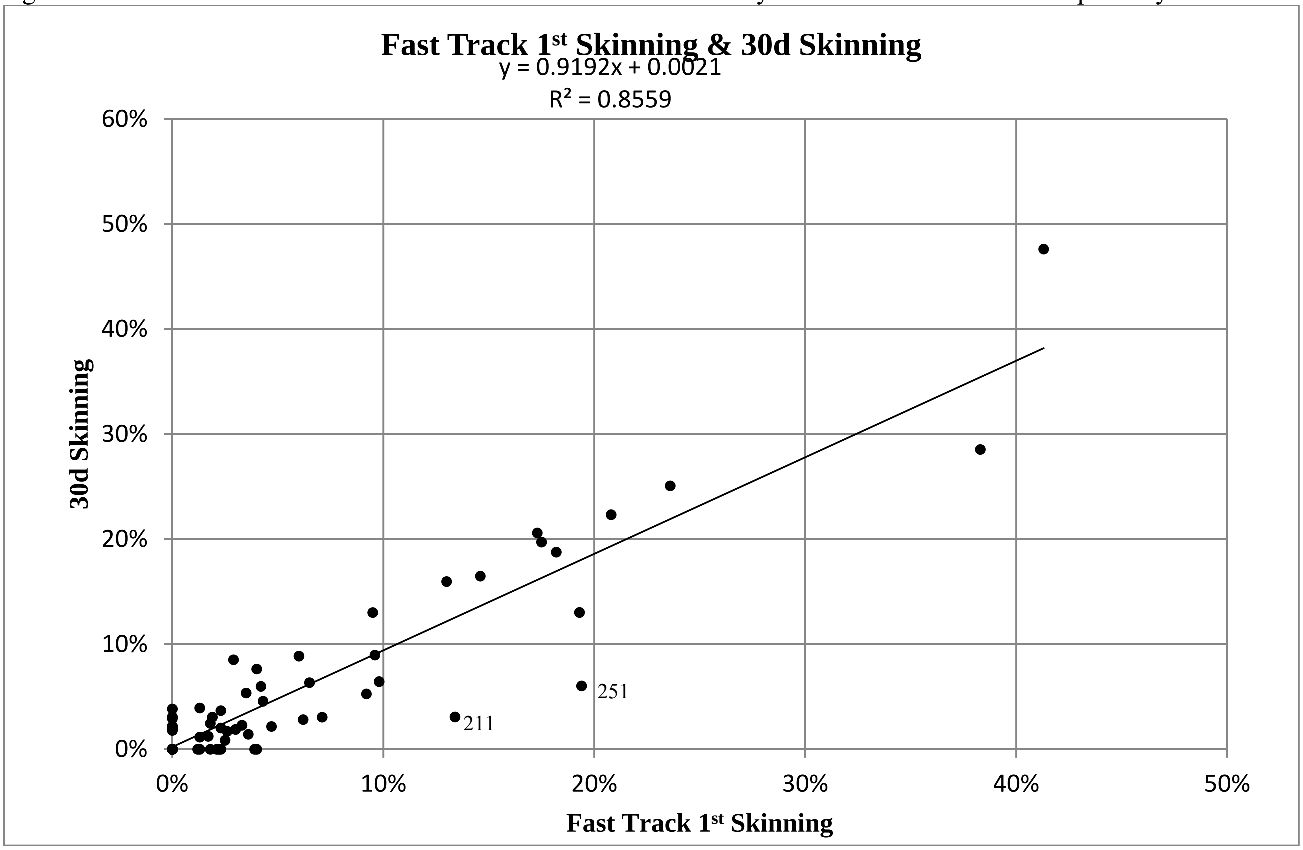


Figure 1.9 Modified correlation between fast track 1st skin assessment and 30 day SOAP from the 2012/13 crop survey

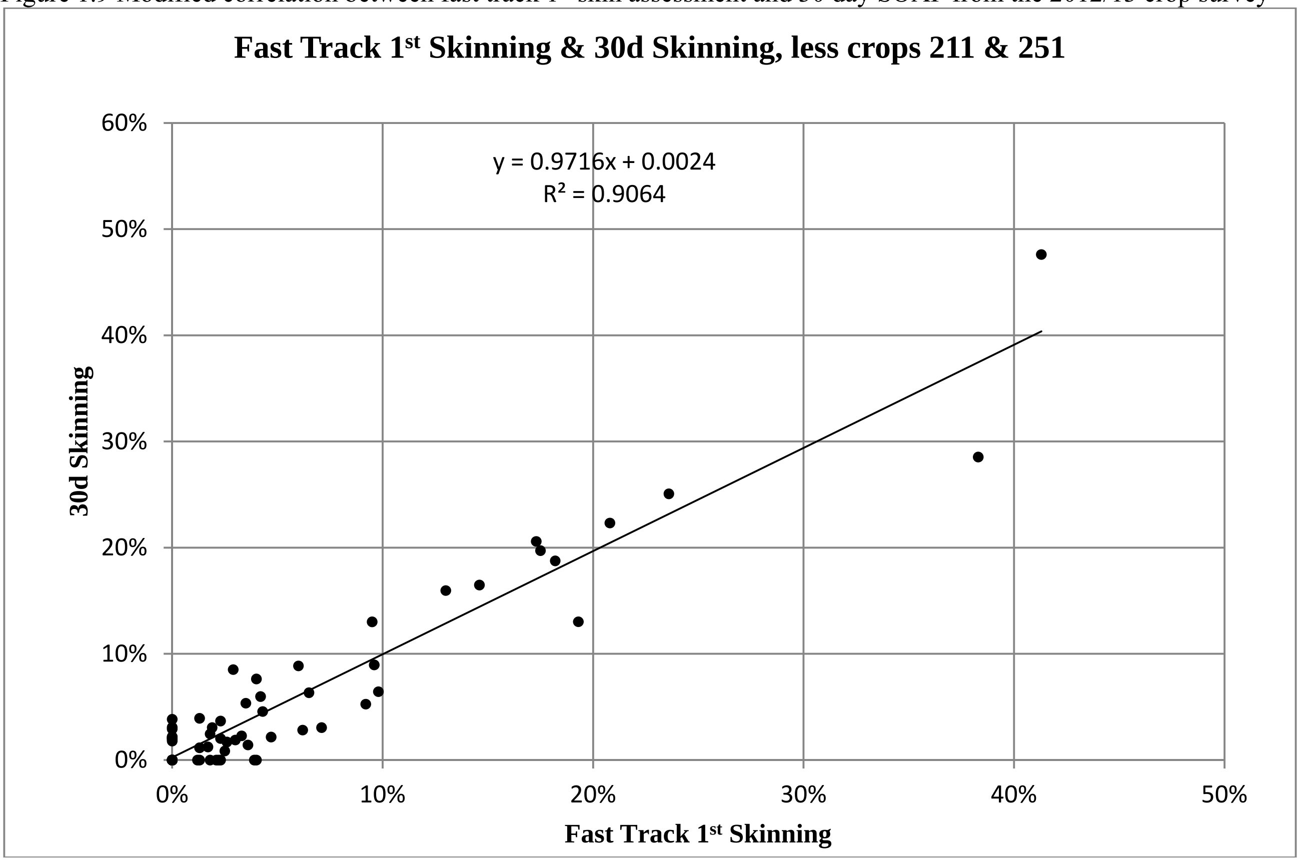


Figure 1.10 Correlation between fast track 2nd skin assessment and 90 day SOAP from the 2013/14 crop survey

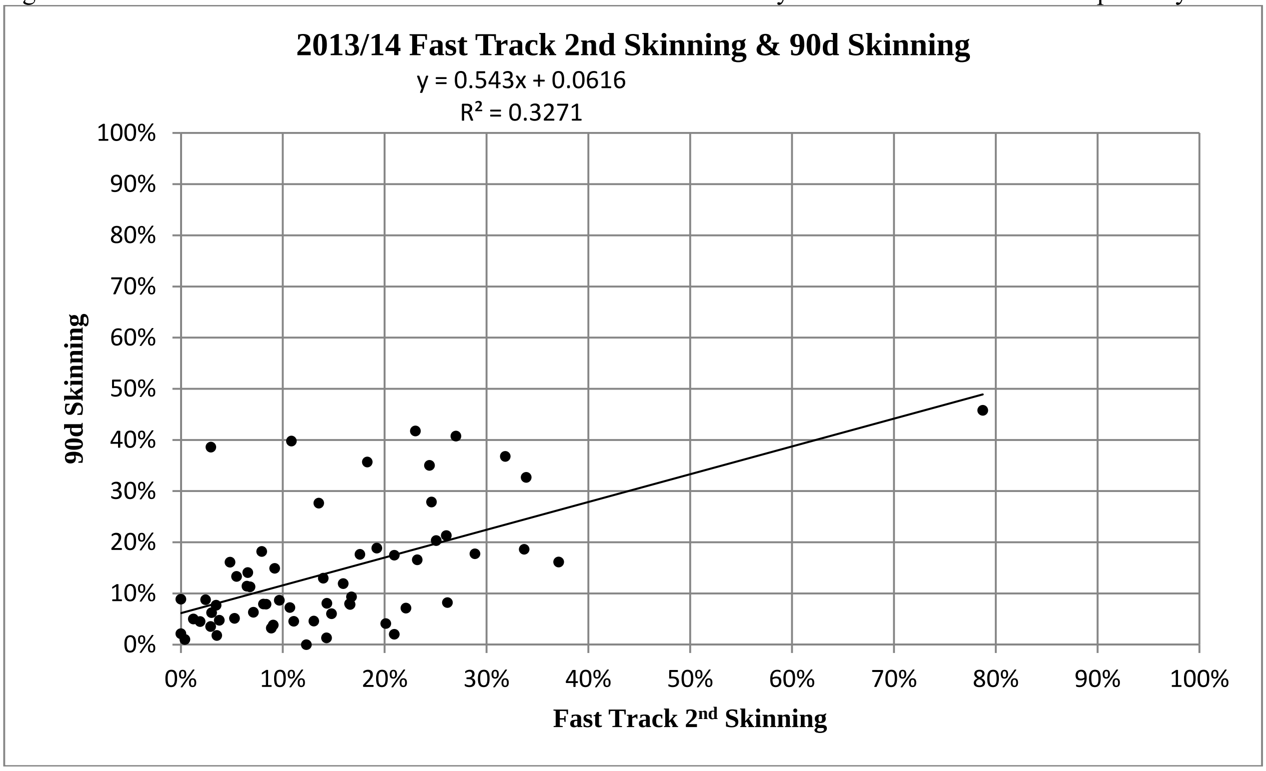


Table 1.12 Auto skinning trial results

Trial Reference	Variety	Crop	Pre Condition Time hrs	Treatments	Incubator Temp	Incubator Time hrs	Incubator %RH Range	Mins to assess	Main Sample % Split Bulbs	Main Sample % Split Bulbs >1mm	Main Sample Av Max Split Width >1mm	10 Bulb Av. % Increase in Diameter	10 Bulb Sample # Bulbs Split	10 Bulb Sample # Bulbs Split >1mm	10 Bulb Sample Av Max Split Width >1mm
17/07/2013	Baron	207	16	Tumble & Air	34	6	60-80	60	66.7%	58.3%	3	0.0%	6	4	4.2
17/07/2013	Baron	207	16	Tumble & NO Air	34	6	60-80	60	75.0%	75.0%	2.3				
17/07/2013	Baron	207	16	NO Tumble & Air	34	6	60-80	60	85.7%	85.7%	5.2				
17/07/2013	Baron	207	16	NO Tumble & NO Air	34	6	60-80	60	66.7%	50.0%	5.3				
19/07/2013	Baron	207	8	Tumble & Air	34	18	40-60	60	73.1%	50.0%	1.9				
19/07/2013	Baron	207	8	Tumble & NO Air	34	18	40-60	60	58.3%	41.7%	2.4				
22/07/2013	Baron	207	8	Tumble & NO Air	34	18	60-80	60	76.9%	61.5%	2.3				
23/07/2013	NZ103	103	Standard	nil	34	24	40-60	30	66.7%	46.7%	1.8	0.7%	7	6	2.2
23/07/2013	Python	207	Standard	nil	34	24	40-60	30	86.7%	73.3%	2.1				
24/07/2013	NZ103	103	Standard	nil	34	24	40-60	30	70.0%	53.3%	2.1	0.5%	8	6	2.9
24/07/2013	Python	207	Standard	nil	34	24	40-60	30	80.0%	63.3%	1.9				
25/07/2013	NZ103	103	Standard	nil	34	24	40-60	30	83.3%	66.7%	2.1	0.8%	8	6	1.9
25/07/2013	Goblin	207	Standard	nil	34	24	40-60	30	73.3%	53.3%	2				
26/07/2013	NZ103	207	Standard	nil	34	24	40-60	30	66.7%	53.3%	2.3	0.7%	8	6	3.2
26/07/2013	Goblin	207	Standard	nil	34	24	40-60	30	80.0%	63.3%	2.4				
27/07/2013	MDY	207	Standard	nil	34	24	40-60	30	63.3%	43.3%	2	0.8%	9	7	2.4
27/07/2013	Goblin	207	Standard	nil	34	24	40-60	30	83.3%	70.0%	1.7				
28/07/2013	Goblin	207	Standard	nil	34	24	40-60	30	76.7%	63.3%	1.8				
28/07/2013	MDY	207	Standard	nil	34	24	40-60	30	90.0%	83.3%	2.5				
29/07/2013	Goblin	207	Standard	nil	34	24	40-60	30	70.0%	50.0%	1.9				
29/07/2013	Python	207	Standard	nil	34	24	40-60	30	86.7%	70.0%	1.6				
30/07/2013	Goblin	207	Standard	nil	34	24	40-60	30	63.3%	56.7%	1.9				
30/07/2013	Python	207	Standard	nil	34	24	40-60	30	73.3%	63.3%	1.6				

2. Variety Evaluation

Purpose: To evaluate new varieties for suitability for export to Europe

Materials & Methods

Field Trials
A total of 46 varieties were compared in standard randomized block trials with 4 replicates. Two planting windows representative of current commercial drilling times were evaluated: Early (May) and Regular (Jul/Aug/Sep/Oct). Each plot was machine drilled using precision air drills, as per standard industry practice. Each plot was 2m long by 1.8m wide. Observation plots were used occasionally where there was insufficient seed supplied, but these trials were not included in the data analysis. All trials were located within commercial onion crops and were subjected to standard onion agronomy inputs.

Varieties assessed in the early planting window (May)

Variety	Company	Type
11-DR-211	FFT	Open pollinated
Atom	Takii	Hybrid
Enza	Enza	Hybrid
MDY	Seminis	Hybrid
NZ103	Ryan	Open pollinated
Pinotage	Terranova	Hybrid, Red
Python	Terranova	Hybrid
Toughball	Takii	Hybrid

Varieties assessed in the cream gold onion regular planting window (July/August/September/October)

Variety	Company	Type
211	FFT	Open pollinated
161	FFT	Open pollinated
162	FFT	Open pollinated
181	FFT	Open pollinated
19045	Seminis	Hybrid
Arnie	Terranova	Hybrid
Baron	Terranova	Open pollinated
Brown Keep	Seminis	Open pollinated
Canterbury	Seminis	Hybrid
Conan	Terranova	Hybrid
Cowboy	Bejo	Hybrid
Cricket	Clause	Hybrid
Goblin	Terranova	Hybrid
Kauri	Terranova	Hybrid
Manuka	Terranova	Hybrid
MDY	Seminis	Hybrid
MurrayBrown	Terranova	Open pollinated
Patterson	Bejo	Hybrid
Perez	Seminis	Hybrid
Plutonus	Terranova	Hybrid
R5592	Terranova	Hybrid
Python	Terranova	Hybrid
Rhinestone	Lefroy	Hybrid
Rugby	Clause	Hybrid
SA Brown	-	Open pollinated
T6001	Enza	Hybrid
T6004	Enza	Hybrid
T6074	Enza	Hybrid
Thesis	Bejo	Open pollinated
Yankee	Bejo	Hybrid

Varieties assessed in the red onion regular planting window (July/August/September/October)

Variety	Company	Type
10-SP-317A	FFT	Open pollinated
Cabernet	Terranova	Hybrid
Countach	Nunhems	Hybrid
Marenge	Nunhems	Hybrid
Pinotage	Terranova	Hybrid
Red Bull	Bejo	Hybrid
Red Shipper (CLX 111)	Clause	Hybrid
Vulcan	Fairbanks	Hybrid

All variety trials included internal standards or controls appropriate for each planting window, as follows:

- "211" an early cream gold open pollinated control variety for all May planted trials, representative of commercially available open pollinated lines.
- "161" a regular cream gold open pollinated control variety for all Jul/Aug planted trials, representative of commercially available open pollinated lines. In trials where "161" did not fully mature, "211" was used as the default control variety.
- "Canterbury" a late season hybrid cream gold control variety for all Sep/Oct planted trials; commercially available hybrid from Seminis.
- "Red Shipper" a hybrid red control variety for all red trials; commercially available hybrid from Clause.

The remainder of the varieties were a mix of open pollinated and hybrid onions, but not restricted to the cream gold genetic types that currently dominate exports; all onion seed suppliers and distributors in Tasmania were invited to submit commercial or near commercial lines for testing.

Throughout the term of the project there were 19 replicated trials harvested; 6 May planted trials, 6 July/August planted trials and 7 September/October planted trials. An additional 3 standard randomized block trials with 4 replicates were planted but 2 were not harvestable due to the damage caused by the disease onion white rot, and 1 was not analysed due to the level of tractor wheel damage.

The Standard Onion Assessment Protocol (SOAP) developed in this project (Chapter 1) was used throughout the variety trials for consistency of assessment. The SOAP was designed to be representative of industry practices, so that variety trial data could be directly extrapolated to commercial outcomes.

The density of 1m^2 of each plot was recorded at the 2-3 true leaf stage, as per standard industry practice.

Each plot of each variety was hand lifted within one week of reaching 80% tops down, to standardise maturity for the purposes of the variety trials. Varieties not maturing were labelled DNF (Did Not Finish); typically the tops of these varieties did not go down and bulb formation was incomplete. In the 2010/11 trials, soil moisture was recorded in each plot at the time of hand lifting with an Aquaterr 200, capacitive sensor (range 0-100%). Plots were field cured in the paddock as per standard industry practice.

Gross yield was measured in 2m^2 of each windrow within each trial plot once onions were fully cured; typically 14-21 days after lifting if May/Jun sown and 21-28 days after lifting if Jul/Aug or Sep/Oct sown.. The level of bolters was estimated in each plot at this time. 20L (10-11kg) of hand topped bulbs from each plot were sampled and removed to the controlled atmosphere storage facility for post harvest evaluation of skins, weight loss and sprouting. The following conditions were maintained: 21^{o}C and 60% RH from 6am to 6pm, and 11^{o}C and 80% RH from 6pm to 6am.

In the 2011/12 and 2012/13 trials, bulb colour of the cream gold onions was assessed on a scale from 1-3

- 1 = Paler than standard cream gold onion
- 2 = Standard cream gold onion
- 3 = Darker than standard cream gold onion

Skins were put under mechanical pressure using a method adapted from Hole et al. (2002). Our system used a 200L drum with two rubber ribs attached to the inside of the drum as per Gracie et al. (2006), rotating at 40rpm for 10 minutes for cream gold onions or 5 minutes for red onions. Two 20L (10-11kg) bags of samples were placed in the drum at a time. The measurement of skinning was defined to be representative of European customer standards where any amount of visible scale is classified as skinning, regardless of the cause (includes splits, cracks or shelling). Onion samples were put under mechanical pressure in the drum at strategic times to replicate standard times that commercial onions are exposed to skin pressure: namely 30-40 days post lifting which is representative of standard packing time, and 90-100 days post lifting which is representative of standard repacking time after arrival in Europe. In the 2011/12 and 2012/13 seasons, onions were tumbled for a third time and skinning evaluated at 160-170 days after lifting representative of long term storage and multiple handling of onions that occurs in difficult market seasons.

Weight loss was recorded at 90-100 days and 160-170 days post lifting, taking into account any losses due to disease.

Shoot development was measured at 160-170 days post lifting by cutting all onions in half and recording the relative shoot height within the bulb, from the bulb base to the top of the bulb shoulder as follows:

- 0 to ¼
- ¼ to ½
- ½ to ¾
- ¾ to 1
- >1

The data presented in the results tables is the average of the 4 replicates for each variety plus the outcome of the analysis of variance, using Genstat 13.

All variety trials are named with a four digit number for the year of the trial, such as 1011 for 2010/11, the letter V for variety trial, and a three digit code for the location, such as 106. Location codes represent the following areas in Tasmania

- 100-199 = Devonport
- 200-249 = Deloraine to Westbury/Hagley
- 250-299 = Longford
- 300-349 = Wynyard
- 350-399 = Forest/Smithton

European Market Assessment

Selected samples of 10kg of hand topped, hand graded and hand packed samples from the variety field trials were sent in commercial shipping consignments to Europe. The samples were stacked on top of the pallets at the door end of the container. Each sample was assessed for market acceptability by the European customer as per current industry standard for assessing onions in the market.

Market acceptability was rated as either excellent, good, pass or fail. This assessment is made from the point of view of the onion importer in Europe, and is representative of the end customer expectations.

Criteria included shape, firmness, skin colour, skin condition, internal colour, internal growth and an overall assessment.

In 2010/11 four red onion samples were sent in both a fantainer and a reefer (4^{o}C) to compare the two shipment methods. Cream gold early samples were sent in a separate shipment in a fantainer; however the samples were lost after arrival.

In 2011/12 six cream gold samples were sent to Norway in a fantainer and four red samples were sent in a reefer to the UK. In 2012/13 four cream gold samples were sent in a fantainer to Norway. A temperature and humidity data logger was included with the variety trial samples in the consignment sent to Norway for evaluation in 2011/12 and 2012/13. The data represents the return air as Fantainers use a positive pressure air flow system and the samples were located at the top of the load where the air exhausts.

Results

Field Trials
The data profiles presented in this report are the first time varieties have been evaluated using the new onion assessment protocol (SOAP) developed in this project (Chapter 1). Every variety that grew successfully has a complete production profile consisting of data including growing days relative to the control, bolters, density, gross yield, skinning, weight loss and shoot development (Tables 2.1-2.25). Information regarding trial site conditions and observations from the statistical analysis are located beneath each table, for ease and efficiency of reference.

Results are then aggregated across all years for each planting window in Table 2.26 for cream gold and red onions planted in May, Table 2.27 for cream gold onions planted in July to October and Table 2.28 for red onions planted in July to October.

Individual variety performance has been reviewed in detail for every variety that performed as well as the control in at least 4 trials, in terms of yield and skinning 90 days post lifting. These two parameters have been used as they provide industry with a quick and relevant reference to variety performance regarding yield and final quality when crops are repacked in Europe. Only varieties with at least 4 trial results comparable to the control have been reviewed to eliminate varieties that either did not perform well or varieties that were only planted in a few sites and therefore not exposed to a broad range of site conditions.

In the early planting window (May) there were no varieties with 4 or more trial results statistically comparable to the control (Table 2.26). All the early varieties evaluated either had significantly lower yield, significantly higher skinning or both (Table 2.26), except for one variety in one trial where yield and skinning were not significantly different from the control (Table 2.17). The consistent quality of skins of the control line is easily illustrated from the 6 trials analysed where the control skinning level was less than 20% at both 30 days and 90 days post lifting in 5 of the 6 trials (Tables 2.14 -2.19), and only went as high as 21.2% at 90 days post lifting in the remaining trial (Table 2.18). Weight loss 30-90 days post lifting was significantly lower than the control in 2 varieties in one trial (Table 2.17), otherwise weight loss was either statistically higher than the control or not different from the control (Tables 2.14-2.19). Visible shoot development to the point where a green shoot extended beyond the shoulder in the early cream gold varieties was not significantly different from the control (Tables 2.14-2.19).

The trial results have verified that the early cream gold standard, represented in these trials by the control variety “211”, is long established as the most reliable variety to plant in May to produce an onion with reasonable skins and shelf life suitable for export to Europe.

In the main cream gold planting window of July to October there were 5 varieties (Baron, Manuka, Plutonus, Rhinestone & T6074) with 4 or more trial results statistically comparable to the control (Table 2.27). Due to the duration of this planting window 2 controls were required in these variety trials; the regular open pollinated cream gold genetics represented in these trials by the control variety “161” for July/August sown trials and a later season cream gold hybrid variety Canterbury for September/October sown trials. The skinning level of the control variety “161”, or “211” where used by default, was less than 20% at both 30 days and 90 days post lifting in 5/6 trials (Table 2.27), and only went as high as 21.7% (Table 2.11) in the remaining trial. The skinning level of the control variety Canterbury was less than 20% at both 30 days and 90 days post lifting in 5/7 trials, and only went as high as 24.7% (Table 2.5) and 26.4% (Table 2.22) in the remaining 2 trials.

Baron yield was only significantly different from the control at 1/7 sites where the yield was lower than the control (Table 2.27). Skinning was not significantly different from the control at any site (Table 2.27). Skinning was <20% 30 days and 90 days post lifting at 6/7 sites (Table 2.27). Weight loss was only significantly different from the control at 1/7 sites, where weight loss 30-90 days post lifting was significantly higher than the control (Table 2.20). Visible shoot development to the point where a green shoot extended beyond the shoulder was not significantly different from the control at any site. The number of growing days compared to the “161” control was from 0 to 20 days earlier. The number of growing days compared to the Canterbury control was from 6 days earlier to 7 days later.

Manuka yield was only significantly different than the control at 1/8 sites, where the yield was higher than the control (Table 2.27). Skinning was only significantly different than the control at 1/8 sites, where skinning was higher than the control (Table 2.27). Skinning was <20% 30 days and 90 days post lifting at 5/8 sites (Table 2.27). Weight loss was only significantly different at 1/8 sites, where weight loss 30-90 days post lifting was lower than the control (Table 2.11). Visible shoot development to the point where a green shoot extended beyond the shoulder was not significantly different at any site. The number of growing days compared to the “161” control was from 0 to 12 days earlier. The number of growing days compared to the Canterbury control was from 0 to 14 days later.

Plutonus yield was not significantly different from the control at any of the 6 sites (Table 2.27). Skinning was significantly different from the control at 2/6 sites, where skinning was higher than the control at both sites (Table

2.27). Skinning was <20% 30 days and 90 days post lifting at 3/6 sites (Table 2.27). Weight loss was only significantly different from the control at 1/6 sites, where weight loss 30-90 days post lifting was higher than the control (Table 2.12). Visible shoot development to the point where a green shoot extended beyond the shoulder was not significantly different at any site. The number of growing days compared to the "161" control was the same. The number of growing days compared to the Canterbury control was from 7 to 21 days later.

Rhinestone yield was only significantly different from the control at 1/7 sites, where yield was lower than the control (Table 2.27). Skinning was only significantly different from the the control at 1/7 sites, where skinning was lower than the control (Table 2.27). Skinning was <20% 30 days and 90 days post lifting at all 7 sites (Table 2.27). Weight loss was only significantly different from the control at 1 site, where weight loss 30-90 days post lifting was significantly lower than the control (Table 2.11). Visible shoot development to the point where a green shoot extended beyond the shoulder was not significantly different at any site. The number of growing days compared to the "161" control was from 12 to 21 days earlier. The number of growing days compared to the Canterbury control was from 0 to 7 days later.

T6074 yield was significantly different from the control at 3/12 sites; at 2 sites the yield was lower than the control and at 1 site the yield was higher than the control (Table 2.27). Skinning was significantly higher than the control at 7/12 sites but was not significantly lower than the control at any site (Table 2.27). Skinning was <20% 30 days and 90 days post lifting at 7/12 sites (Table 2.27). Weight loss was only significantly different from the control at 1/12 sites, where weight loss 90-160 days post lifting was significantly higher than the control (Table 2.9). Visible shoot development to the point where a green shoot extended beyond the shoulder was not significantly different at any site. The number of growing days compared to the "161" control was from 0 to 21 days earlier. The number of growing days compared to the Canterbury control was from 6 days earlier to 7 days later.

The assessment of colour in the May planted early cream gold onion variety trials during the 2012/13 season revealed two varieties with colour consistently darker than standard cream gold in all five trial sites where the varieties grew successfully; Enaza and Python (Tables 2.14-2.19). Other early varieties with darker colour at only some of the sites included Atom at 2/6 sites, NZ103 at 3/4 sites and Toughball at 2/6 sites.

The assessment of colour in the Jul/Aug/Sep/Oct regular cream gold onion variety trials during the 2011/12 and 2012/13 seasons revealed three varieties with colour consistently darker than standard cream gold in all trial sites where the varieties were grown; Brown Keep at 3/3 sites (Tables 2.21-2.23) Python at 3/3 sites (Tables 2.9, 2.10, 2.20) and Thesis at 2/2 sites (Tables 2.9, 2.10). Other regular varieties with darker colour but only at some of the sites included Baron at 4/7 sites (Tables 2.9, 2.21-2.23), Cricket at 1/4 sites (Table 2.12), Goblin at 1/4 sites (Table 2.21), Kauri at 1/6 sites (Table 2.21), Manuka at 1/8 sites (Table 2.23), Plutonus at 2/6 sites (Tables 2.21, 2.22), R5592 at 1/2 sites (Table 2.23), Rhinestone at 3/7 sites (Tables 2.21-2.23), Rugby at 1/5 sites (Table 2.9), SA Brown at 2/4 sites where the variety fully matured (Tables 2.20, 2.12) and T6074 at 1/12 sites (Table 2.9).

Analysis of 3 paired sites reveals a trend towards more varieties developing darker colour at coastal sites compared to inland sites. The first pair of sites consists of site 109 (Table 2.9) which is a coastal site planted 17th July 2011 and site 211 (Table 2.10) which is an inland site planted 20th July 2011; there were 8 varieties common to both sites, 5 of these varieties developed darker colour than standard cream gold at the coastal site compared to 2 varieties at the inland site. The second pair of sites consists of site 107 (Table 2.21) which is a coastal site planted 19th August 2012 and site 207 (Table 2.20) which is an inland site planted 24th July 2012; there were 6 varieties common to both sites, 3 of these varieties developed darker colour than standard cream gold at the coastal site compared to no varieties at the inland site. The third pair of sites consists of site 313 (Table 2.22) which is a coastal site planted 12th September 2012 and site 256 (Table 2.23) which is an inland site planted 27th September 2012; there were 11 varieties common to both sites, 4 of these varieties developed darker colour than standard cream gold at the coastal site compared to 5 varieties at the inland site. Overall 48% of the varieties developed darker colour than standard cream gold at the coastal site compared to 28% of the varieties at the inland site.

Historically, the cream gold colour has been paler than long term stored European onions, and the relative paler and brighter appearance of the cream gold onions used to provide a strategic marketing advantage for Tasmanian grown onions to signal the arrival of fresh new season crop. In Australia however, the general preference is for darker skinned onions more typical of the old long term stored crop than the fresh appearance of the cream gold crop, resulting in the two markets being largely incompatible at least in terms of onion skin colour. However trends change, and in Europe there appears to be a movement more towards uniformity of product throughout the year, so the distinction and competitive advantage between old crop and new season crop is potentially being lost in some markets.

In the main red planting window of July to October there was one variety (Cabernet) with 4 or more trial results statistically comparable to the control (Table 2.28). Red Shipper was selected as the control for the red onion variety trials as the previous industry standard was considered marginal for Tasmania's day length, and produced inconsistent results.

Note that the Red Shipper control level of skinning was less than 20% at both 30 days and 90 days post lifting in 4/8 sites (Tables 2.3, 2.4, 2.9, 2.10), however at the other 4 sites the level of skinning was >50% at 90 day post lifting (Tables 2.5, 2.11, 2.12, 2.13). All other red varieties also had skinning levels >50% 90 days post lifting at these 4 sites. This level of inconsistency in skin quality at 90 days post lifting presents a major risk for exports to Europe under the current management protocols.

Cabernet yield was significantly different than the control at 2/8 sites, where yield was higher than the control at both sites (Table 2.28). Skinning was significantly different than the control at 2/8 sites, where skinning was higher than the control at both sites (Table 2.28). Skinning was <20% 30 days and 90 days post lifting at 1/8 sites (Table 2.28). Weight loss was not significantly different from the control at any of the 8 sites. Visible shoot development to the point where a green shoot extended beyond the shoulder was not significantly different at any sites. The number of growing days compared to the Red Shipper control was from 12 days earlier to 14 days later.

Pinotage did not have 4 or more trial results statistically comparable to the control, but was the only red included in the early planting window (May) trials. In the early planting window (May) trials Pinotage yield was significantly different from than the cream gold control in 2/5 sites, where yield was lower than the cream gold control (Table 2.26). Skinning was significantly higher than the cream gold control in all 5 sites, although in 2 of these sites the level of skinning was <20% at both 30 days and 90 days post lifting (Table 2.26). Weight loss 30-90 days post lifting was significantly different from the cream gold control in 3/5 sites, where weight loss was higher than the cream gold control (Tables 2.14, 2.15, 2.18).Weight loss 90-160 days post lifting was significantly different from the cream gold control in 4/5 sites, where weight loss was higher than the cream gold control (Tables 2.14, 2.15, 2.16, 2.17). Visible shoot development to the point where a green shoot extended beyond the shoulder was significantly different from the cream gold control at 1/5 sites, where shoot development was higher than the cream gold control (Table 2.17).

In the main red planting window of July to October, Pinotage yield was not significantly different from the Red Shipper control at any of the 5 sites (Table 2.28). Skinning was significantly higher at 3/5 sites but was not significantly lower than the control at any site (Table 2.28). Skinning was never <20% at both 30 days and 90 days post lifting at any of the 5 sites (Table 2.28). Weight loss was significantly higher at 1/5 sites (Table 2.12) at both 30-90 days and 90-160 days post lifting. Visible shoot development to the point where a green shoot extended beyond the shoulder was not significantly different at any sites. The number of growing days compared to the Red Shipper control was from 9 to 0 days earlier.

Although no shoot development was significantly different from the control, there were a number of trials where red varieties did develop an unacceptable level of visible shoots (Tables 2.4, 2.11, 2.12, 2.13), including the Red Shipper control in some trials.

European Market Assessment
Results from the 2010/11 comparison of reefer and fantainer trials of 4 red varieties sent to Europe (Table 2.29) revealed differences in market suitability, mostly between varieties rather than between the reefer and fantainer shipment options. "317" had better firmness and skin condition in the reefer; some mould was noted on the outer skins in the fantainer. "9005" performed the same in both shipping configurations. Red Shipper had poorer skins in the reefer. Cabernet had better skin condition and internal colour in the reefer. The overall assessment from the market was that reefer and fantainer conditions produced similar results, except skins were stronger in the reefer. The market assessment also confirmed suitability of Red Shipper, "9005" and potential for Cabernet.

Assessments of the 2011/12 cream gold onions varieties sent to Europe revealed variability in outcomes between sizes from the same variety, including from the same crop, and also variability between varieties (Table 2.30). From the market perspective 2 varieties (Kauri, Plutonus) were clearly identified as suitable while an additional variety (Manuka) had mixed results but was also clearly assessed as suitable (Table 2.30). One of the varieties (Rhinestone) that had produced very positive results in the field trials (Table 2.27) did not receive a positive market assessment; the issues identified were shape and internal growth. In the field trials only 1/7 sites recorded visible shoot development to the point where a green shoot extended beyond the shoulder with an average incidence of 0.6% (Table 2.11) which suggests only a single bulb out of 1 of the 4 replicates actually had a visible shoot; this would most likely be associated with disease. The concern over shape relates to the shoulder of the bulb in the context of mechanical peeling of onions; flatter shoulders result in more waste, but for retail markets this shape is not an issue, although the traditional globe shape is still preferred.

The temperature and humidity conditions inside the shipping container at the top of the load were logged during the 2011/12 shipment of cream gold trial samples to Europe (Figure 2.1). The results show the typical export pattern where temperatures at the start of the voyage were 15-20^{o}C and gradually rose to 30^{o}C as the voyage progressed through the tropics then rose to 30-33^{o}C through the Middle East, but then dropped to below 20^{o}C later in the voyage as the vessel approached Europe. Humidity conditions were more variable, but generally declined as the voyage progressed, starting at 70-90% RH and finishing at 40-70% RH. There was however a major anomaly recorded where both temperature and humidity fluctuated daily from 30-40°C and 40-85% RH respectively for a period of 10 days. The diurnal fluctuation in temperature and humidity from 12-22 May occurred when the container was in transit in Singapore. It is unknown if this fluctuation was associated with exposure of the container to full sun or a fan malfunction. Later in the voyage, the pronounced drop in humidity to 40% RH while the temperature was still 32°C likely occurred during transit through the Suez Canal. It is interesting to note that despite the broad range of conditions recorded during the voyage, the market assessment regarding quality was positive for many of the samples (Table 2.36).

Results from the 2011/12 reefer trial of 4 red varieties sent to Europe (Table 2.31) revealed differences in market suitability between varieties. Red Shipper and Cabernet were reconfirmed as suitable for the European market; the main concern with Pinotage was skin colour and skin condition. As with the field trials, the market assessments of the red onions produced variable results.

Red Shipper, Cabernet and Pinotage have shown potential for export to Europe; however under the conditions evaluated, all showed variable levels of risk with respect to skinning and shelf life. A new approach to red variety management is almost certainly needed to improve the consistency of outcomes of these red varieties if grown for export to Europe.

Assessments of the 2012/13 cream gold onions sent to Europe revealed variability within the same variety derived from different crops, although this may have been disease related (Table 2.32). From the market perspective one variety Kauri was clearly identified as suitable while an additional variety R5592 had mixed results but was also clearly assessed as suitable (Table 2.32). As per 2010/11 one of the varieties, Rhinestone that had produced very positive results in the field trials (Table 2.27) did not receive a positive market assessment; the issues identified were shape and internal growth, although in this instance the internal growth was a reference to a dry internal core or sheath typically associated with bolters. The variety Goblin also received a mixed market assessment, however one of the samples was from a crop affected by disease which could have influenced the market assessment; in this instance the disease was Botrytis which is typically symptom free at packing and manifests itself during the transit time to Europe.

The temperature and humidity conditions inside the shipping container at the top of the load were logged during the 2012/13 shipment of cream gold samples to Europe (Figure 2.2). As per 2011/12 the results show the typical export pattern where temperatures at the start of voyage were 15-20°C and gradually rose to 30°C as the voyage progressed through the tropics and through the Middle East, but then dropped to below 20°C later in the voyage as the vessel approached Europe. Humidity conditions were more variable, but generally declined as the voyage progressed, starting at 60-90% RH and finishing at 40-70% RH. Unlike 2011/12, there was no long transit in Singapore, and no major anomaly recorded where both temperature and humidity fluctuated daily from 30-40°C and 40-85% RH respectively as was the case in 2011/12. As per 2011/12, there was a pronounced drop in humidity to 40% RH while the temperature was still 30°C during the transit through the Suez Canal. Despite the broad range of conditions recorded during the voyage, the market assessment regarding quality was positive for many of the samples (Table 2.32).

Discussion

The data profiles presented in this report are the first time variety trials have been evaluated using the new assessment method developed in this project (Chapter 1).

The conditions recorded inside the shipping containers from both years highlight the need for onions to have a high degree of robustness to be suitable for export to Europe. The new assessment method developed in this project is providing insightful information about variety robustness and suitability for export to Europe, and better reflects industry commercial experiences, none more so than the introduction of the second skinning assessment which highlights the experience commonly encountered by industry where a variety may pack out well and have very little skinning but upon repacking in Europe can have a very high level of skinning even to the point of total rejection. Although there are other compounding factors (Chapters 3 & 4), variety selection is an important risk mitigation strategy for exporting, however variety alone does not ensure all risks are removed (Chapters 3 & 4). The new assessment method introduces a way to screen varieties that mirrors the timing of skinning pressure that commercial exports to Europe are put under.

Field Trials

Although no varieties were identified that were consistently better than the controls the cream gold variety trials have successfully identified a number of varieties with potential for export to Europe; Baron, Manuka, Plutonus, Rhinestone and T6074. The addition of these alternative varieties should help with risk mitigation especially in regard to seed availability. The reduced growing days identified in some of these varieties also reduces the risks associated with planting either at the end or towards the end of the planting windows, as crops are more likely to fully mature, senesce and cure normally.

The assessment of onion skin colour highlighted variability between sites and varieties, especially in the regular planting window from July to October. Further analysis of the data when grouped into paired sites revealed a trend towards varieties more likely to develop darker skin colour at coastal sites than inland sites. This observation is consistent with industry observation regarding stronger colour development at coastal sites amongst cream gold varieties. However if more Australian brown genetics were included, then the opposite trend would be expected owing to the greater heat units at inland sites during the maturity phase of the regulars.

The red variety trials have identified, or confirmed, a fundamental risk with red onions for export with regards to high risk of skinning and limited shelf life. Nonetheless, three red varieties have shown consistent promise for export to Europe; Red Shipper, Cabernet and Pinotage.

The inconsistency in results from some varieties between sites and seasons is highlighted in the aggregated results in Table 2.27. This has demonstrated the value of running variety trials over multiple locations and multiple planting times over multiple years to identify both the strengths and potential limitations of new varieties. In some trial sites such as those shown in Table 2.20 and Table 2.13 all varieties screened have performed as well as the control in terms of skinning, however the level of skinning was very low in both sites; on their own these sites provide very limited useful information due to the low skinning level, whereas at other sites such as shown in Tables 2.11 and 2.22 the skinning levels are much higher and any inherent skinning weakness of some of these varieties become apparent.

Another significant finding from the variety trials is the tremendous variation that occurred from site to site, clearly visible in the inconsistency shown in the aggregated results in Tables 2.26-2.28. This level of variation presents a large challenge to both researchers and industry. While some of the variation can be attributed to variety performance, there is clearly a major site contribution as well. Time of lifting and time on ground were all standardised in the variety trials to remove these sources of potential variation; in all the variety trials each individual variety plot was hand lifted within one week of 80% tops down and all varieties were harvested typically 14-21 days after lifting if May/Jun sown, and 21-28 days after lifting if Jul/Aug or Sep/Oct sown.

In this era of climate change, industry now has a choice to either continue older style variety screening programs, or introduce this new approach involving the combination of multi site, multi year and the new assessment protocol, to truly understand the strengths and weaknesses of new varieties under the broad range of conditions that industry now faces.

The stand out key to the new assessment method is the skinning assessment being done twice, 60 days apart, at 30 days post lifting and then again at 90 days post lifting, as this provides industry with an insight into how the varieties will perform upon repacking in Europe.

European Market Assessment

The European market assessments have provided some useful insights into the quality requirements of the end customer as well as the transit conditions onions experience in a shipping container.

Although the comparison between the reefer and fantainer did not demonstrate any major difference in condition of red onions upon arrival, another factor to be considered, but not covered in the scope of this project, is the potential for insect proliferation during transit especially by onion Thrips. At the reefer temperature, the Thrips life cycle is effectively suspended whereas in the ambient fantainer the Thrips life cycle continues and during the 6-8 week voyage another 2-3 generations can occur, potentially resulting in major Thrips levels and damage, even if the starting levels were low. To mitigate this risk, reefer shipments are the current preferred option for red onions despite the additional cost.

It is concerning that the market assessments in Europe were able to detect differences between samples of the same variety sourced from different crops. The variation between paddocks was clearly evident in the field trial results however it was not expected that this would carry right through to the market. The causes of the variation between paddocks would ideally be fully defined in order to better manage the production risks. Since curing practices were standardised in the variety trials, a likely source of variation between paddocks may be nutrition however this is not yet well defined (Chapter 3).

The broad range of temperature and humidity conditions experienced inside the container during fantainer shipments to Europe highlights the need for onions to be very robust to even be considered for export. These variable conditions present a major challenge to screening new varieties for suitability for export. The main current industry practice is to store new varieties at ambient conditions and attempt to make judgments about shelf life and robustness for export, but these conditions bear no resemblance to the actual conditions onions need to endure. The new assessment method used in this project, at least attempted to put the onions under daily pressure by having the different day/night settings for both temperature and humidity. This causes the onions to expand and shrink and the skins to dry and rehydrate every 24 hours. Although this is not intended as a voyage simulation, is does provide conditions to repeatedly put the onions under pressure both for skinning and sprout development, that would not occur using the older style assessment method of storing onions solely at ambient conditions.

Australian onion exports to Europe are mostly shipped in ventilated dry shipping containers using a configuration developed by the CSIRO in the 1980's. This ventilation system has a fundamental limitation in that there is only one ventilation configuration, regardless of the export destinations, shipping times, and crop conditions. During shipping the system is permanently on; drawing in ambient air at the same rate regardless of the ambient conditions; from monsoonal downpours in the tropics to 45^{o}C dry air in the Middle East.

The quality of product and environmental conditions at packing has been identified as a key risk factor by Field Fresh Tasmania. The final measure of quality is the customer pack out; it is worth noting that exporters are liable for this final pack out regardless of how customers may store and handle the product after arrival. The pack out measured by customers typically includes: skin colour (standard, above/below standard), skin retention (one complete skin after final packing), Penicillium blue mould, staining, disease, breakdown and internal growth (colour; customers cut bulbs and use internal sprout colour as an assessment of potential shelf life; Europe vertical cut; coloured sprout >50% customer likely to have concern for expected shelf life).

Standard or above standard product packed in standard or above standard conditions, typically results in a low risk of the shipping conditions adversely affecting product quality, however this scenario does not account for the majority of situations. Having either product or packing conditions below standard, typically results in a moderate risk of the shipping conditions adversely affecting product quality and likely represents a typical season. Having both product and packing conditions below standard, typically results in a high risk of shipping conditions adversely affecting product quality, and likely represents a situation where product should not be exported, as shipping conditions can't be expected to compensate for inherent risk factors.

Recommendations

It is recommended that varieties be screened in multiple trial site locations and planting times over at least 2 years, using the new standard onion assessment protocol (SOAP), developed in this project (Chapter 1). Key results will be consistency of performance and or identification of a variety's limitations; either is of value to industry. The main drawback with this recommendation is that it is very expensive and time consuming to carry out such comprehensive screening. However the risks involved with growing a new variety for export are high and warrant the additional effort.

It is also recommended that a new technique be used to assess onion sprouting. While cutting the onions from top to base and measuring the length of the sprout is standard procedure, in practice it can be very difficult to distinguish a sprout from a bladeless scale. It is recommended instead to only assess coloured sprouts, which typically range from pale yellow to green in colour. This allows for an easily repeatable measure of sprouting, and also better represents how customers typically measure sprouting as well; that is by the length of the coloured shoot.

The actual in market assessments are not recommended in future, owing to the high cost and limited detail information that can be obtained; in its place it is recommended that industry sponsored technical staff visit Europe to assess new varieties in collaboration with European customers to provide a more robust technical assessment of variety performance.

The cause of the tremendous variation between sites is worth intensive investigation, as this may hold the final key to truly restoring consistency to production and ensuring crops are suitable for export to Europe.

Finally, further work is recommended to better understand the influence of the transit conditions during shipping on onion quality. This area of research by its very nature is complex and will likely require a multi disciplinary approach, but given that the shipping ventilation method is largely unchanged since first developed in the 1980's there may be an opportunity to introduce new technology such as fan controllers that respond to both environmental conditions and conditions inside the container to improve the final outcome in Europe.

Table 2.1 Results for trial 1011 V 106
Commercial Crop Variety: 10-SP-211
Planted: 26 May 2010
Lifted: 9 Jan 2011

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Soil Moisture at 10cm	Density	Gross Yield/2m^2	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
											¼	½	¾	1	>1
07-SP-211	31 Dec	Control	0	52	102	8.7	0	6.5	0.9	3.0	4.0	24.7	50.6	20.6	0.1
08-BG-316	31 Dec	0	0	60	59	3.9	26.1	4.9	+0.7	5.1	0	8.9	48.4	42.7	0
EPLK	31 Dec	0	0	62	93	7.6	3.3	3.4	0.6	3.2	0	9.2	52.6	38.2	0
Cabernet	31 Dec	0	0	60	112	5.1	0	44.9	1.2	4.7	0	3.9	55.6	40.6	0
Cutlass	16 Dec	-15	0	75	90	4.5	3.6	13.8	2.4	2.7	0	0	20.0	80.0	0
M&R ECG	31 Dec	0	0	64	129	4.4	0	4.4	+2.0	4.5	0	9.5	52.3	38.2	0
Python	16 Dec	-15	0	75	76	6.0	11.5	4.7	2.3	2.3	0	3.7	18.4	78.0	0
Red Dragon	16 Dec	-15	0	75	76	4.4	35.0	51.8	4.4	3.4	0	11.1	31.6	57.3	0
R5583	16 Dec	-15	0	75	88	4.2	46.2	53.6	5.4	2.9	0	0	39.2	60.8	0
Shinto	Lost to tractor wheel damage														

- No statistical analysis for this trial as the design was observation plots with no replication; reds tumbled for 10 minutes
- Very poor site; yields and bulb size well below standard; extensive tractor wheel damage through trial site
- Not representative of typical growing conditions; varieties unlikely to have grown true to type
- Data excluded from the summary for the early planting window

Results Colour Key

(green)	Skinning <20% at both 30d post and 90d post lifting

Table 2.2 Results for trial 1011 V 110
Commercial Crop Variety: 10-DR-161
Planted: 28 Jul 2010
Lifted: 2 Feb 2011

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Soil Moisture at 10cm	Density	Gross Yield/2m^2	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
											¼	½	¾	1	>1
10-DR-161	4/2/11	Control	0	65	101.5	13.3	5.2	2.7	2.4	3.2	0	3.3	26.3	70.4	0
Baron	21/1/11	-14	0	48	91.8	11.1	0	1.6	2.2	2.8	0.2	8.5	42.2	49.0	0
Perez	15/1/11	-20	0	67	112.5	10.8	0.3	2.6	1.7	3.0	0	14.8	34.9	49.7	0.6
19045	7/1/11	-28	0	62	105.5	11.4	4.8	1.0	2.7	2.9	0	17.0	37.2	45.8	0
P					.044	.045	<.001	NS	NS	NS	NS	.016	NS	.024	NS
LSD 5%					13.95	1.82	2.17					8.40		16.21	

- Very firm soil by lifting; small canopy growth in trial area; canopy growth not representative of typical canopy growth for cream gold onions
- This type of "hard growth" typically produces bulbs with high skin quality and long storage life
- Yield was significantly different between some varieties
- The level of skinning was significantly different between some varieties, but only at 30 days post lifting
- Weight loss did not differ significantly between varieties
- Visible shoot development (>1) was not significantly different between varieties

Results Colour Key

(green)	Skinning <20% at both 30d post and 90d post lifting

Table 2.3 Results for trial 1011 V 253
Commercial Crop Variety: Canterbury
Planted: 26 Sep 2010
Lifted: 9 Feb 2011

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Soil Moisture at 10cm	Density	Gross Yield/2m^2	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
											¼	½	¾	1	>1
10-DR-161	12 Feb	6	0	51	52	10.1	21.9	0	2.4	2.1	0	2.4	38.1	59.4	0
10-SP-181	12 Feb	6	0	49	46	11.4	15.7	0	2.0	1.7	0	0	24.3	75.7	0
Arnie	3 Feb	-3	0	62	62	10.9	3.6	0.9	1.9	1.9	0	5.9	32.1	62.0	0
Cabernet	3 Feb	-3	0	62	55	12.9	7.2	7.7	2.8	1.6	0	11.2	28.5	60.3	0
Canterbury	6 Feb	Control	0	61	52	12.3	5.2	0	1.6	2.1	0	1.9	24.1	73.9	0
Conan	6 Feb	0	0	58	49	14.0	9.4	0	2.4	1.9	0	2.8	44.9	52.2	0
Countach	12 Feb	6	0	49	55	10.8	8.2	3.5	3.0	2.0	0	7.3	32.4	60.2	0
Cricket	9 Feb	3	0	52	42	10.9	5.9	4.0	2.2	1.6	0	0	20.5	79.5	0
E 72.T 6001	9 Feb	3	0	52	52	14.6	7.6	1.8	2.3	1.9	0	5.0	29.3	65.7	0
E 72.T 6004	9 Feb	3	0	53	51	12.9	15.0	0	2.9	1.9	0	4.9	23.6	71.4	0
E 72.T 6074	3 Feb	-3	0	62	54	13.5	4.8	0	1.9	1.8	0	4.4	34.1	61.5	0
Manuka	6 Feb	0	0	57	64	10.5	3.8	0	2.5	1.7	0	4.3	20.4	75.2	0
Red Shipper	9 Feb	3	0	51	52	12.3	10.9	0.9	2.7	1.6	0	17.7	32.6	49.7	0
Rugby	3 Feb	-3	0	62	51	13.4	4.4	7.0	1.1	1.7	0	0.7	34.5	64.8	0
P						.007	.053	NS	NS	NS	-	NS	.042	NS	-
LSD 5%						2.16	10.37								
Marenge	DNF		-	-	59	-	-	-	-	-	-	-	-	-	-

- Trial site located in a drier part of the paddock; conditions harder than standard
- Yield was significantly different between some varieties
- The level of skinning was significantly different between some varieties, but only at 30 days post lifting
    - High skinning incidence at 30 days post lifting of 10-DR-161 and 10-SP-181 may be due to immaturity of these varieties
    - Note that onions that skinned at the 30 day assessment were removed from the sample and not re assessed at the 90 day assessment
- Weight loss did not differ significantly between varieties
- Visible shoot development (>1) was not significantly different between varieties

Results Colour Key

(green)	Skinning <20% at both 30d post and 90d post lifting

Table 2.4 Results for trial 1011 V 333
Commercial Crop Variety: Canterbury
Planted: 29 Sep 2010
Lifted: 28 Feb 2011

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Soil Moisture at 10cm	Density	Gross Yield/2m^2	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
											¼	½	¾	1	>1
10-DR-161	10 Mar	16	0	57	58	13.1	10.2	14.8	1.8	4.5	0	0	18.1	81.1	0.7
10-SP-211	22 Feb	0	0	74	54	12.4	4.3	3.3	1.6	4.3	0	1.8	32.9	65.3	0
Arnie	22 Feb	0	0	78	58	12.4	10.8	8.6	2.7	5.3	0	1.2	25.1	73.6	0
Cabernet	22 Feb	0	0	76	63	14.2	6.5	36.2	2.4	5.2	0	1.4	19.6	73.3	5.7
Canterbury	22 Feb	Control	0	80	60	12.0	0	3.1	1.8	4.4	0	0	31.0	68.5	0.5
Conan	22 Feb	0	0	73	59	14.9	7.7	24.4	2.7	4.7	0	1.0	20.9	76.0	1.9
E 72.T 6001	3 Mar	9	0	68	59	11.9	13.1	7.2	2.7	4.0	0	0	15.7	80.6	3.6
E 72.T 6004	22 Feb	0	0	71	55	11.3	3.6	5.9	2.6	4.8	0	5.0	34.8	60.1	0
E 72.T 6074	22 Feb	0	0	76	45	14.0	3.2	19.1	2.2	3.4	0	2.5	23.6	73.9	0
Manuka	22 Feb	0	0	72	62	13.4	0.8	7.9	2.1	4.2	0	0.4	26.3	73.2	0
Red Shipper	3 Mar	9	0	76	55	11.0	19.7	13.4	2.6	4.6	0	0	15.3	83.7	1.0
Rugby	22 Feb	0	0	70	55	13.9	4.9	40.1	2.5	5.0	0	0	14.6	82.8	1.5
P						.006	<.001	<.001	NS	NS	-	NS	NS	NS	NS
LSD 5%						1.72	6.36	13.32							
10-SP-181	DNF		-	-	52	-	-	-	-	-	-	-	-	-	-
Countach	DNF		-	-	60	-	-	-	-	-	-	-	-	-	-
Marenge	DNF		-	-	58	-	-	-	-	-	-	-	-	-	-

- Trial site was exposed to high mildew pressure late in the season
- Yield was significantly different between some varieties
- The level of skinning was significantly different between some varieties, at both 30 and 90 days post lifting, with some varieties having very high skinning levels 90 days post lifting
  - High skinning incidence at 30 days post lifting of 10-DR-161 may be due to immaturity of this variety
  - Note that onions that skinned at the 30 day assessment were removed from the sample and not re assessed at the 90 day assessment
- Weight loss did not differ significantly between varieties
- Visible shoot development (>1) was not significantly different between varieties

Results Colour Key

(green)	Skinning <20% at both 30d post and 90d post lifting

Table 2.5 Results for trial 1011 V 235
Commercial Crop Variety: Canterbury
Planted: 9 Oct 2010
Lifted: 5 Mar 2011

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Soil Moisture at 10cm	Density	Gross Yield/2m^2	30d Skin%	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
											¼	½	¾	1	>1
10-DR-161	10 Mar	15	0	60	59	13.8	25.2	22.9	2.9	3.9	0	1.6	20.5	77.9	0
10-SP-211	23 Feb	0	0	71	54	10.9	12.6	28.4	2.1	4.1	0	0	23.6	75.5	0.8
Arnie	23 Feb	0	0	76	57	14.0	12.1	29.0	2.3	4.6	0	0	20.2	79.8	0
Cabernet	23 Feb	0	0	77	62	15.6	18.4	75.6	2.0	8.3	0	0	3.0	97.0	0
Canterbury	23 Feb	Control	0	72	51	13.8	5.1	24.7	2.0	3.1	0	0	17.0	83.0	0
Conan	23 Feb	0	0	68	52	10.8	19.4	36.1	2.9	4.8	0	0	18.2	81.8	0
E 72.T 6001	23 Feb	0	0	75	57	14.1	20.6	44.4	2.1	5.0	0	6.5	28.2	63.5	1.7
E 72.T 6004	23 Feb	0	0	77	63	13.2	8.2	40.2	2.9	4.3	0	0	39.0	61.0	0
E 72.T 6074	23 Feb	0	0	68	52	11.5	17.3	62.0	2.5	4.5	0	0	26.4	73.6	0
Manuka	23 Feb	0	0	74	60	15.4	4.1	37.4	1.7	6.8	0	1.4	35.7	62.8	0
Red Shipper	3 Mar	8	0	54	59	12.9	24.2	63.1	1.9	7.1	0	0	12.4	87.6	0
Rugby	23 Feb	0	0	72	55	15.0	20.8	73.6	1.8	8.4	0	3.7	18.4	77.8	0
P						<.001	.001	.021	NS	NS	-	NS	NS	NS	NS
LSD 5%						1.33	8.36	31.44							
10-SP-181	DNF		-	-	55	-	-	-	-	-	-	-	-	-	-
Countach	DNF		-	-	55	-	-	-	-	-	-	-	-	-	-
Marenge	DNF		-	-	60	-	-	-	-	-	-	-	-	-	-

- This site was planted towards the end of the currently recognised planting window for this variety, in a season where the crop was maturing in cool conditions
  - Early growth was slower than expected
- Yield was significantly different between some varieties
- The level of skinning was significantly different between some varieties, at both 30 and 90 days post lifting, with many varieties having extremely high skinning levels 90 days post lifting
  - High skinning incidence at 30 days post lifting of 10-DR-16 may be due to immaturity of this variety
  - Note that onions that skinned at the 30 day assessment were removed from the sample and not re assessed at the 90 day assessment
- Weight loss did not differ significantly between varieties
- Visible shoot development (>1) was not significantly different between varieties

Results Colour Key

	Skinning <20% at both 30d post and 90d post lifting

Table 2.6 Results for trial 1112 V 104
Commercial Crop Variety: 11-SP-211
Planted: 24 May 2011
Commercial Crop Lifted: 4 Jan 2012

Variety	Density	Gross Yield (2m^2)	% OWR
10-SP-317A	75.0	8.3	16.7
10-SP-161A	78.7	6.9	13.9
11-SP-162	70.5	9.1	13.3
11-SP-211	86.2	7.8	18.3
Baron	77.7	8.8	15.0
Electric	70.2	9.7	9.3
Perez	96.0	9.0	17.9
Pinotage	90.5	8.2	25.4
Python	103.8	8.1	18.6
Red Shipper	76.7	8.2	22.5
Thesis	102.5	7.2	33.7
P	<.001	NS	.001
LSD 5%	15.88		9.56

- This entire trial was not harvestable, due to severe onion white rot
- An assessment of onion white rot severity was completed on the varieties
  - Thesis had significantly higher disease incidence than all other varieties, however it also had the highest density, and high density is known to favour OWR

Table 2.7 Results for trial 1112 V 104 (adjacent trial)
Commercial Crop Variety: 11-SP-211
Planted: 24 May 2011
Commercial Crop Lifted: 4 Jan 2012

Variety	Date Lifted	Bolters %	Colour 30d	Density	Gross Yield/2m^2	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %
Baron	4 Jan	0	3	-	-	0	2.4	13.7	3.2	3.5
R5868 (Enza)	4 Jan	0	3	-	-	4.3	2.1	46.2	2.6	4.0
Pinotage	4 Jan	0	NA	-	-	3.3	38.8	73.9	3.4	4.9

- Observation plot variety trial (not replicated)
- Lifted with commercial crop, not when tops were 80% down, due to onion white rot impact masking tops down; no density nor yield data
- No sprouting data
- Note the consistently low skinning levels in Baron

Results Colour Key

(green)	Skinning <20% at both 30d post and 90d post lifting

Table 2.8 Results for trial 1112 V 105
Commercial Crop Variety: 10-DR-161
Planted: 13 Jul 2011
Commercial Crop Lifted: 25 Jan 2012

Variety	Gross Yield/2m^2
10-SP-317A	OWR
10-SP-161A	OWR
11-DR-211	OWR
11-SP-162	OWR
Baron	OWR
Cabernet	OWR
Cowboy	OWR
MDY (EXO7985905)	OWR
Perez	OWR
Pinotage	OWR
Python	OWR
Red Shipper	OWR
Rugby	OWR
T6074	OWR
Thesis	OWR

- The density was very erratic in this trial site, and unsuitable for comparing varieties
- This entire trial was not harvestable, due to late onset of onion white rot

Table 2.9 Results for trial 1112 V 109
Commercial Crop Variety: Baron
Planted: 17 July 2011
Commercial Crop Lifted: 20 Jan 2012

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Colour 30d	Density	Gross Yield/2m^2	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
												¼	½	¾	1	>1
10-SP-161A	DNF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10-SP-317A	DNF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11-DR-211	20 Jan	Control	0	2	55.5	12.8	0.4	6.1	54.0	2.0	3.9	0	4.6	34.7	60.2	0.2
11-SP-162	27 Jan	7	0	1.75	52.2	14.1	3.9	0.9	36.6	2.4	3.2	0	7.1	31.1	61.7	0
Baron	20 Jan	0	0	3	64.7	14.9	0	6.1	56.0	2.2	3.6	0	3.4	37.0	58.8	0.6
Cabernet	27 Jan	7	0	NA	43.2	16.5	4.0	20.2	93.0	2.0	3.3	0	20.9	36.8	41.4	0.8
Cowboy	27 Jan	7	0	2	43.0	14.4	14.5	29.1	70.4	2.9	4.2	0	0	13.4	83.1	3.3
Perez	13 Jan	-7	0	2	49.2	12.1	0.2	0.7	26.9	2.1	2.8	0	6.0	41.4	52.5	0
Pinotage	13-20 Jan	-7 to 0	0	NA	77.5	15.5	1.3	22.1	94.5	2.4	3.8	0	23.2	52.4	23.9	0.4
Python	6 Jan	-14	0	3	61.7	12.9	0.2	0.7	18.3	2.1	3.0	0	6.8	44.1	49.0	0
Red Shipper	13-20 Jan	-7 to 0	0	NA	68.5	13.5	1.9	16.0	90.5	2.0	3.2	0	16.8	57.4	25.3	0.3
Rugby	27 Jan	7	0	2.5	46.5	14.6	6.7	34.1	78.7	2.2	3.8	0	0.9	32.2	65.1	1.5
T6074	13 Jan	-7	0	2.5	74.2	14.2	0.8	0.5	19.3	2.1	2.8	0	4.4	35.4	60.1	0
Thesis	6 Jan	-14	0	3	96.7	14.6	1.9	13.0	74.8	2.5	3.7	0	10.2	22.1	67.1	0.4
P					<.001	.037	<.001	<.001	<.001	.038	.035	-	<.001	<.001	<.001	.002
LSD 5%					14.52	2.41	4.73	10.73	15.88	0.49	0.88		11.35	16.28	19.44	1.23
MDY (EXO7985905)	27 Jan	7	0	1		-	6.7	14.1	59.7	1.8	3.6	0	1.8	43.5	54.5	0

- 10-SP-161A and 10-SP-317A did not reach 80% tops down
- Cowboy did not reach 80% tops down in 2 of the 4 blocks; severe downy mildew
- EXO7985905 only 2 rows drilled; all 4 blocks pooled for a composite sample; no density nor yield data
- Density was significantly different between some varieties, and may need to be taken into account when reviewing the other data
- Yield was significantly different between some varieties
- The level of skinning was significantly different between some varieties at 30 days, 90 days and 160 days post lifting
  - Many varieties had skinning below 20% at both 30 days and 90 days post lifting
- Weight loss was significantly different between some varieties at 30-90 days and 90-160 days post lifting
- Visible shoot development (>1) was significantly different between varieties
  - Cowboy had an unacceptably high level of externally visible shoots; 3.3%

Results Colour Key

(green)	Skinning <20% at both 30d post and 90d post lifting

Table 2.10 Results for trial 1112 V 211
Commercial Crop Variety: 10-SP-161A
Planted: 20 July 2011
Commercial Crop Lifted: 21 Jan 2012

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Colour 30d	Density	Gross Yield/2m^2	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
												¼	½	¾	1	>1
10-SP-317A	DNF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11-DR-211	9 Jan	Control	0	1	68.7	15.4	0.6	2.9	39.0	2.2	3.3	0	7.0	47.6	45.2	0
11-SP-162	9 Jan	0	0	1.25	39.2	14.0	1.4	2.2	36.5	2.1	2.8	0	2.6	24.5	72.8	0
Baron	9 Jan	0	0	2	60.2	14.3	0	0	23.2	2.3	3.3	0	2.1	30.7	67.0	0
Cabernet	9 Jan	0	0	2	65.2	15.8	1.3	21.5	81.0	2.2	3.4	0	7.5	55.5	36.5	0.3
Cowboy	DNF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Perez	9 Jan	0	0	1	59.7	14.7	0	1.2	47.8	1.9	3.5	0	4.4	41.6	53.9	0
Pinotage	9 Jan	0	0	NA	64.5	17.2	2.0	29.6	86.0	2.5	3.7	0	9.0	50.6	39.0	1.2
Python	9 Jan	0	0	2.25	63.7	14.8	0.2	7.8	40.3	2.0	2.5	0	4.8	47.9	47.2	0
Red Shipper	9 Jan	0	0	NA	67.2	14.5	3.2	16.3	79.8	2.3	3.1	0	16.5	43.8	39.6	0
Rugby	9 Jan	0	0	2	60.5	12.6	1.9	21.2	89.5	2.0	3.3	0	4.6	34.2	61.0	0
T6074	9 Jan	0	0	1.25	73.7	14.3	0.9	1.1	27.2	2.2	2.9	0	6.5	38.9	54.5	0
Thesis	9 Jan	0	0	2.25	77.7	14.6	2.4	43.5	93.0	2.1	4.4	0	4.0	43.2	52.7	0
P					.003	.008	.015	<.001	<.001	NS	.01	-	NS	<.001	<.001	NS
LSD 5%					16.23	2.04	2.10	10.59	13.05		0.97			12.35	17.80	
10-SP-161A	9 Jan	0	0	1	61.0	13.6	0	0	38.4	2.0	2.3	0	6.3	30.2	63.4	0
MDY (EXO7985905)	9 Jan	0	0	1	-	-	0	0	38.3	2.4	2.7	0	10.5	50.5	38.8	0

- Inputs were stopped earlier than normal at this site due to the presence of OWR
    - This may account for the apparent uniformity of maturity/lifting date
- 10-SP-317A and Cowboy did not reach 80% tops down
- 10-SP-161A did not reach 80% tops down in 3 of the 4 blocks
- EXO7985905 only 2 rows drilled; all 4 blocks pooled for a composite sample; no density nor yield data
- Density was significantly different between some varieties, and may need to be taken into account when reviewing the other data
- Yield was significantly different between some varieties
- The level of skinning was significantly different between some varieties at 30 days, 90 days and 160 days post lifting
    - Many varieties had skinning below 20% at both 30 days and 90 days post lifting
- Weight loss was significantly different between some varieties 90-160 days post lifting
- Visible shoot development (>1) was not significantly different between varieties

Results Colour Key

(green)	Skinning <20% at both 30d post and 90d post lifting

Table 2.11 Results for trial 1112 V 219
Commercial Crop Variety: 10-SP-181A
Planted: 25 August 2011
Commercial Crop Lifted: 11 Feb 2012

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Colour 30d	Density	Gross Yield/2m^2	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
												¼	½	¾	1	>1
10-SP-161A	6 Feb	Control	0	1	41.0	21.6	7.0	21.7	55.6	3.0	3.2	0	0	13.3	85.5	1.2
10-SP-317A	6 Feb	0	0	NA	40.5	21.0	4.3	69.6	100	2.7	5.0	0	0	22.5	59.1	18.3
Cabernet	25 Jan	-12	0	NA	47.5	22.6	10.6	76.4	100	2.2	10.9	0	19.4	41.2	39.4	0
Canterbury	16-25 Jan	-21 to -12	0	1.25	48.5	16.4	2.9	14.6	63.2	2.0	3.3	0	4.3	22.6	72.9	0.2
Cricket	25/1 – 6/2	-12 to 0	0	1.5	41.2	19.7	5.8	52.1	94.8	2.4	4.4	0	0	27.5	72.5	0
Kauri	6 Feb	0	0	1	51.0	21.0	2.9	46.2	66.8	2.4	3.1	0	4.3	23.7	72.0	0
Manuka	25/1 – 6/2	-12 to 0	0	1	52.0	23.1	2.5	39.3	89.7	2.1	3.1	0	0.9	25.1	73.6	0.4
Patterson	DNF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pinotage	16-25 Jan	-21 to -12	0	NA	55.0	20.7	10.0	73.2	100	2.3	6.5	0	25.8	54.4	19.8	0
Plutonus	6 Feb	0	0	1	52.2	20.8	4.3	38.7	68.0	3.1	3.2	0	2.4	25.0	71.6	0.9
Red Shipper	25/1 – 6/2	-12 to 0	0	NA	51.5	17.7	10.6	65.5	100	2.4	6.8	0	13.3	36.0	50.7	0
Rhinestone	16-25 Jan	-21 to -12	0	1	58.0	20.1	1.4	18.6	84.3	2.0	3.0	0	2.9	24.1	72.3	0.6
SA Brown	6 Feb	0	0	1.25	49.7	25.9	8.1	17.0	29.2	3.1	3.2	0	0	12.7	78.9	8.4
T6074	16 Jan	-21	0	1	52.7	18.9	1.4	49.0	98.1	2.3	3.8	0	0	19.4	80.6	0
Yankee	DNF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P					.003	<.001	<.001	<.001	<.001	.019	.018	-	.004	.005	<.001	<.001
LSD 5%					8.70	3.14	4.11	15.77	9.59	0.73	4.22		13.85	18.75	27.19	7.16

- Patterson and Yankee did not reach 80% tops down; both had bolters
- Density was significantly different between some varieties, and may need to be taken into account when reviewing the other data
- Yield was significantly different between some varieties
- The level of skinning was significantly different between some varieties at 30 days, 90 days and 160 days post lifting
    - Only three varieties had skinning below 20% at both 30 days and 90 days post lifting; Canterbury, Rhinestone & SA Brown
- Weight loss was significantly different between some varieties at 30-90 days and 90-160 days post lifting
- Visible shoot development (>1) was significantly different between varieties
    - 10-SP-317 had an unacceptably high level of externally visible shoots; 18.3%
    - SA Brown had an unacceptably high level of externally visible shoots; 8.4%

Results Colour Key

(green)	Skinning <20% at both 30d post and 90d post lifting

Table 2.12 Results for trial 1112 V 223
Commercial Crop Variety: 09-DR-180
Planted: 2 September 2011
Commercial Crop Lifted: 14 Feb 2012

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Colour 30d	Density	Gross Yield/2m^2	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
												¼	½	¾	1	>1
10-SP-181A	DNF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10-SP-317A	DNF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cabernet	6 Feb	0	0	NA	45.0	17.9	4.4	80.0	97.4	2.4	6.7	0	1.7	25.7	72.6	0
Canterbury	6 Feb	Control	0	1.25	45.8	14.1	0	10.6	59.3	2.4	3.4	0	1.7	42.0	56.2	0
Cricket	6 Feb	0	0	2.75	43.8	14.3	0	46.0	75.6	2.4	4.2	0	3.3	31.8	64.9	0
Kauri	6-13 Feb	0 to 7	0	1.6	46.5	14.0	0.2	29.6	66.4	2.3	2.8	0	7.8	27.8	63.9	0.4
Murray Brown	DNF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Patterson	DNF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pinotage	6 Feb	0	0	NA	55.2	16.5	7.3	80.5	100	2.8	8.0	0	0	13.9	84.2	1.9
Plutonus	13-20 Feb	7 to 14	0	2	52.2	14.6	0.3	29.7	54.9	2.8	2.7	0	8.4	27.1	63.8	0.6
Red Shipper	6 Feb	0	0	NA	41.0	13.4	3.2	63.0	70.1	2.5	6.0	0	3.7	26.8	55.0	14.4
Rhinestone	6 Feb	0	0	1.5	50.8	14.7	0	8.1	48.0	2.4	3.2	0	5.8	31.7	62.5	0
SA Brown	13 Feb	7	0	3	57.2	16.3	1.2	9.9	19.2	2.2	3.9	0	0	24.4	73.6	2.0
T6074	6 Feb	0	0	1.5	56.0	15.1	0.2	47.2	67.1	2.4	3.2	0	6.5	44.3	49.1	0
Yankee	DNF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P					NS	.022	<.001	<.001	<.001	<.001	<.001	-	NS	.044	.031	NS
LSD 5%						2.45	1.97	8.61	10.08	0.24	1.42			16.69	18.77	

- 10-SP-181A, 10-SP-317A, Murray Brown, Patterson and Yankee did not reach 80% tops down
- Density was not significantly different between varieties
- Yield was significantly different between some varieties
- The level of skinning was significantly different between some varieties at 30 days, 90 days and 160 days post lifting
    - Only three varieties had skinning below 20% at both 30 days and 90 days post lifting; Canterbury, Rhinestone & SA Brown
- Weight loss was significantly different between some varieties at 30-90 days and 90-160 days post lifting
- Visible shoot development (>1) was not significantly different between varieties

Results Colour Key

(green)	Skinning <20% at both 30d post and 90d post lifting

Table 2.13 Results for trial 1112 V 255
Commercial Crop Variety: Canterbury
Planted: 13 September 2011
Commercial Crop Lifted: 20 Feb 2012

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Colour 30d	Density	Gross Yield/2m^2	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
												¼	½	¾	1	>1
10-SP-181A	27 Feb	14	0	1	65.8	17.9	3.9	17.3	41.9	2.4	2.6	0	1.5	37.0	61.4	0
10-SP-317A	20-27 Feb	7 to 14	0	NA	57.5	17.1	11.5	53.0	75.8	2.4	4.1	0	0	16.1	78.0	5.7
Cabernet	6-13 Feb	0	0	NA	66.0	15.9	3.7	72.9	96.6	2.5	6.0	0	2.3	29.1	66.8	1.6
Canterbury	6-13 Feb	Control	0	1	83.0	16.4	0	10.2	48.2	2.2	2.4	0	0.5	25.6	73.1	0.6
Cricket	13 Feb	0	0	2	55.8	15.7	0	17.6	54.9	2.3	2.7	0	13.5	24.3	61.8	0.3
Kauri	13-20 Feb	0 to 7	0	1.75	75.8	16.2	0	12.4	53.3	2.1	2.7	0	1.0	35.3	62.7	0.9
Manuka	13-20 Feb	0 to 7	0	1.75	53.2	14.7	0	13.4	51.3	2.1	2.7	0	1.8	29.3	67.9	0.7
Murray Brown	27 Feb	14	0	1.5	80.2	19.0	4.4	5.2	19.4	2.8	2.7	0	1.2	37.9	60.8	0
Patterson	27 Feb	14	0	1	85.8	17.9	11.3	17.4	40.7	2.3	2.9	0	1.4	37.0	61.4	0
Pinotage	13-20 Feb	0 to 7	0	NA	74.8	16.7	15.2	83.4	77.3	2.5	6.5	0	0	9.8	87.8	2.2
Plutonus	20-27 Feb	7 to 14	0	1.5	78.8	17.0	0	16.3	52.9	2.2	2.5	0	1.1	35.8	63.0	0
Red Bull	DNF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red Shipper	6-20 Feb	0 to 7	0	NA	68.2	16.6	4.6	63.3	80.7	2.2	8.4	0	1.6	31.1	63.3	3.9
Rhinestone	6-13 Feb	0	0	1.5	80.2	15.3	0.3	3.6	33.1	2.7	2.3	0	1.1	29.8	68.9	0
SA Brown	20-27 Feb	7 to 14	0	2	81.8	16.8	2.8	2.9	25.9	2.7	2.8	0	2.2	33.4	64.2	0
T6074	6 Feb	0	0	1	82.0	15.4	0	13.3	67.3	2.3	2.8	0	3.4	35.5	60.0	0.8
Vulcan	DNF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yankee	DNF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P					.009	NS	<.001	<.001	<.001	NS	NS	-	<.001	.025	NS	.003
LSD 5%					19.16		4.69	10.0	16.94				4.22	17.92		3.06
9005	20-27 Feb	7 to 14	0	NA		-	8.7	58.1	70.3	2.1	3.8	0	0	49.3	50.6	0

- Red Bull, Vulcan and Yankee did not reach 80% tops down
- Red Bull and 9005 only 2 rows drilled; 9005 all 4 blocks pooled for a composite sample; no density nor yield data
- Density was significantly different between some varieties, and may need to be taken into account when reviewing the other data
- Yield was not significantly different between varieties
- The level of skinning was significantly different between some varieties at 30 days, 90 days and 160 days post lifting
    - Many varieties had skinning below 20% at both 30 days and 90 days post lifting
- Weight loss was not significantly different between varieties
- Visible shoot development (>1) was significantly different between varieties
    - 10-SP-317 had an unacceptably high level of externally visible shoots; 5.7%
    - Red Shipper had an unacceptably high level of externally visible shoots; 3.9%

Results Colour Key

(green)	Skinning <20% at both 30d post and 90d post lifting

Table 2.14 Results for trial 1213 V 202
Commercial Crop Variety: 11-DR-211
Planted: 14 May 2012
Commercial Crop Lifted: 31 Dec 2012

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Colour 30d	Density	Gross Yield/2m^2	30 Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
												¼	½	¾	1	>1
11-DR-211	28 Dec	Control	0	1.2	84.8	17.8	0.4	0.8	21.9	1.9	2.3	0.9	5.8	29.8	63.3	0
Enza	2 Jan	5	0	2.7	34.5	16.9	3.7	26.9	77.9	2.3	2.9	0	0.5	20.0	78.9	0.5
Pinotage	28 Dec	0	0	-	88.2	16.9	8.0	9.2	57.0	2.3	3.2	0.6	7.9	41.9	49.1	0.4
Python	10-17 Dec	-18 to -11	0	2.2	84.2	17.7	1.6	19.9	79.9	2.1	3.5	0	1.8	39.6	58.5	0
Atom	10 Dec	-18	0	1	87.5	16.7	19.3	74.5	100	2.5	5.9	0	4.6	29.4	66.0	0
Toughball	10 Dec	-18	0	1.5	91.2	16.9	20.8	51.3	97.5	2.3	3.6	0	2.4	29.0	68.6	0
P					<.001	NS	<.001	<.001	<.001	<.001	<.001	NS	NS	.014	.005	NS
LSD 5%					11.61		3.65	6.43	10.20	0.21	0.54			11.99	13.28	

- Density was significantly different between some varieties, and may need to be taken into account when reviewing the other data
- Yield was not significantly different between varieties
- The level of skinning was significantly different between some varieties at 30 days, 90 days and 160 days post lifting
    - Many varieties had skinning below 20% at both 30 days and 90 days post lifting
- Weight loss was significantly different between some varieties at both 30-90 days and 90-160 days post lifting
- Visible shoot development (>1) was not significantly different between varieties

Results Colour Key

(green)	Skinning <20% at both 30d post and 90d post lifting

Table 2.15 Results for trial 1213 V 203
Commercial Crop Variety: 11-DR-211
Planted: 15 May 2012
Commercial Crop Lifted: 3 Jan 2013

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Colour 30d	Density	Gross Yield/2m^2	30 Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
												¼	½	¾	1	>1
11-DR-211	3 Jan	Control	0	1.7	58.0	8.8	0.3	10.9	29.7	2.2	1.6	0	0	29.4	70.6	0
Enza	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pinotage	3 Jan	0	0	-	63.2	7.4	6.8	34.3	92.7	2.9	2.1	0.6	19.4	45.1	34.0	0.8
Python	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Atom	11-17 Dec	-23 to -17	0	1	65.0	7.9	21.7	71.8	100	2.3	2.9	0	0	4.9	95.1	0
Toughball	11-17 Dec	-23 to -17	0	1.5	66.0	7.1	7.8	64.7	100	2.1	2.6	0	5.7	22.3	72.0	0
P					NS	.031	<.001	<.001	<.001	.001	.038	NS	<.001	.007	<.001	NS
LSD 5%						1.14	4.22	14.62	7.77	0.36	0.41		7.80	20.18	22.46	

- Prolonged water logging early in the growing season, severely restricted emergence and crop growth
- 2 varieties, ENZA & Python did not grow through the water logging and were discontinued
- Density was not significantly different between varieties
- Yield was significantly different between some varieties
- The level of skinning was significantly different between some varieties at 30 days, 90 days and 160 days post lifting
- Weight loss was significantly different between some varieties at both 30-90 days and 90-160 days post lifting
- Visible shoot development (>1) was not significantly different between varieties

Results Colour Key

(green)	Skinning <20% at both 30d post and 90d post lifting

Table 2.16 Results for trial 1213 V 103
Commercial Crop Variety: 11-DR-211
Planted: 18 May 2012
Commercial Crop Lifted: 30 Dec 2012

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Colour 30d	Density	Gross Yield/2m^2	30 Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
												¼	½	¾	1	>1
11-DR-211	27 Dec	Control	0	2	90.2	18.1	0	0	21.5	2.7	2.3	0	3.8	30.4	65.7	0
Enza	27 Dec	0	0	2.7	36.5	12.3	0	22.6	89.9	2.7	2.7	0	0	20.8	79.2	0
NZ103	18 Dec	-9	0	1.7	91.0	16.4	6.4	2.7	19.4	2.7	3.2	1.2	6.3	41.3	51.2	0
Pinotage	2 Jan	6	0	-	87.2	17.6	1.4	11.0	83.6	2.5	3.3	0	1.6	45.8	50.9	1.6
Python	14 Dec	-13	0	2.2	79.5	13.1	1.7	14.0	63.3	2.4	2.8	0	7.8	26.8	65.3	0
Atom	14 Dec	-13	0	1	85.0	15.6	11.4	62.9	100	2.7	4.8	0	1.7	13.6	84.6	0
Toughball	14 Dec	-13	0	1.5	89.5	16.1	3.6	45.4	98.2	2.5	4.0	0	0	17.9	82.1	0
P					<.001	<.001	<.001	<.001	<.001	NS	<.001	.032	NS	<.001	<.001	NS
LSD 5%					10.58	1.08	4.50	8.17	10.0		.70	.73		13.27	13.99	

- Late irrigation, but free draining soil
- Density was significantly different between some varieties, and may need to be taken into account when reviewing the other data
- Yield was significantly different between some varieties
- The level of skinning was significantly different between some varieties at 30 days, 90 days and 160 days post lifting
    - Many varieties had skinning below 20% at both 30 days and 90 days post lifting
- Weight loss was significantly different between some varieties only at 90-160 days post lifting
- Visible shoot development (>1) was not significantly different between varieties

Results Colour Key

(green)	Skinning <20% at both 30d post and 90d post lifting

Table 2.17 Results for trial 1213 V 301
Commercial Crop Variety: 11-DR-211
Planted: 20 May 2012
Commercial Crop Lifted: 3 Jan 2013

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Colour 30d	Density	Gross Yield/2m^2	30 Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
												¼	½	¾	1	>1
11-DR-211	4 Jan	Control	0	2	59.2	11.4	3.5	4.7	13.5	2.6	2.0	0	3.1	23.8	73.1	0
Enza	4 Jan	0	0	3	25.0	6.7	26.2	24.4	100	3.0	3.0	0	1.7	9.9	88.4	0
NZ103	29 Dec	-6	0	2.7	66.5	10.5	0	0.5	7.2	2.5	1.9	0	1.9	20.7	77.3	0
Pinotage	4 Jan	0	0	-	65.0	8.7	23.8	23.1	97.1	2.9	2.8	0	3.6	27.1	67.5	1.7
Python	29 Dec	-6	0	3	63.2	7.5	0	11.2	82.8	2.0	1.7	0	1.4	12.8	85.7	0
Atom	29 Dec	-6	0	2.2	64.8	11.4	2.1	37.9	100	2.4	2.8	0	0.9	8.3	90.8	0
Toughball	29 Dec	-6	0	2.5	63.2	11.5	1.0	27.9	100	1.8	2.7	0	0	10.1	89.9	0
P					<.001	<.001	<.001	<.001	<.001	<.001	.003	-	NS	.006	.009	.033
LSD 5%					11.22	1.81	3.49	5.59	5.53	.51	0.73			12.97	15.12	1.06

- High weed pressure adversely affected emergence
- Dry site
- Density was significantly different between some varieties, and may need to be taken into account when reviewing the other data
- Yield was significantly different between some varieties
- The level of skinning was significantly different between some varieties at 30 days, 90 days and 160 days post lifting
    - Many varieties had skinning below 20% at both 30 days and 90 days post lifting
- Weight loss was significantly different between some varieties at both 30-90 days and 90-160 days post lifting
- Visible shoot development (>1) was significantly different between varieties, although most were within acceptable levels

Results Colour Key

(green)	Skinning <20% at both 30d post and 90d post lifting

Table 2.18 Results for trial 1213 V 306
Commercial Crop Variety: 11-DR-211
Planted: 29 May 2012
Commercial Crop Lifted: 30 Dec 2012

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Colour 30d	Density	Gross Yield/2m^2	30 Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
												¼	½	¾	1	>1
11-DR-211	30 Dec	Control	0	2	95.7	11.7	7.2	21.2	39.6	2.5	2.8	0	3.6	40.0	56.2	0
Enza	30 Dec	0	0	2.7	37.5	13.9	24.8	60.2	98.3	2.8	4.0	0	2.3	14.9	82.6	0
NZ103	30 Dec	0	0	2.5	96.2	9.9	9.4	22.5	40.5	2.5	2.8	0	3.1	42.8	54.0	0
Pinotage	30 Dec	0	0	-	86.7	12.6	27.0	54.0	94.3	3.0	3.7	0	3.5	40.6	55.8	0
Python	18 Dec	-12	0	2.5	83.7	9.9	7.6	36.2	79.8	2.6	3.4	0	0.7	24.3	74.0	0.8
Atom	18 Dec	-12	0	1.5	94.6	13.5	26.3	58.3	100	3.3	5.3	0	4.1	15.9	79.8	0.2
Toughball	18 Dec	-12	0	1.5	92.7	14.1	15.8	74.9	100	2.7	5.6	0	0	0	98.8	1.1
P					<.001	<.001	<.001	<.001	<.001	.008	<.001	-	NS	.003	.003	NS
LSD 5%					14.91	0.92	7.28	14.46	9.00	0.43	1.09			23.08	24.80	

- NZ103 were affected by downy mildew very late in the crop
- All varieties grew bulbs partially underground
- Trial matured earlier than expected; possibly due to high densities
- Density was significantly different between some varieties, and may need to be taken into account when reviewing the other data
- Yield was significantly different between some varieties
- The level of skinning was significantly different between some varieties at 30 days, 90 days and 160 days post lifting
  - No varieties had skinning below 20% at both 30 days and 90 days post lifting
- Weight loss was significantly different between some varieties at both 30-90 days and 90-160 days post lifting
- Visible shoot development (>1) was not significantly different between varieties

Results Colour Key

(green)	Skinning <20% at both 30d post and 90d post lifting

Table 2.19 Results for trial 1213 V 307
Commercial Crop Variety: 11-SP-211
Planted: 31 May 2012
Commercial Crop Lifted:10 Jan 2013

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Colour 30d	Density	Gross Yield/2m^2	30 Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
												¼	½	¾	1	>1
11-DR-211	5 Jan	Control	0	1.7	96.2	11.7	0.8	0	10.0	2.4	2.3	0	7.6	25.7	66.7	0
Enza	5 Jan	0	0	3	39.0	11.3	34.0	16.6	94.9	2.8	2.2	0	0	11.9	88.1	0
MDY	5 Jan	0	0	1	72.5	8.8	11.7	6.2	44.2	2.4	2.1	0	5.4	25.4	69.1	0
NZ103	29 Dec	-7	0	2.7	98.8	9.6	0	0.3	12.9	2.4	2.0	0	2.8	29.7	67.4	0
Python	29 Dec	-7	0	3	89.2	6.7	0.4	11.2	76.6	2.2	2.6	0	1.1	17.2	81.7	0
Atom	29 Dec	-7	0	2.2	100.5	12.2	2.8	58.5	100	2.6	3.2	0	0	9.7	90.3	0
Toughball	29 Dec	-7	0	2.5	96.8	12.6	4.8	57.9	100	2.5	2.9	0	0	6.4	93.6	0
P					<.001	<.001	<.001	<.001	<.001	.011	.03	-	NS	.001	<.001	-
LSD 5%					14.75	1.87	5.29	10.59	10.41	.26	0.76			14.30	16.00	

- High weed pressure during early growth
- Dry site
- Density was significantly different between some varieties, and may need to be taken into account when reviewing the other data
- Yield was not significantly different between some varieties
- The level of skinning was significantly different between some varieties at 30 days, 90 days and 160 days post lifting
    - Many varieties had skinning below 20% at both 30 days and 90 days post lifting
- Weight loss was significantly different between some varieties at both 30-90 days and 90-160 days post lifting
- Visible shoot development (>1) was not significantly different between varieties

Results Colour Key

(green)	Skinning <20% at both 30d post and 90d post lifting

Table 2.20 Results for trial 1213 V 207
Commercial Crop Variety: Baron
Planted: 24 Jul 2012
Commercial Crop Lifted:11 Jan 2013

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Colour 30d	Density	Gross Yield/2m^2	30 Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
												¼	½	¾	1	>1
12-DR-161	16 Jan	Control	0	2	91.0	17.4	0	1.5	22.7	2.0	4.0	0	0.6	16.6	82.6	0
6074	28/12-3/1	-19 to -13	0	1.5	98.5	14.9	0	2.3	22.4	2.2	2.0	0	2.6	24.9	72.3	0
Baron	3-9 Jan	-13 to -7	0	2	102.8	17.1	0.7	0.5	17.1	2.4	2.1	0	5.7	24.2	68.9	0.9
Canterbury	9 Jan	-7	0	1	98.5	17.1	0	0.2	22.2	2.1	2.3	0	2.3	31.2	66.3	0
Goblin	3-9 Jan	-13 to -7	0	2	91.0	16.4	0	1.0	29.1	2.3	2.2	0	0.6	13.9	85.1	0.2
MDY	28/12-3/1	-19 to -13	0	1	90.8	14.0	0	1.3	25.0	1.9	1.7	0	2.0	23.7	73.5	0.6
Python	28 Dec	-19	0	3	94.5	15.3	0	0.2	28.7	2.0	1.8	0	3.3	31.1	65.4	0
Rhinestone	3-9 Jan	-13 to -7	0	2	101.2	15.9	0	0	14.2	2.2	1.9	0	1.9	37.6	60.3	0
SA Brown	16 Jan	0	0	2.7	96.5	16.9	3.1	0.4	7.4	2.8	2.0	0	0	15.3	84.6	0
P					NS	<.001	.001	NS	<.001	<.001	NS	-	NS	.002	<.001	NS
LSD 5%						1.16	1.45		6.67	0.20				11.36	11.18	

- Note: SA Brown did not finish; average tops down at lifting was 51%
- Late irrigation
- Very early maturing site; all varieties and commercial crop; very high densities may have affected maturity – lower risk of excessive nitrate levels in leaves, resulting in better skin quality
- Density was not significantly different between varieties
- Yield was significantly different between some varieties
- The level of skinning was significantly different between some varieties at 30 days and 160 days post lifting
    - Many varieties had skinning below 20% at both 30 days and 90 days post lifting
- Weight loss was significantly different between some varieties at 30-90 days post lifting
- Visible shoot development (>1) was not significantly different between varieties

Results Colour Key

	Skinning <20% at both 30d post and 90d post lifting

Table 2.21 Results for trial 1213 V 107
Commercial Crop Variety: 12-DR-161
Planted: 19 Aug 2012
Commercial Crop Lifted: 5 Feb 2013

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Colour 30d	Density	Gross Yield/2m^2	30 Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
												¼	½	¾	1	>1
12-DR-161	1-8 Feb	Control	0	2	100.2	16.1	6.2	7.1	30.7	2.6	2.0	0	6.4	21.7	71.9	0
6074	19 Jan	-13 to -20	0	2	98.8	15.9	2.8	15.0	52.7	2.7	2.1	0	0.4	17.4	82.1	0
Baron	19 Jan	-13 to -20	0	2.2	105.2	15.6	3.2	1.9	31.2	2.7	2.2	0	0.7	21.6	77.6	0
Brown Keep	5 Feb	0	0	3	95.5	16.0	0	6.8	25.8	3.0	2.4	0	6.9	24.8	67.4	0.7
Canterbury	19 Jan	-13 to -20	0	2	106.5	16.2	6.6	7.5	36.7	2.5	2.0	0	2.8	21.1	76.0	0
Conan	19 Jan	-13 to -20	0	2	95.5	16.1	3.1	17.2	50.4	2.9	2.6	0	3.0	18.7	78.1	0
Goblin	19 Jan	-13 to -20	0	2.2	91.8	16.1	3.2	14.4	47.6	2.6	2.1	0	1.9	14.1	83.6	0.3
Kauri	1 Feb	0	0	3	105.8	15.6	10.9	20.5	48.9	3.0	2.6	0	2.3	15.4	82.2	0
Manuka	1-5 Feb	0	0	2	97.2	16.3	4.1	11.4	41.9	2.6	1.8	0	0.3	26.0	73.0	0.6
Plutonus	5-8 Feb	0	0	2.5	102.8	16.7	0.2	10.4	40.9	2.7	2.1	0	7.2	21.5	71.2	0
Rhinestone	19 Jan	-13 to -20	0	2.5	94.2	15.9	0	0	31.5	2.5	1.9	0	4.4	19.1	76.3	0
SA Brown	DNF	-	-	-	98.5	-	-	-	-	-	-	-	-	-	-	-
P					NS	NS	.006	<.001	.003	NS	.022	-	NS	NS	NS	NS
LSD 5%							5.34	6.38	14.13		0.49					

- Note: SA Brown started to bolt and was affected by downy mildew
- Very high density
- Yield reduced by tractor tyre erosion of edge of beds; severe wheel track erosion created deep trenches that would have enabled very fast soil drying despite late irrigations and rain
- Trench depth likely to have been greater than the depth of most of the onion roots
- Density was not significantly different between varieties
- Yield was not significantly different between varieties
- The level of skinning was significantly different between some varieties at 30 days, 90 days and 160 days post lifting
  - Many varieties had skinning below 20% at both 30 days and 90 days post lifting
- Weight loss was significantly different between some varieties at both 30-90 days and 90-160 days post lifting
- Visible shoot development (>1) was not significantly different between varieties

Results Colour Key

(green)	Skinning <20% at both 30d post and 90d post lifting

Table 2.22 Results for trial 1213 V 313
Commercial Crop Variety: Manuka
Planted: 12 Sep 2012
Commercial Crop Lifted: 5 Mar 2013

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Colour 30d	Density	Gross Yield/2m^2	30 Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
												¼	½	¾	1	>1
11-DR-211	11-18 Feb	0 to 7	0	2	29.0	15.3	17.0	33.8	73.0	5.8	2.8	0	0	29.2	70.8	0
6074	11-18 Feb	0 to 7	0	2	51.5	18.1	15.0	44.5	73.5	3.4	2.6	0	0.4	12.3	87.3	0
Baron	18 Feb	7	0	2.2	34.0	15.1	9.9	21.9	74.8	3.1	2.3	0	3.2	21.5	75.3	0
Brown Keep	25/2-4/3	14 to 21	0	2.5	38.8	15.4	9.4	11.9	37.4	3.4	2.8	0	1.3	29.7	68.9	0
Canterbury	11 Feb	Control	0	2	53.8	18.6	12.2	26.4	67.6	2.6	1.8	0	2.9	20.1	77.0	0
Goblin	11-18 Feb	0 to 7	0	2	46.8	16.7	6.4	31.9	73.4	3.6	3.5	0	1.3	8.8	87.6	2.2
Kauri	25/2-4/3	14 to 21	0	2	49.8	16.8	12.2	23.5	89.3	3.7	2.7	0	0	22.4	77.6	0
Manuka	25 Feb	14	0	2	40.2	15.2	10.4	33.0	92.9	3.0	2.7	0	0	21.8	78.2	0
Plutonus	25/2-4/3	14 to 21	0	2.5	44.2	16.8	11.6	30.2	89.9	3.7	3.7	0	0	17.9	82.1	0
R5592	25/2-4/3	14 to 21	0	2	37.0	15.7	10.6	33.3	85.8	3.7	2.8	0	0	12.8	83.9	3.3
Rhinestone	18 Feb	7	0	2.7	38.5	17.3	2.0	11.2	66.4	2.4	2.0	0	0	16.2	83.8	0
SA Brown	DNF	-	-	-	41.0	-	-	-	-	-	-	-	-	-	-	-
P					NS	NS	.010	<.001	.006	NS	NS	-	NS	NS	NS	NS
LSD 5%							6.76	12.31	25.00							

- Low density
- Restricted growth early in the season; rapid lush growth late in the season
- Large bulbs
- Density was not significantly different between varieties
- Yield was not significantly different between varieties
- The level of skinning was significantly different between some varieties at 30 days, 90 days and 160 days post lifting
- Weight loss was not significantly different between varieties at both 30-90 days and 90-160 days post lifting
- Visible shoot development (>1) was not significantly different between varieties

Results Colour Key

(green)	Skinning <20% at both 30d post and 90d post lifting

Table 2.23 Results for trial 1213 V 256
Commercial Crop Variety: Manuka
Planted: 27 Sep 2012
Commercial Crop Lifted: 21 Feb 2013

Variety	Date Lifted	# Growing days < or > than Control	Bolters %	Colour 30d	Density	Gross Yield/2m^2	30 Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
												¼	½	¾	1	>1
11-DR-211	12-20 Feb	0 to 8	0	1.5	42.0	10.8	9.3	24.5	46.7	2.0	2.1	0	1.5	20.9	77.5	0
6074	6 Feb	-6	0	1.7	63.5	10.0	0	22.2	36.9	2.0	1.5	0	4.1	18.8	77.0	0
Baron	6 Feb	-6	0	3	58.0	9.8	0.2	11.0	31.9	2.3	2.1	0	1.6	18.5	79.4	0.3
Brown Keep	20-28 Feb	8 to 16	0	2.6	45.6	13.0	0	6.2	14.8	2.1	1.7	0	5.1	25.6	69.1	0
Canterbury	12 Feb	Control	0	2	49.5	12.2	0	7.9	26.2	2.0	1.7	0.1	1.3	15.8	82.5	0
Goblin	12-20 Feb	0 to 8	0	2	47.5	12.6	0.9	16.9	45.3	2.1	2.1	0	1.2	20.8	77.9	0
Kauri	12-20 Feb	0 to 8	0	1.6	55.6	11.3	0	5.3	30.2	1.9	1.8	0.4	2.6	16.4	80.5	0
Manuka	12-20 Feb	0 to 8	0	2.5	56.2	13.0	0.6	8.7	36.8	2.0	1.9	0.3	0.7	19.2	79.7	0
Plutonus	20 Feb	8	0	2.3	54.0	13.0	3.2	5.6	28.5	2.1	2.1	0	2.6	19.6	77.7	0
R5592	20 Feb	8	0	2	31.0	12.1	1.8	18.8	67.2	2.1	2.0	0	0	15.9	83.4	0.5
Rhinestone	12 Feb	0	0	2.7	54.7	12.3	0	6.2	24.1	2.0	1.5	0	1.1	20.9	77.9	0
SA Brown	DNF	-	-	-	47.7	-	-	-	-	-	-	-	-	-	-	-
P					<.001	NS	<.001	<.001	<.001	NS	NS	NS	NS	NS	NS	NS
LSD 5%					10.15		2.02	4.96	10.86							

- The following variety plots had been disturbed and the yield may not be accurate: Rep 1 Manuka, Rep 2 Manuka & Plutonus, Rep 3 Kauri
- 3 reps instead of 4 were assessed in the following varieties owing to pivot wheel damage: Bown Keep, Plutonus & Kauri
- High weed pressure may have reduced density
- Well drained & windy site
- Density was significantly different between some varieties, and may need to be taken into account when reviewing the other data
- Yield was not significantly different between varieties
- The level of skinning was significantly different between some varieties at 30 days, 90 days and 160 days post lifting
    - Many varieties had skinning below 20% at both 30 days and 90 days post lifting
- Weight loss was not significantly different between varieties at both 30-90 days and 90-160 days post lifting
- Visible shoot development (>1) was not significantly different between varieties

Results Colour Key

(green)	Skinning <20% at both 30d post and 90d post lifting

Table 2.24 Results for trial 1213 V 215
Commercial Crop Variety: 12-DR-317
Planted: 28 Aug 2012
Commercial Crop Lifted: 21 Feb 2013

Variety	Date Lifted	Bolters %	Colour 30d	Density	Gross Yield/2m^2	30 Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
											¼	½	¾	1	>1
Red Label	12 Feb	0	-	96	-	26.5	95.2	100	2.5	2.5	0	0	0	100	0
Vulcan	DNF	-	-	91	-	-	-	-	-	-	-	-	-	-	-
Griffin	DNF	-	-	109	-	-	-	-	-	-	-	-	-	-	-

- Non replicated observation plots
- Red Label affected by downy mildew infection
- Vulcan and Griffin not affected by downy mildew

Results Colour Key

	Skinning <20% at both 30d post and 90d post lifting

Table 2.25 Results for trial 1213 V 223
Commercial Crop Variety: Red Shipper
Planted: 20 Sep 2012
Commercial Crop Lifted: 17 Feb 2013

Variety	Date Lifted	Bolters %	Colour 30d	Density	Gross Yield/2m^2	30 Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
											¼	½	¾	1	>1
Red Label	12 Feb	0	-	64	-	30.2	84.9	100	2.5	1.7	0	0	0	100	0
Vulcan	DNF	-	-	61	-	-	-	-	-	-	-	-	-	-	-
Griffin	DNF	-	-	66	-	-	-	-	-	-	-	-	-	-	-

- Non replicated observation plots

Results Colour Key

	Skinning <20% at both 30d post and 90d post lifting

Table 2.26 Results Summary 2012/13 Early Planting Window (May)

Variety	Company	Type	Trial Outcome Summary* Crop # and (Planting Date)						Statistically Significant Differences compared to the Control
			202 14/5/12	203 15/5/12	103 18/5/12	301 20/5/12	306 29/5/12	307 31/5/12	
11-DR-211	FFT	OP	Control	Control	Control	Control	Control	Control	Control
Atom	Takii	Hyb	S	S	YS	S	SYield↑	S	Skinning higher at 6/6 sites, yield lower at 1/6 site, yield higher at 1/6 site
Enza	Enza	Hyb	S	Water	YS	YS	SYield↑	S	Skinning higher at 5/5 sites, yield lower at 2/5 sites, yield higher at 1/5 sites
MDY	Seminis	Hyb	-	-	-	-	-	Y	Insufficient data
NZ103	Ryan	OP	-	-	Y	✓	Y	Y	Yield lower at 3/4 sites
Pinotage	Terranova	Hyb, Red	S	YS	S	YS	S	-	Note: this was the only red onion in the early trials, so no direct comparison against the control has been made
Python	Terranova	Hyb	S	Water	YS	Y	YS	YS	Skinning higher at 4/5 sites, yield lower at 4/5 sites
Toughball	Takii	Hyb	S	YS	YS	S	SYield↑	S	Skinning higher at 6/6 sites, yield lower at 2/6 sites, yield higher at 1/6 sites

*Trial Outcome Summary:

- Control = industry standard for that planting time
- \- = not planted, or sample too small
- ✓ = yield not significantly below control AND skinning not significantly above control at 90d
- Y = yield significantly lower than control
- Yield↑ = yield significantly higher than control
- S = skinning significantly above control at 90d
- Skin↓ = skinning significantly lower than control at 90d
- M = maturity did not reach 80% tops down
- Water = varieties did not grow through period of water logging, and were discontinued

Results Summary Colour Key:

(green)	Skinning <20% at both 30d post and 90d post lifting	(orange)	Skinning >20% at either 30d post or 90d post lifting	(red)	Maturity did not reach 80% tops down

Table 2.27 Results Summary 2010/11, 2011/12 and 2012/13 Cream Gold Onion Regular Planting Window (July/August/September/October)

Variety	Company	Type	Crop # and (Planting Date)												
			109 17/7/11	211 20/7/11	207 24/7/12	110 28/7/10	107 19/8/12	219 25/8/11	223 2/9/11	313 12/9/12	255 13/9/11	253 26/9/10	256 27/9/12	333 29/9/10	235 9/10/10
211	FFT	OP	Control	Control	-	-	-	-	-	✓	-	-	S	✓	Y
161	FFT	OP	M	M	Control	Control	Control	Control	-	-	-	Y	-	✓	✓
162	FFT	OP	✓	✓	-	-	-	-	-	-	-	-	-	-	-
181	FFT	OP	-	-	-	-	-	-	M	-	✓	✓	-	M	M
19045	Seminis	Hyb	-	-	-	Y	-	-	-	-	-	-	-	-	-
Arnie	Terranova	Hyb	-	-	-	-	-	-	-	-	-	✓	-	✓	✓
Baron	Terranova	OP	✓	✓	✓	Y	✓	-	-	✓	-	-	✓	-	-
Brown Keep	Seminis	OP	-	-	-	-	✓	-	-	✓Skin↓	-	-	✓	-	-
Canterbury	Seminis	Hyb	-	-	✓	-	✓	Y	Control	Control	Control	Control	Control	Control	Control
Conan	Terranova	Hyb	-	-	-	-	S	-	-	-	-	✓	-	SYield↑	Y
Cowboy	Bejo	Hyb	S	M	-	-	-	-	-	-	-	-	-	-	-
Cricket	Clause	Hyb	-	-	-	-	-	S	S	-	✓	✓	-	-	-
Goblin	Terranova	Hyb	-	-	✓	-	S	-	-	✓	-	-	S	-	-
Kauri	Terranova	Hyb	-	-	-	-	S	S	S	✓	✓	-	✓	-	-
Manuka	Terranova	Hyb	-	-	-	-	✓	S	-	✓	✓	✓	✓	✓	Yield↑
MDY	Seminis	Hyb	-	-	Y	-	-	-	-	-	-	-	-	-	-
MurrayBrown	Terranova	OP	-	-	-	-	-	-	M	-	✓	-	-	-	-
Patterson	Bejo	Hyb	-	-	-	-	-	M	M	-	✓	-	-	-	-
Perez	Seminis	Hyb	✓	✓	-	Y	-	-	-	-	-	-	-	-	-
Plutonus	Terranova	Hyb	-	-	-	-	✓	S	S	✓	✓	-	✓	-	-
R5592	Terranova	Hyb	-	-	-	-	-	-	-	✓	-	-	S	-	-
Python	Terranova	Hyb	✓	✓	Y	-	-	-	-	-	-	-	-	-	-
Rhinestone	Lefroy	Hyb	-	-	Y	-	✓	✓	✓	✓Skin↓	✓	-	✓	-	-
Rugby	Clause	Hyb	S	YS	-	-	-	-	-	-	-	✓	-	SYield↑	S
SA Brown	-	OP	-	-	✓	-	M	Yield↑	✓	M	✓	-	M	-	-
T6001	Enza	Hyb	-	-	-	-	-	-	-	-	-	Yield↑	-	✓	✓
T6004	Enza	Hyb	-	-	-	-	-	-	-	-	-	✓	-	✓	✓
T6074	Enza	Hyb	✓	✓	Y	-	S	S	S	S	✓	✓	S	SYield↑	YS
Thesis	Bejo	OP	✓	S	-	-	-	-	-	-	-	-	-	-	-
Yankee	Bejo	Hyb	-	-	-	-	-	M	M	-	M	-	-	-	-

• Control = industry standard for that planting time • - = not planted, or sample too small • ✓ = yield not significantly below control AND skinning not significantly above control at 90d • Y = yield significantly lower than control • Yield↑ = yield significantly higher than control • S = skinning significantly above control at 90d • Skin↓ = skinning significantly lower than control at 90d • M = maturity did not reach 80% tops down

Results Summary Colour Key:

Green	Skinning <20% at both 30d post and 90d post lifting
Orange	Skinning >20% at either 30d post or 90d post lifting
Red	Maturity did not reach 80% tops down

Table 2.28 Results Summary 2010/11 and 2011/12 Red Onion Regular Planting Window (July/August/September/October)

Variety	Company	Type	Trial Outcome Summary* Crop # and (Planting Date)							
			109 (17/7/11)	211 (20/7/11)	219 (28/7/11)	223 (2/9/11)	255 (13/9/11)	253 (26/9/10)	333 (29/9/10)	235 9/10/10
10-SP-317A	FFT	OP	M	M	✓	M	✓	-	-	-
Cabernet	Terranova	Hybrid	✓	✓	✓	S	✓	✓	SYield↑	Yield↑
Countach	Nunhems	Hybrid	-	-	-	-	-	✓	M	M
Marenge	Nunhems	Hybrid	-	-	-	-	-	M	M	M
Pinotage	Terranova	Hybrid	✓	S	✓	S	S	-	-	-
Red Bull	Bejo	Hybrid	-	-	-	-	M	-	-	-
Red Shipper (CLX 111)	Clause	Hybrid	Control	Control	Control	Control	Control	Control	Control	Control
Vulcan	Fairbanks	Hybrid	-	-	-	-	M	-	-	-

• Control = industry standard for that planting time • - = not planted, or sample too small • ✓ = yield not significantly below control AND skinning not significantly above control at 90d • Y = yield significantly lower than control • Yield↑ = yield significantly higher than control • S = skinning significantly above control at 90d • Skin↓ = skinning significantly lower than control at 90d • M = maturity did not reach 80% tops down

Results Summary Colour Key:

Green	Skinning <20% at both 30d post and 90d post lifting
Orange	Skinning >20% at either 30d post or 90d post lifting
Red	Maturity did not reach 80% tops down

Table 2.29 Results 2010/11Variety Trial Red Onion Export Samples – UK - Fantainer & Reefer Shipments

					Market Acceptability (Excellent, Good, Pass, Fail)						
Variety	Crop	Size	Container	Date Assessed	Shape	Firmness	Skin Colour	Skin Condition	Internal Colour	Internal Growth	Overall Assessment
10-SP-317	236	60/80	Fantainer	27/6/2011	Pass to Good	Pass	Pass	Pass	Pass	Fail	Pass
10-SP-317	236	60/80	Reefer		Pass to Good	Good	Pass	Good	Pass	Fail	Pass
10-SP-317 Comments: Fantainer had some mould on the outer shell, softer, internal slightly better, more skin cracking											
9005	227	60/80	Fantainer	27/6/2011	Good	Good	Good	Good	Good	Pass	Good
9005	227	60/80	Reefer		Good	Good	Good	Good	Good	Pass	Good
9005 Comments: Better than 10-SP-317, single centred no mould. No difference between Fantainer and Reefer											
Red Shipper	235, 333	60/80	Fantainer	27/6/2011	Good - elongated	Good	Good	Good to Excellent	Pass	Pass	Good to Excellent
Red Shipper	235, 333	60/80	Reefer		Good - elongated	Good	Good	Pass - cracked	Pass	Pass	Good to Excellent
Red Shipper Comments: Better than 10-SP-317 and 9005 apart from elongated shape. Only difference between Fantainer and Reefer was that bulbs in the Reefer had the odd cracked skin around the centre											
Cabernet	235, 253, 333	60/80	Fantainer	27/6/2011	Good – flattish	Good	Pass – pale	Pass to Good	Pass - wet	Pass	Pass to Good
Cabernet	235, 253, 333	60/80	Reefer		Good - flattish	Good	Pass – pale	Good	Pass	Pass	Pass to Good
Cabernet Comments: Better than 10-SP-317 although pale skin may limit future opportunities. Fantainer and Reefer similar result, except skins stronger in Reefer											

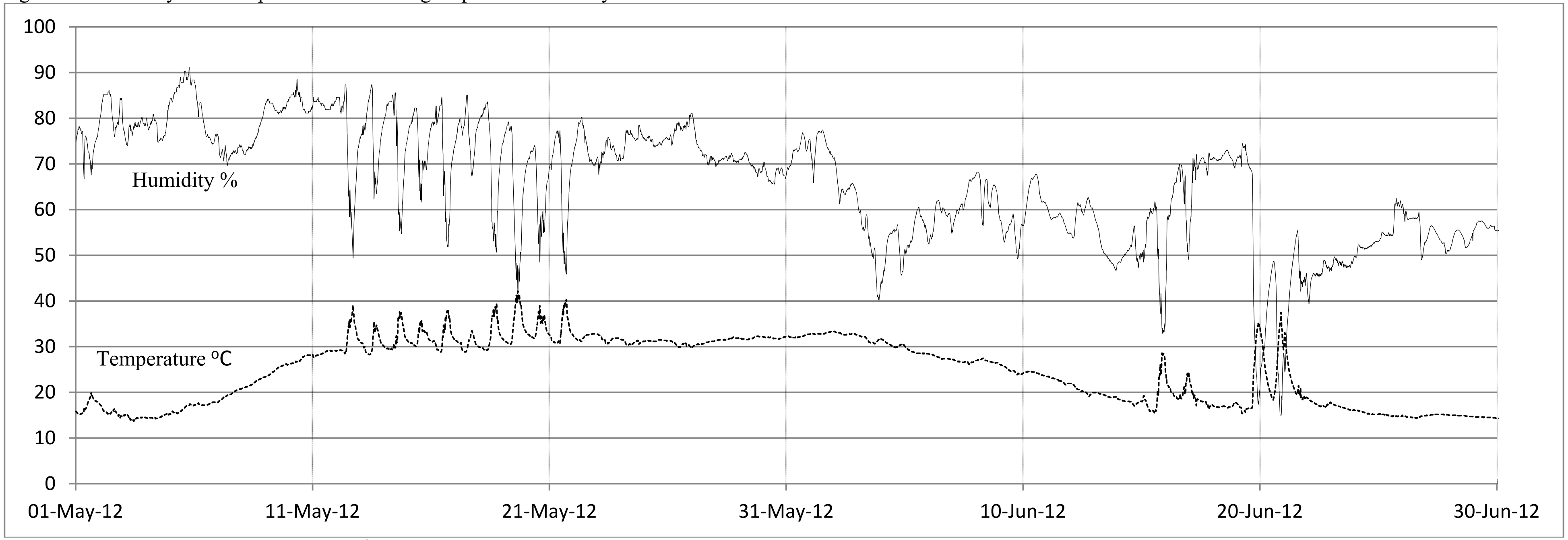
- Reefer container # OOLU 6177433
- Fantainer container # OOLU 1229874
- Sent 29th April 2011
- Assessed 27th June 2011

Table 2.30 Results 2011/12 Variety Trial Cream Gold Onion Export Samples – Norway – Fantainer Shipment

					Market Acceptability (Excellent, Good, Pass, Fail)						
Variety	Crop	Size	Bags	Date Assessed	Shape	Firmness	Skin Colour	Skin Condition	Internal Colour	Internal Growth	Overall Assessment
Kauri	223	50-70mm	1	3 Jul	Pass	Excellent	Excellent	Good	Good	Pass	Good
Kauri	219	70-90mm	1		Good	Excellent	Excellent	Good	Good	Pass	Good
Kauri	219	90-110mm	1		Good	Excellent	Excellent	Good	Excellent	Pass	Good
Kauri Comments: Issues – high round/flat shape (not practical for peeling operation) and internal growth											
6074	219	50-70mm	1	3 Jul	Good	Good	Good	Fail	Good	Fail	Fail
6074	223	50-70mm	1		Good	Good	Excellent	Pass	Good	Pass	Pass
6074	219	70-90mm	1		Good	Pass	Excellent	Pass	Good	Pass	Pass
6074 Comments: Issues - skinning and internal growth											
Rhinestone	219	50-70mm	1	3 Jul	Pass	Good	Excellent	Good	Good	Fail	Fail
Rhinestone	223	50-70mm	1		Pass	Good	Good	Excellent	Good	Good	Good
Rhinestone	219	70-90mm	1		Pass	Good	Good	Good	Good	Pass	Pass
Rhinestone Comments: Issues – high round/flat top shape (not practical for peeling operation) and internal growth											
SA Brown	223	50-70mm	1	3 Jul	Good	Good	Pass	Good	Good	Good	Pass
SA Brown	219	70-90mm	1		Good	Good	Pass	Good	Good	Good	Good
SA Brown	219	90-110mm	1		Good	Pass	Pass	Good	Pass	Good	Pass
SA Brown Comments: Issues - too many roots, and skin colour too dark											
Plutonus	223	50-70mm	1	3 Jul	Pass	Good	Good	Good	Good	Excellent	Good
Plutonus	219	70-90mm	1		Pass	Good	Good	Good	Good	Good	Good
Plutonus	219	90-110mm	1		Good	Good	Good	Good	Good	Excellent	Good
Plutonus Comments: Issues - shape											
Manuka	219	50-70mm	1	3 Jul	Pass	Good	Pass	Good	Good	Pass	Pass
Manuka	219	70-90mm	1		Good	Good	Good	Good	Good	Good	Good
Manuka	219	90-110mm	1		Good	Good	Good	Good	Good	Good	Good
Manuka Comments: Issues – variable skin colour 70mm											

- Container OOLU8753250
- Sent 1st May 2012
- Assessed 3rd July 2012

Figure 2.1 Humidity and Temperature data during shipment to Norway 2011/12



- Container arrived at customer 25th June 2012
- Logger was placed with the sample onions on top of the main commercial product
    - The data provides a measure of the exhaust air that has passed through the onions in the container plus any direct heat that may be transferred from the container ceiling; not the ambient conditions
    - The data illustrates the broad range of conditions the sample onions were exposed to during the voyage
    - The large diurnal fluctuations in humidity recorded in mid May, occurred when the container was located at the Port of Singapore for a 10 day lay over

Table 2.31 Results 2011/12 Variety Trial Red Onion Export Samples – UK - Reefer Shipment

				Market Acceptability (Excellent, Good, Pass, Fail)						
Variety	**Bag Brand**	**Size mm**	**Date Assessed**	**Shape**	**Firmness**	**Skin Colour**	**Skin Condition**	**Internal Colour**	**Internal Growth**	**Overall Assessment**
317	Clemar 20kg	40-60								
317	Clemar 20kg	60-80	30 Jun	Pass	Pass	Fail	Fail	Pass	Pass	Pass/Fail (Marginal)
317	Clemar 20kg	80-100								
317 Comments: Thin skins, shoots										
Cabernet	FFT 15kg	40-60								
Cabernet	FFT 15kg	60-80	30 Jun	Excellent	Excellent	Pass	Good	Good	Pass	Good
Cabernet	FFT 15kg	80-100								
Cabernet Comments: Best shape and skins, hard; 1st overall										
Pinotage	Premium Gold 20kg	40-60								
Pinotage	Premium Gold 20kg	60-80	30 Jun	Good	Good	Pass/Fail	Pass	Good	Excellent	Pass
Pinotage	Premium Gold 20kg	80-100								
Pinotage Comments: Split skins, pale, but best internal; 3rd overall										
Red Shipper	Premium Gold 10kg	40-60								
Red Shipper	Premium Gold 10kg	60-80	30 Jun	Good	Good	Good	Good	Good	Fail	Good
Red Shipper	Premium Gold 10kg	80-100		Pass	Pass					Pass
Red Shipper Comments: Best colour, medium skins; 2nd overall										

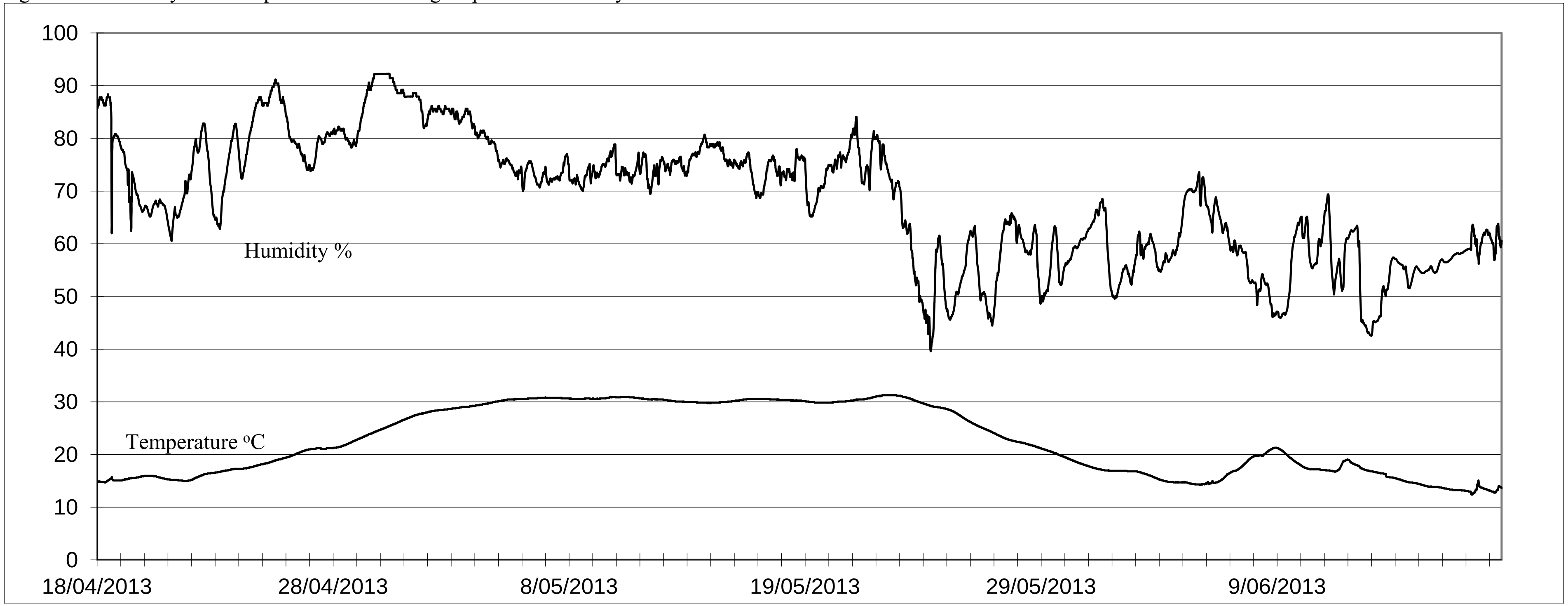
- Container MSCU3396329
- Sent 1st May 2012
- Assessed 30th June 2012

Table 2.32 Results 2012/13 Variety Trial Cream Gold Onion Export Samples – Norway - Fantainer Shipment

					Market Acceptability (Excellent, Good, Pass Fail)						
Variety	**Crop**	**Size**	**Bags**	**Date Assessed**	**Shape**	**Firmness**	**Skin Colour**	**Skin Condition**	**Internal Colour**	**Internal Growth**	**Overall Assessment**
Kauri	313	50-100mm	1	10.07.13	G	E	G	E	E	G	G
Kauri, 313 Comments:											
Kauri	256	50-100mm	1	10.07.13	E	E	E	E	E	G	G
Kauri, 256 Comments:											
Rhinestone	313	50-100mm	1	10.07.13	G	E	G	E	E	G	P
Rhinestone, 313 Comments: There was not much internal growth, but they had layers of dry skin/scale inside the onions, on quite a few of them; it is the reason why they just passed.											
Rhinestone	256	50-100mm	1	10.07.13	P	E	E	E	G	F	P
Rhinestone, 256 Comments:											
Goblin	313	50-100mm	1	10.07.13	G	G	G	P	P	P	F
Goblin, 313 Comments: 30% of these were rotten; that's the reason why they failed											
Goblin	256	50-100mm	1	10.07.13	G	E	G	E	G	E	G
Goblin, 256 Comments:											
R5592	313	50-100mm	1	10.07.13	E	G	G	F	P	G	P
R5592, 313 Comments:											
R5592	256	50-100mm	1	10.07.13	G	G	E	E	E	G	G
R5592, 256 Comments:											

- Container BMOU 308232(3)
- Sent 18th April 2013
- Assessed 10th July 2013

Figure 2.2 Humidity and Temperature data during shipment to Norway 2012/13



- Logger located beneath the 4 sample bags from crop 256 near the surface of one of the door end single height bins
  - The data provides a measure of the exhaust air that has passed through the onions in the container plus any direct heat that may be transferred from the container ceiling; not the ambient conditions
  - The data illustrates the broad range of conditions the sample onions were exposed to during the voyage

3. Fertiliser Program

Materials & Methods

Methods common to all fertiliser trials
The Standard Onion Assessment Protocol (SOAP) developed in this project (Chapter 1) was used throughout the fertiliser trials for consistency of assessment. The SOAP was designed to be representative of industry practices, so that fertiliser trial data could be directly extrapolated to commercial outcomes.

All trials were located within commercial onion crops, and all trials were machine lifted at standard commercial lifting times.

Gross yield was measured in $2m^2$ of each windrow once onions were fully cured; typically 14-21 days after lifting if May/Jun sown and 21-28 days after lifting if Jul/Aug or Sep/Oct sown. 20L (10-11kg) samples from each plot were then sampled and removed to the controlled atmosphere storage facility for post harvest evaluation of skins, weight loss and sprouting, where the following conditions were maintained: 6am to 6pm 21°C and 60% RH, 6pm to 6am: 11°C and 80% RH.

Skins were put under mechanical pressure using a method adapted from Hole et al. (2002). Our system used a 200L drum with two rubber ribs attached to the inside of the drum as per Gracie et al. (2006), rotating at 40rpm for 10 minutes for cream gold onions or 5 minutes for red onions. Two 20L (10-11kg) bags of samples were placed in the drum at a time. The measurement of skinning was defined to be representative of European customer standards where any amount of visible scale is classified as skinning, regardless of the cause (includes splits, cracks or shelling). Onion samples were put under mechanical pressure in the drum at strategic times to replicate standard times commercial onions are exposed to skin pressure; namely 30-40 days post lifting which is representative of standard packing time, and 90-100 days post lifting which is representative of standard repacking time after arrival in Europe. In the 2011/12 and 2012/13 seasons, skins were further evaluated at 160-170 days after lifting representative of long term storage and multiple handling of onions that occurs in difficult market seasons.

Weight loss was recorded at 90-100 days and 160-170 days post lifting, taking into account any losses due to disease.

Shoot development was measured at 160-170 days post lifting by cutting all onions in half and recording whether a shoot was visible beyond the shoulder of the bulb.

The data presented in the results tables is the average of the replicates plus the outcome of the analysis of variance, using Genstat 13.

All fertiliser trials are named with a four digit number for the year of the trial, such as 1011 for 2010/11, a letter for the type of trial such as FN for fertiliser nitrogen trial, and a three digit code for the location, such as 106. Location codes represent the following areas in Tasmania

- 100-199 = Devonport
- 200-249 = Deloraine to Westbury/Hagley
- 250-299 = Longford
- 300-349 = Wynyard
- 350-399 = Forest/Smithton

Chelated nutrients and silica
Purpose: To evaluate the affect of applying chelated nutrients or silica on skin quality

Two chelated nutrient products and two silica products were evaluated in three standard randomized block trials with 4 replicates, in trials superimposed in already established commercial onion crops. All trials were subjected to standard onion agronomy inputs. Plots were 7m long by 3 beds wide and treatments were applied to all 3 beds, but only the middle section of the middle bed was assessed to ensure ample buffers between neighbouring treatments.

Treatments
- Control
- Copper Chelate (Cu/S) – Stoller
    - Copper 5% w/v, Sulphur 4% w/v
    - 4 applications, 1.5L/ha Copper Chelate in 200L/ha water
    - Sprays applied at 5-leaf, 7-leaf (pre-bulbing), 9-leaf (post bulbing) and 2-3 weeks later
- MX Special (Mix) – Stoller

    - Boron 0.5% w/v, Copper 0.17% w/v, Iron 1.33% w/v, Magnesium 0.33% w/v, Manganese 1.0% w/v, Molybdenum 0.02% w/v, Sulphur 1.0% w/v, Zinc 1.33% w/v
    - 4 applications, 3.0L/ha MX Special in 200L/ha water
    - Sprays applied at 5-leaf, 7-leaf (pre-bulbing), 9-leaf (post bulbing) and 2-3 weeks later
- Stand SKH (Stand) – Agrichem
    - Silica 20% w/v, Potassium 15% w/v, Humic Acid 1% w/v
    - 4 applications, 3.0L/ha Stand SKH in 200L/ha water
    - Sprays applied at 5-leaf, 7-leaf (pre-bulbing), 9-leaf (post bulbing) and 2-3 weeks later
- Enhance KCS (Enhance) – Agrichem
    - Silica 11% w/v, Potassium 5% w/v, Calcium 7% w/v, Nitrogen 1.7% w/v
    - 2 applications, 6.0L/ha Enhance KCS in 200L/ha water
    - Sprays applied at 9-leaf (post bulbing) and 2-3 weeks later

Bulbing is defined as when the bulb diameter first becomes greater than twice the stem diameter.

Post bulbing nitrogen
Purpose: To evaluate the effect of applying nitrogen post bulbing on skins and shelf life

Four different sources of nitrogen were evaluated in three standard randomized block trials with 4 replicates, in trials superimposed in already established commercial onion crops. All trials were subjected to standard onion agronomy inputs. Plots were 7m long by 3 beds wide and treatments were applied to all 3 beds, but only the middle section of the middle bed was assessed to ensure ample buffers between neighbouring treatments. Treatments were applied at the start of bulbing by broadcasting the dry fertiliser evenly over the entire plot; bulbing is defined as when the bulb diameter first becomes greater than twice the stem diameter.

Treatments
- Control
- Urea
    - Nitrogen 46%
    - 100kg/ha Urea
- Ammonium Sulphate (Amm Sul)
    - Nitrogen 21%, Sulphur 24%
    - 100kg/ha
- Nitrophoska (Nitroph)
    - Nitrogen 12.0%, Phosphorus 5.2%, Potassium 14.1%, Calcium 4.3%, Magnesium 1.2%, Sulphur 6.0%, Boron 0.02% and Zinc 0.01%
    - 100kg/ha
- Calcium Nitrate (Cal Nit)
    - Nitrogen 15.5%, Calcium 19%
    - 100kg/ha

Post bulbing boron
Purpose: To evaluate the effect of applying boron on maturity, to prevent vigorous crops overgrowing

Two different sources of boron were evaluated in two standard randomized block trials with 4 replicates, in trials superimposed in already established commercial onion crops. All trials were subjected to standard onion agronomy inputs. Plots were 7m long by 3 beds wide and treatments were applied to all 3 beds, but only the middle section of the middle bed was assessed to ensure ample buffers between neighbouring treatments. Treatments were applied twice; the first at the start of bulbing and the second 2-3 weeks later. Bulbing is defined as when the bulb diameter first becomes greater than twice the stem diameter.

Treatments
- Control
- SugarMover (Mover) – (Stoller)
    - Boron 10%, Molybdenum 0.13%
    - 2 applications, 1.5L/ha SugarMover in 200L/ha
- Supa Bor (Bor) – (Agrichem)
    - Boron 10%, Nitrogen 4%
    - 2 applications, 3L/ha Supa Bor in 200L/ha

Early post emergence nitrogen and silica, and growth manipulation

Purpose: To determine the influence of early application of nitrogen and silica on skin quality, and to attempt to manipulate growth to improve quality

Ten standard randomized block trials with 4 replicates, superimposed in already established commercial onion crops were established across a range of planting times and areas. All trials were subjected to standard onion agronomy inputs. Plots were 7m long by 3 beds wide and treatments were applied to all 3 beds, but only the middle section of the middle bed was assessed to ensure ample buffers between neighbouring treatments. Dry treatments were applied by broadcasting the dry fertiliser evenly over the entire plot, while liquid treatments were sprayed in an equivalent rate of 200L/ha water. All plots were machine lifted when the crop was mature.

Six different sources of nitrogen or silica were applied at one true leaf (1TL); the rate of application was determined so that each nitrogen source applied 40kg/ha of elemental nitrogen. Treatments designed to manipulate growth were additional applications of urea at three true leaf (3TL), 6 true leaf (6TL) and bulbing in addition to standard commercial applications (effectively doubling the Urea application amount) designed to promote excessive vegetative growth, application of boron at bulbing and 2-3 weeks later designed to promote the movement of sugars to aid maturity, and a physical growth check at 3 true leaf (3TL) designed to disrupt growth pattern by cutting all the leaves just above the growing apex or applying a strong herbicide mix of Totril and Bladex.

Treatment Rate & Schedule

Treatment	Rate kg/ha	Timing	N kg/ha
Control	-	-	-
Urea	87	1TL	40
DAP	222	1TL	40
Calcium Nitrate	258	1TL	40
Ammonium Sulphate	190	1TL	40
Rustica	333	1TL	40
Nitrophoska	333	1TL	40
3 x Urea	87 87 87	3TL 6TL Bulbing	40 40 40
Maxsil	50	1TL	-
Supa Bor	3L/ha 3L/ha	Bulbing 2-3 weeks later	- -
Physical growth check – Cut	Cut	3TL	-
Herbicide growth check – Totril + Bladex	1L/ha Totril + 0.65kg/ha Bladex + 400ml/ha Activator	3TL	-

Products

- Urea (Nitrogen 46%)
- DAP, Di Ammonium Phosphate (Nitrogen 18%, Phosphorous 20%, Sulphur 1.6%)
- Calcium Nitrate **(**Nitrogen 15.5%, Calcium 19%)
- Ammonium Sulphate **(**Nitrogen 21%, Sulphur 24%)
- Rustica **(**Nitrogen 12.0%, Phosphorus 5.2%, Potassium 14.1%, Calcium 4.3%, Magnesium 1.2%, Sulphur 6.0%, Boron 0.02% and Zinc 0.01%)
- Nitrophoska **(**Nitrogen 12.0%, Phosphorus 5.2%, Potassium 14.1%, Calcium 4.3%, Magnesium 1.2%, Sulphur 6.0%, Boron 0.02% and Zinc 0.01%)
- Maxsil **(**Amorphous Silica 72%, Calcium 11.5%, Sodium Carbonate 13%, Aluminium Oxide 1.5%, Potassium 0.45%, Phosphorous 0.03%)
- Supa Bor **(**Boron 10%, Nitrogen 4%)
- Totril (250g/L ioxynil)
- Bladex (900g/kg cyanazine)

Planting phosphorous and nitrogen interaction

Purpose: To determine the influence of phosphorous applied at planting, and any interaction with post planting nitrogen on onion quality

Two standard randomized block trials with 5 replicates were established in commercial onion paddocks prior to application of any fertiliser and prior to planting. Factorial trial designs were used to compare the impact of drilling MAP (mono ammonium phosphate) and foliar applications of Urea at 1 true leaf (1TL), 3 true leaf (3TL) and 6 true leaf (6TL).

Trials were subjected to standard onion agronomy inputs other than fertiliser as none of the fertilisers applied to the commercial crops were applied across the trial sites. Plots were 7m long by 3 beds wide and treatments were applied to all 3 beds, but only the middle section of the middle bed was assessed to ensure ample buffers between neighbouring treatments. Drilling treatments were applied using standard commercial precision drills. Post planting treatments were applied by broadcasting the dry fertiliser evenly over the entire plot.

Treatment Rate & Schedule

Planting Treatment	Rate kg/ha	P kg/ha	N kg/ha	Post Planting Treatment	Rate kg/ha	Timing	N kg/ha	g/bed 5m	g/plot 3 beds
Nil MAP (no Folicur)	0	0	0	0 Urea	0	-	0	-	-
Nil MAP (no Folicur)	0	0	0	1 Urea	87	1TL	40	78	235
Nil MAP (no Folicur)	0	0	0	2 Urea	87	1TL 3TL	40 40	78 78	235 235
Nil MAP (no Folicur)	0	0	0	3 Urea	87	1TL 3TL 6TL	40 40 40	78 78 78	235 235 235
MAP (with Folicur)	200	44	20	0 Urea	0	-	0	-	-
MAP (with Folicur)	200	44	20	1 Urea	87	1TL	40	78	235
MAP (with Folicur)	200	44	20	2 Urea	87	1TL 3TL	40 40	78 78	235 235
MAP (with Folicur)	200	44	20	3 Urea	87	1TL 3TL 6TL	40 40 40	78 78 78	235 235 235

Products

- Urea (Nitrogen 46%)
- MAP, Mono Ammonium Phosphate (Nitrogen 10%, Phosphorous 21.9%, Calcium 1.6%)

Nutrient status benchmark

This benchmark was initiated and implemented by Tim Smallbon and forms part of a higher degree research study with the University of Tasmania.

Purpose: To conduct a survey of commercial crops to determine if any nutrition factor (deficiency or excess) may account for the variation in quality that is observed between paddocks

Thirty four benchmark sites were established in commercial crops in the Longford, Westbury, Hagley and Deloraine areas; all sites were exposed to standard commercial agronomy inputs. Samples were collected at 6 growth stages and sent for dry ash nutrient analysis at Phosyn Analytical Queensland laboratories. Leaf samples were collected at 2, 4, 6, 8 leaf and mid bulbing. A mature bulb (fully cured/dried bulb) sample was collected at harvest and analysed within a few weeks of harvest. In order to remove any variability within a paddock, samples were always collected from a pre defined area of each paddock, and a large number of subsamples were pooled each time samples were collected; the number of individual plants sub sampled reduced as each growth stage progressed owing to the increasing volume of the leaf samples.

Samples were analysed for the content of the following 15macro and micro nutrients:

- Boron
- Calcium
- Chloride
- Copper
- Iron
- Magnesium
- Manganese
- Molybdenum
- Nitrate
- Nitrogen

- Phosphorous
- Potassium
- Sodium
- Sulphur
- Zinc

The data has been presented graphically, with the nutrient level for all 34 sites plotted against each of the 6 growth/sample stages. Correlation (R^2) analysis was used to test for any relationship between nutrient levels and each of the skin assessments for each of the growth stages. For the purposes of discussion correlations are grouped as follows:

- R^2 <0.3 no relationship
- R^2 >0.3-0.5 mild relationship
- R^2 >0.5-0.7 moderate relationship
- R^2 >0.7-1.0 strong relationship

Sulphur, nitrogen and molybdenum interaction

This trial was initiated and implemented by Tim Smallbon and forms part of a higher degree research study with the University of Tasmania.

Purpose: To evaluate the interaction between sulphur (S), nitrogen (N) and molybdenum (Mo) on skin quality.

Four Youden Square trials with 4 replicates were established in commercial onion crops. Trials were subjected to standard onion agronomy inputs. Plots were 7m long by 3 beds wide and treatments were applied to all 3 beds, but only the middle section of the middle bed was assessed to ensure ample buffers between neighbouring treatments. Treatments were all watered in before the next leaf stage was reached. In addition to the standard trial measurements, pyruvate levels were measured in these trials as they are reportedly influenced by both sulphur and nitrogen. Ten dry bulbs were sent to the NSW DPI laboratory in Wagga for analysis; bulbs were sent 90 days post lifting to coincide with typical arrival time in Europe.

Treatments

- Control
- Sulphur applied at 90kg/ha elemental sulphur
    - 100kg/ha Brimstone 90 (90% sulphur)
    - Applied at 1 true leaf, by broadcast over the entire plot
- Molybdenum applied at 780g/ha elemental molybdenum
    - 2kg/ha Sodium Molybdate (390g/kg Mo)
    - Applied at 1 true leaf, by spray in the equivalent of 200L/ha water
- Sulphur and Molybdenum – above 2 treatments applied
    - Applied at 1 true leaf
- Sulphur and Nitrogen applied at a total of 108kg/ha elemental sulphur and 94.5kg/ha elemental nitrogen
    - 3 x 150 kg/ha Sulphate of Ammonia (21-0-0-24)
    - applied in 3 applications at standard commercial timing; 1, 4 and 8 true leaf

Results

The data profiles presented in this report are the first time fertiliser trials have been evaluated using the new assessment method developed in this project (Chapter 1). Every fertiliser treatment has a complete production profile generally consisting of data including gross yield, skinning, weight loss and shoot development. Information regarding trial site conditions and observations from the statistical analysis are located beneath each table, for ease and efficiency of reference.

Chelated nutrients and silica

The treatments had no significant effect on yield, skinning 30 days post lifting or weight loss (Tables 3.1-3.3). Stand (20% silica) did significantly reduce skinning 90 days post lifting but only in one of the three trial sites (Table 3.2). Sprouting was significantly more advanced in the copper chelate (Cu/S) treatment in one of the three trials sites (Table 3.3), although no shoot was visible in any treatment. There were no consistent trends across the trials. Overall, the application of chelated elements or silica at the timings and rates applied, in addition to the standard commercial crop inputs, provided no consistent measureable benefit to crop yield or skin quality.

Post bulbing nitrogen

The treatments had no significant effect on yield, the level of skinning 30 or 90 days post lifting or weight loss at any of the three trial sites (Table 3.4-3.6). Sprouting was significantly higher in the Urea treatment compared to the control in one trial site (Table 3.4). There were no consistent trends across the trials. Overall, the application of any of the different forms of nitrogen post bulbing, in addition to the standard commercial crop inputs, resulted in no consistent measureable impact on crop yield or skin quality.

Post bulbing boron

The treatments had no significant effect on yield, the level of skinning 30 or 90 days post lifting, weight loss or shoot development (Tables 3.7-3.8). There were no consistent trends across the trials. Overall, the application of either of the different formulations of boron post bulbing, in addition to the standard commercial crop inputs, resulted in no consistent measureable impact on crop yield or skin quality, or any observable affect on crop maturity.

Early post emergence nitrogen and silica, and growth manipulation

Two of the ten trials were not harvestable due to onion white rot infection levels (Tables 3.13, 3.15). Yield was significantly increased in only one of the remaining eight trials, and was significantly reduced in three of the eight trials. At site 230-Canterbury (Table 3.17) yield was significantly increased by the Entec Nitrophoska and Supa Bor treatments, and was significantly reduced by the Cut and Totril/Bladex treatments. This is the only trial where a significant increase in yield was recorded; it was also the only site planted with a hybrid. At site 102 (Table 3.10) yield was significantly reduced by all treatments other than DAP and Maxsil; no treatments at this site significantly increased yield. At site 204 (Table 3.12) yield was significantly reduced by all treatments other than Entec Nitrophoska; no treatments at this site significantly increased yield. At site 109 (Table 3.16) yield was significantly reduced by the Cut and Totril/Bladex treatments; no treatments at this site significantly increased yield.

The Cut and Totril/Bladex treatments produced an easily visible growth check at all sites. The cut test removed all leaves at the 3 true leaf stage but within a week new growth was clearly evident in the form of extension of the cut leaves, which ultimately grew almost to the same length as uncut leaves of the same age. The herbicide burn resulted in yellowing of the leaves and some leaf curling; from this point on it was generally evident that growth was mostly behind unsprayed leaves by 1-2 weeks.

The level of skinning 30 days post lifting was not significantly affected by any treatment in any trial (Tables 3.9-3.18).

The level of skinning 90 days post lifting was significantly affected in four of the eight trials harvested. At site 355 (Table 3.14) the level of skinning 90 days post lifting was significantly reduced by the Cut treatment, and significantly increased by the Calcium Nitrate treatment. At site 109 (Table 3.16) the level of skinning 90 days post lifting was significantly increased by the 3 x Urea treatment. At site 230-Canterbury (Table 3.17) the level of skinning 90 days post lifting was significantly reduced by the Cut treatment, and significantly increased by the Ammonium Sulphate treatment. At site 230-161 (Table 3.18) the level of skinning 90 days post lifting was significantly increased by all fertiliser treatments other than the Supa Bor treatment.

The level of skinning 160 days post lifting was significantly affected in four of the eight trials harvested. At site 101 (Table 3.9) the level of skinning 160 days post lifting was significantly reduced by the Cut and Totril/Bladex treatments. At site 102 (Table 3.10) the level of skinning 160 days post lifting was significantly increased by the Urea, Ammonium Sulphate and Nitrophoska treatments. At site 204 (Table 3.12) the level of skinning 160 days post lifting was significantly reduced by the Cut treatment and significantly increased by the Ammonium Sulphate treatment. At site 230-161 (Table 3.18) the level of skinning 160 days post lifting was significantly reduced by the Cut and Totril/Bladex treatments.

Weight loss was significantly affected in only one of the eight trials, 230-161 (Table 3.18), by only one treatment (Urea).

Sprouting was not significantly affected by any treatment in any trial. Note that the only bulbs that did sprout had also skinned at the 160 day assessment (Tables 3.14, 3.17, 3.18).

Planting phosphorous and nitrogen interaction

Density was not significantly affected by any treatment (Tables 3.19, 3.20). Yield was significantly increased by the application of MAP at planting or by the applications of Urea at site 104 (Table 3.19) but yield was not significantly affected by any treatment at site 107 (Table 3.20).

At site 104 (Table 3.19) the level of skinning 30days and 90 days post lifting was significantly increased by the application of Urea. At site 107 (Table 3.20) the level of skinning 30days post lifting was significantly increased by the application of MAP at planting, while the application of Urea significantly increased the level of skinning at all three assessment times; 30 days, 90days and 160 days post lifting.

The treatments had no significant effect on weight loss or shoot development at either site (Table 3.19, 3.20).

Nutrient status benchmark
This benchmark was initiated and implemented by Tim Smallbon and forms part of a higher degree research study with the University of Tasmania.

The data from all 34 sites has been graphed in clusters at each growth/sample stage; 2, 4, 6 & 8 all correspond to leaf number, 12 corresponds to mid bulbing and 14 corresponds to mature bulb. Below each graph are the results of the correlation analysis (R^2) between the 3 skinning assessment times and the nutrient level at each of the 6 growth stages.

Boron levels mostly ranged between 15-50ppm and showed little variation between each of the growth stages sampled (Figure 3.1). The levels of boron at each growth stage showed no correlation with skinning at any of the 3 skinning assessments (Figure 3.1).

Calcium levels mostly ranged between 0.5-2%, except at the dry bulb stage where levels ranged from 0.25-0.7%; calcium levels also showed an unusual trend steadily decreasing from 2 true leaf to 8 true leaf but then rising in the order of double at the mid bulbing stage before declining again at the dry bulb stage (Figure 3.2). The levels of calcium at each growth stage showed no correlation with skinning at any of the 3 skinning assessments (Figure 3.2).

Chloride levels mostly ranged between 0.5-2%, except at the dry bulb stage where levels ranged from 0.2-0.4%; chloride levels had a broad range at the 2, 4, 6 and 12 true leaf stage but were very tightly clustered at the 8 true leaf and dry bulb stage (Figure 3.3). The levels of chloride at each growth stage showed no correlation with skinning at any of the 3 skinning assessments (Figure 3.3).

Copper levels mostly ranged between 1-15ppm and showed little variation between each of the growth stages sampled except at 8 true leaf and mid bulbing, however the increase in levels at these stages is likely due to the application of copper fungicide sprays (Figure 3.4). The levels of copper at each growth stage showed no correlation with skinning at any of the 3 skinning assessments (Figure 3.4).

Iron levels initially ranged from 20-1,200ppm at 2 true leaf, 20-400ppm at 4 true leaf and then mostly ranged between 20-100ppm and showed little variation between each of the remaining growth stages sampled (Figure 3.5). The levels of iron at each growth stage showed no correlation with skinning at any of the 3 skinning assessments (Figure 3.5).

Magnesium levels mostly ranged between 0.1-0.5%, with levels steadily decreasing from 2 true leaf to dry bulb but had higher levels at the mid bulbing stage before declining again at the dry bulb stage (Figure 3.6). The levels of magnesium at each growth stage showed no correlation with skinning at any of the 3 skinning assessments (Figure 3.6).

Manganese levels mostly ranged from 50-500ppm and showed little variation between each of the growth stages sampled, other than one extremely high value at the 2 true leaf stage which was likely due to the application of excessive micro nutrients in the basal fertiliser (Figure 3.7). The levels of manganese at each growth stage showed no correlation with skinning at any of the 3 skinning assessments (Figure 3.7).

Molybdenum levels mostly ranged between 0.05-0.6ppm, with levels steadily decreasing from the 2 true leaf stage to the dry bulb stage (Figure 3.8). The levels of molybdenum at each growth stage showed no correlation with skinning at any of the 3 skinning assessments (Figure 3.8). There were a number of the results at each growth stage where no detectable level of molybdenum was recorded (Figure 3.8).

Nitrate levels initially mostly ranged from 300-6,000ppm at 2 true leaf although one site was as high as 10,000ppm, 0-4,000ppm at 4 and 6 true leaf and then mostly ranged between 0-1,000ppm at 8 true leaf and mid bulbing, finishing with a small range of 0-100ppm at the dry bulb stage (Figure 3.9). The levels of nitrate at the dry bulb stage showed a positive moderate correlation with skinning 30 days post lifting and a positive mild correlation with skinning 90 days post lifting (Figure 3.9). The levels of nitrate at all other growth stages showed no correlation with skinning at any of the 3 skinning assessments (Figure 3.9).

Nitrogen levels mostly ranged between 3-6% at the 2, 4 and 6 true leaf stages, 2.5-4% at the 8 true leaf and mid bulbing stages and then 1-2% at the dry bulb stage, with levels generally decreasing from 2 true leaf to dry bulb but with an elevated level at mid bulbing (Figure 3.10). The levels of nitrogen at each growth stage showed no correlation with skinning at any of the 3 skinning assessments (Figure 3.10).

Phosphorous levels mostly ranged from 0.2-0.4% gradually increasing from 2 true leaf to 8 true leaf and then gradually declining to mid bulbing and dry bulb (Figure 3.11). The levels of phosphorous at the dry bulb stage showed a positive mild correlation with skinning 30 days post lifting (Figure 3.11). The levels of phosphorous at all other growth stages showed no correlation with skinning at any of the 3 skinning assessments (Figure 3.11).

Potassium levels gradually declined, initially ranging between 1-9% at the 2 true leaf stage, 1-7% at the 4 true leaf stage, 1-5% at the 6 true leaf stage, 0.75-3.5% at the 8 true leaf and mid bulbing stages and then 0.5-1.5% at the dry bulb stage (Figure 3.12). The levels of potassium at the 6 and 8 true leaf stage showed a mild negative correlation with skinning 30 days post lifting (Figure 3.12). The levels of potassium at all other growth stages showed no correlation with skinning at any of the 3 skinning assessments (Figure 3.12).

Sodium levels mostly ranged between not detectable and 0.3% and showed little variation between each of the growth stages with the exception of 2 of the sites (Figure 3.13). Many of the sites recorded levels as not detected; in the correlation analysis these sites were entered as having a level of zero. The levels of sodium at all 6 growth stages showed positive correlations with skinning 30 days post lifting; mild positive correlation at the dry bulb stage, moderate positive correlation at 2, 4 and 8 true leaf and strong positive correlation at 6 true leaf and mid bulbing (Figure 3.13). There were 2 sites with elevated sodium levels which have been shown on Figure 3.13 by connecting each site's data points with lines. These 2 sites also had severe downy mildew by mid bulbing, although the disease was only first evident at the 8 true leaf stage in one of the sites. The levels of sodium at all growth stages showed no correlation with skinning at the 90d and 160d skinning assessments (Figure 3.14).

Sulphur levels mostly ranged from 0.3-0.7% at all stages and showed little variation between the stages other than dry bulb where levels mostly ranged from 0.2-0.5% (Figure 3.14). The levels of sulphur at the mid bulbing and dry bulb stages showed a positive mild correlation with skinning 30, 90 and 160 days post lifting (Figure 3.14). The levels of sulphur at all other growth stages showed no correlation with skinning at any of the 3 skinning assessments (Figure 3.14).

Zinc levels mostly ranged from 10-40ppm at all stages and showed little variation between the stages (Figure 3.15). The levels of zinc at all growth stages showed no correlation with skinning at any of the 3 skinning assessments (Figure 3.15).

The level of skinning 30, 90 and 160 days post lifting was highly variable between the 34 sites of the nutrient benchmark and followed the typical pattern identified in Chapter 1 of this project, where the level of skinning is typically relative low 30 days post lifting (range 0-30%) but is higher at both 90 (range 0-60%) and 160 (range 15-100%) days post lifting (Figure 3.16).

Sulphur, nitrogen and molybdenum interaction
This trial was initiated and implemented by Tim Smallbon and forms part of a higher degree research study with the University of Tasmania.

At all four trials sites the yield, skinning at all three assessment times, weight loss and sprout development were not significantly affected by any treatment (Tables 3.21-3.24).

Site 10 (Table 3.21) had a high level of bolters and was lifted earlier than standard to try and reduce the final level of bolters; this may have caused the unusual skinning pattern where the level of skinning 30 days post lifting was consistently higher than the level of skinning 90 days post lifting in all treatments and the control. This unusual pattern of skinning is covered in detail in Chapter 4 but is likely associated with early lifting.

Pyruvate levels were significantly affected in two of the sites (Tables 3.23, 3.24). At site 50 (Table 3.23) the pyruvate level was significantly increased by the Sulphur and Nitrogen combined treatment compared to the control, and all other treatments involving sulphur also had higher levels than the control. The pyruvate level from the Molybdenum alone treatment was significantly lower than all the treatments involving sulphur at site 50 (Table 2.23). At site 60 (Table 2.24) the pyruvate levels were significantly increased by the Sulphur alone treatment and the Sulphur and Nitrogen combined treatment compared to the control. Although treatments had no significant effect on pyruvate levels at the other 2 sites, all treatments involving sulphur at all sites had higher pyruvate levels than the control (Tables 3.21, 3.22).

Discussion

Chelated nutrients and silica
The skinning level at all of the chelated nutrients and silica trials was low; skinning 90 days post lifting was at or below 20% at all 3 sites (Tables 3.1-3.3), which may have resulted in treatment effects being too subtle to measure. The significant reduction in skinning by the application of Stand (20% silica) measured at site 108 (Table 3.2) was not repeated at site 251 despite having very similar skinning levels (Table 3.3). Trial results are inconclusive due to the low skinning levels.

Post bulbing nitrogen
The skinning level at two of the three post bulbing nitrogen trial sites was medium and high with control levels of 27.5% and 40% respectively at 90 days post lifting (Tables 3.5, 3.6); the third site had a very low skinning level with

the control <10% (Table 3.4). The absence of any significant impact on yield or skinning is unlikely to be due to any treatment affects being too small to measure, as may have been the case in the chelated nutrients and silica trials. The significant increase in sprouting from the Urea treatment at one site (Table 3.4) was the result expected from late application of nitrogen, but this result was not repeated at the other 2 sites (Tables 3.5, 3.6). The application of post bulbing nitrogen was expected to increase yield and reduce skin quality, but since neither happened the results suggest that either the applications were too late or the rate too low to influence these parameters or that onions don't take up excessive nutrients just because they are added. The amount of nitrogen applied was relatively conservative at 100kg/ha product which provided 12-46kg/ha elemental nitrogen depending on the product; the rate may not have been high enough to create the expected increase in yield and subsequent reduction in skin quality. However, the results pose an interesting challenge for industry regarding the cost and benefit of applying late nitrogen; from these trials there was no evidence to support any benefit of such applications to offset the cost of the product.

Post bulbing boron

The skinning level at both post bulbing boron trial sites was high with control levels above 35% at 90 days post lifting (Tables 3.7, 3.8). The absence of any significant impact on yield or skinning is unlikely to be due to any treatment effects being too small to measure, but as with the post bulbing nitrogen trials perhaps the treatments were applied too late or the rates were too low to influence these parameters. Application rates and timings were extrapolated from the manufacturer's recommendations for vegetables, and are not necessarily appropriate for onions. More work would be needed to fully explore the potential range of application rates and timings.

Early post emergence nitrogen and silica, and growth manipulation

The overall failure to increase yield in all bar 1 site was not expected, particularly with the 3 x Urea treatment which involved an additional 3 x 87kg/ha Urea; this effectively doubled the amount of Urea applied to the crop, and yet this treatment did not significantly increase yield at any site. The only treatments to significantly increase yield were Entec Nitrophoska and Supa Bor, but only at one site (Table 3.17); this was also the only site planted with a hybrid, so perhaps this hybrid has a different interaction with some of the fertilisers.

Perhaps even more unexpectedly, yield was significantly reduced by some fertiliser treatments in two of the sites (Tables 3.10, 3.12); Urea, Calcium Nitrate, Ammonium Sulphate, Rustica, 3 x Urea and Supa Bor at both sites, DAP and Maxsil only at site 204 (Table 3.12) and Nitrophoska only at site 102 (Table 3.10).

The only site where yield was significantly reduced by the Cut and Totril/Bladex treatments was site 109 (Table 3.16). The variety at this site was Baron which has fewer growing days than standard open pollinated varieties. These treatments were designed to disrupt growth by causing a physical growth check, and while this growth check was evident at all sites applied, only one site recorded a significant reduction in yield, suggesting that onions have a tremendous capacity to compensate for growth checks that occur at this relatively early stage except perhaps faster growing types; the cut and herbicide treatments were applied at 3 true leaf.

The skinning level 30 days post lifting in the controls at the early post emergence nitrogen and silica, and growth manipulation trial sites was low (<10%) at all sites (Table 3.9-3.18). Not surprisingly then, there were no significant differences in skinning 30 days post lifting. This very low level of skinning would almost certainly have masked any treatment effect.

The skinning level 90 days post lifting in the controls at the early post emergence nitrogen and silica, and growth manipulation trial sites was low (<20%) at six sites (Tables 3.9, 3.10, 3.12, 3.16, 3.17, 3.18), medium (20%-30%) at one site (Tables 3.11) and high (>30%) at one site (Tables 3.14).

Despite the low level, skinning was significantly reduced in two sites, but only by the Cut treatment (Tables 3.14, 3.17); the mechanism of this reduction is unknown particularly as the effect was confined to just two sites. Another unexpected result was that skinning was significantly increased at four sites by fertiliser treatments but it was a different treatment at three of the sites; Calcium Nitrate at site 355 (Table 3.14), 3 x Urea at site 109 (Table 3.16), Ammonium Sulphate at site 230-Canterbury (Table 3.17) and all the fertiliser treatments other than Supa Bor at site 230-161 (Table 3.18). This very inconsistent set of results perhaps suggests that a number of sites have close to the upper threshold of nutrients and when the threshold is breached it results in a negative impact on skin quality

The skinning level 160 days post lifting was high (>30%) at all trial sites and was significantly reduced by the Cut treatment at three sites (Tables 3.9, 3.12, 3.18) and was also significantly reduced by the herbicide treatment at two sites (Tables 3.9, 3.18). Skinning was significantly increased at two sites by fertiliser treatments; Ammonium Sulphate at sites 102 and 204 (Tables 3.10, 3.12) and by Urea and Nitrophoska treatments at site 102 only (Table 3.10). As with the skinning results 90 days post lifting, no consistent trend is evident across the trials; the significant results appear more as a random scatter.

Planting phosphorous and nitrogen interaction

The level of skinning was very high at site 104 (Table 3.19), however the presence of moderate downy mildew in this site may have influenced the level of skinning, potentially masking treatment effects. The level of skinning at site 107 was very low, with the control <10% (Table 3.20); onion white rot was present throughout the trial area, potentially masking treatment affects.

Despite potentially difficult trial site conditions, a number of significant fertiliser effects were recorded. The significant increase in yield from the application of MAP at drilling or post planting application of Urea at site 104 (Table 3.19) followed the expected pattern, however at site 107 (Table 3.20), yield was not significantly affected by any treatment. This result was definitely not expected given that in these trials the control had no fertiliser applied at all; the only source of nutrients was whatever fertiliser was already present in the soil. It is interesting that a crop could be grown without the addition of any fertiliser, and produce a high yielding crop with low skinning incidence (Table 3.20). It is also interesting that density was not significantly affected by any treatment at either site (Tables 3.19, 3.20), despite the control plots having no basal and no drilling fertiliser applied. These results, suggest that the current approach to fertiliser management is worth reviewing as there are potentially substantial savings to be made if fertiliser applications can be reduced without compromising yield or quality.

As expected the level of skinning 30days and 90 days post lifting was significantly increased by the application of Urea at both sites (Tables 3.19, 3.20) and 160 days post lifting at site 107 (Table 3.20). The application of MAP at site 107 also significantly increased the level of skinning but only at 30 days post lifting (Table 3.20). Overall, in the planting phosphorous and nitrogen interaction trials, the application of fertiliser at planting or post planting either provided no benefit or was detrimental to quality, suggesting that these sites already had high levels of fertiliser, and by adding more the uptake of nutrients may have become unbalanced.

Nutrient status benchmark

This benchmark was initiated and implemented by Tim Smallbon and forms part of a higher degree research study with the University of Tasmania.

The level of skinning between the 34 sites of the nutrient benchmark was variable, but there were at least 10 sites with moderate to high levels of skinning 90 days post lifting (Figure 3.16).

Frome the correlation analysis 4 nutrients showed a positive relationship between nutrient level and skin quality; Sodium, Nitrate, Sulphur and Phosphorous.

The most consistent correlations were recorded between sodium at all 6 growth stages and skinning 30 days post lifting, and while these correlations have been heavily influenced by just 2 sites, both of which had severe downy mildew, the results suggest a potentially very strong indicator of skinning risk, albeit if the risk is from increasing severity of downy mildew. The link with downy mildew severity and elevated levels of sodium suggests that the sodium is having a toxic effect on plant growth and disrupting the plant's natural defence mechanisms. Whether or not sodium levels could be reduced in onion plants during crop growth would require investigation, but even just being able to detect high levels at such early growth stages as 2 and 4 true leaf would be a useful tool for commercial adoption, as at least it would identify crops more at risk of developing severe downy mildew. This would provide Growers with an opportunity to increase the intensity of the downy mildew preventative spray program.

It is interesting to note that the elevated sodium levels occurred well before the downy mildew was first observed; sodium levels were elevated at 2 true leaf and were very clearly elevated at 4 and 6 true leaf, whereas downy mildew was only first evident at 8 true leaf at one site but was then severe by mid bulbing at both sites. This would suggest that the elevated sodium levels may have caused the increased severity of downy mildew, either directly or indirectly.

The correlations between nitrate at the dry bulb stage and skinning 30 and 90 days post lifting, and the correlations between sulphur at the mid bulbing and dry bulb stages and skinning 30, 90 and 160 days post lifting, suggest that testing at this stage may be able to provide an indicator of suitability for export to Europe and long term storage. As the correlations were only mild to moderate further testing and validation would be required, but any test that has the potential to accurately predict onion skin quality long term is a potentially valuable commercially applicable tool.

The correlation between phosphorous at the dry bulb stage and skinning 30 days post lifting is of limited value as a predictive test, since the interval between the dry bulb sampling and the 30 day post lifting test would only be in the order of 1-2 weeks.

The only nutrient to generate a negative relationship between nutrient level and skin quality was potassium. It was only a mild negative correlation between the level of potassium at either 6 or 8 true leaf with skinning 30 days post lifting (Figure 3.12). Presumably this would be caused by either direct potassium deficiency or the lower levels of potassium creating an imbalance and a resultant increase in skinning. Regardless of the cause of the lower potassium levels, this has the potential to be a useful predictor of skin quality, however the relationship was only mild so would require further testing and validation before commercial adoption.

The remaining ten nutrients showed no correlation between nutrient level at any of the growth stages and skinning at any of the 3 skinning assessments; Boron, Calcium, Chloride, Copper, Iron, Magnesium, Manganese, Molybdenum, Nitrogen and Zinc. Calcium, magnesium and nitrogen all followed a similar trend with levels steadily decreasing from 2 true leaf to 8 true leaf but then rising at the mid bulbing stage before declining again at the dry bulb stage, indicating that a supply of these 3 nutrients needs to be available later in the crop life for uptake.

Sulphur, nitrogen and molybdenum interaction

This trial was initiated and implemented by Tim Smallbon and forms part of a higher degree research study with the University of Tasmania.

The skinning level at all four of the sulphur, nitrogen and molybdenum interaction trials was very low; skinning 90 days post lifting was at or below 10% at all four sites (Tables 3.21-3.24), which may have resulted in treatment effects being too subtle to measure. Not surprisingly, there were no significant treatment effects on yield, skinning at all 3 assessment times, weight loss or sprout development.

The significant changes in pyruvate levels in two of the trial sites indicate that the fertiliser treatments did manage to influence the onions. The overall affect of adding sulphur was as expected where all treatments involving sulphur at all sites had higher pyruvate levels than the control, although this increase was not always significant.

General Discussion

During this project there were twenty-four standard replicated block design fertiliser trials run over multiple seasons evaluating multiple fertiliser products, rates and application timings; twenty-one were harvestable, two were lost to onion white rot and one was damaged during preparations for harvest. From the remaining twenty-one trials there were 120 treatments applied (all fully replicated) in addition to the controls, but there were only three significant improvements in yield or skin quality recorded from the application of a fertiliser treatment compared to the control; two significant increases in yield and one significant reduction in skinning. However there were 35 significant deteriorations in yield or skin quality recorded from the application of a fertiliser treatment compared to the control; 15 significant reductions in yield and 20 significant increases in skinning. The nutrient benchmark did identify a number of links between nutrient levels and onion skin quality however the link between individual nutrients was only mild to moderate with the exception of sodium.

A number of suggestions have been discussed regarding possible reasons for individual trials not producing significant results, from skinning level being too low to detect differences, to treatment application timing being too late or treatment rate being too low. However, the overwhelming failure to detect consistent significant improvements from fertiliser treatments, suggests very strongly that the current fertiliser protocols are in almost all cases providing sufficient or even excessive nutrients to the crops requirements. It is common in Tasmania for Growers to note how well grass and cereal crops grow when following onions, and suggesting that this may be due to left over fertiliser from the onion crop that the fine roots of the grasses and cereals are able to remove from the soil.

There is evidence that the soils themselves are acting as a valuable nutrient source/bank, given both the successful results from trials where there was no fertiliser at all added and also noting the very broad range of nutrient levels that were recorded at different growth stages for many nutrients in the nutrient benchmark; if the onions were solely drawing nutrients from the fertilisers added to the crops, which are broadly the same within crop types (May/Jun sown, Jul/Aug sown and Sep/Oct sown) then a much narrower range of nutrient levels would be expected. This extra source of nutrients from the soil is theoretically taken into account when designing the fertiliser program by taking a soil test to determine the levels of nutrients present in the soil. However, the other consideration taken into account is nutrient budgeting; where the estimated amount of nutrients to be removed by the crop are applied to the crop on the basis that the soil will be left with the same nutrient level after the crop as before the crop. It is considered poor practice to "mine" the soil for nutrients however it is well recognised that it is definitely poor practice to apply excessive fertiliser to a crop and potentially create the risk of excess fertiliser contaminating waterways, not to mention the potential wasted expense involved. Current practices are guided heavily by nutrient budgeting, however this raises a question about situations where the soil already has sufficient nutrients, assuming they are available to the crop for uptake.

In summary, fertiliser applications above standard practice mostly had no impact on yield or quality, but when a treatment did have a significant impact it was more frequently either reduced yield and/or reduced quality (increased skinning) and only occasionally provided improvement in yield or quality, suggesting that current fertiliser protocols are at the upper limit of fertiliser required to optimize yield and quality for export. If current fertiliser recommendations are providing adequate nutrient levels and at times bordering on excessive nutrient levels or creating imbalances then there may be an opportunity to reduce fertiliser inputs applied to onion crops. This poses an interesting research question regarding just how little fertiliser can be added to grow onions on Tasmanian soils without compromising yield or quality.

It is proposed that the combined evidence from the fertiliser trials and the nutrient benchmark suggests a strong opportunity to be able to reduce fertiliser inputs for onion crops grown on Tasmanian soils, which are typically relatively fertile with reasonable organic matter content.

Recommendations

The primary recommendation is to commercialise the opportunity to reduce fertiliser inputs for onion production, to deliver a cost saving to Growers and also to reduce the risk of excessive fertiliser application and resulting yield or quality decline as well as reducing the risk of excess fertiliser contaminating waterways.

The recommended strategy is to develop a new approach to onion fertiliser management beginning with validation of soil test guidelines and then instead of conventional nutrient budgeting change the approach to only apply the nutrients needed to supplement those already present (and available) in the soil, and finally develop a strategy to leave a well balanced soil at the end of the crop, rather than the current nutrient budgeting approach to leave soil nutrient levels the same as they were before the crop. Perceptions regarding “mining” the soil will need to be proactively addressed, as this could be a major barrier to adoption of such a new approach to onion fertiliser management.

Defining a well balanced soil in the context of Tasmanian intensive vegetable cropping systems would likely be a challenge, but initially the approach could be to define the criteria specifically for onion cropping, and then if successful follow a similar approach for other crops. To attempt all crop criteria from the outset would be cost and resource prohibitive.

In conjunction with developing a new approach to fertiliser management in onions, it would also be opportune to evaluate whether mycorrhizae could be introduced, possibly within a seed pellet, to improve the consistency and efficiency of onion nutrient uptake.

Validation of sodium as an early indicator of skinning risk and downy mildew susceptibility would be interesting to pursue, however finding suitable sites would be a key challenge to achieve a successful outcome.

Although the main recommendation is not a conventional approach to fertiliser management, this project has demonstrated conclusively that a fundamental change in the way fertiliser programs are managed is worth investigation for the Tasmanian soils as Growers are potentially incurring unnecessary expense on fertiliser products, and also potentially reducing yield and quality through over application of fertilisers. The old catch phrase regarding the addition of supplementary fertilisers that “it can’t hurt” may in fact be incorrect.

Table 3.1 Results of the chelated nutrients and silica trial 1011 FC 101
Variety: 07-AD-211
Planted: 17 May 2010
Lifted: 31 Dec 2010

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Shoot ¼	Shoot ½	Shoot ¾	Shoot 1	Shoot >1
Control	10.2	0	9.8	1.6	4.9	0	0.5	27.2	72.1	0
Cu/S	10.9	1.2	18.6	1.8	4.7	0	2.5	31.8	65.5	0
Enhance	10.7	0.6	20.7	1.9	5.8	0	2.1	18.8	75.9	3.0
Mix	10.5	2.1	16.8	2.2	5.1	0.2	2.0	27.1	70.4	0
Stand	12.4	3.3	19.5	3.5	7.1	0	0	25.1	71.9	2.8

- No statistical analysis has been done for this trial as a number of plots were lost when several beds within the trial area were consolidated in preparation for harvest.

1011 FC 101

Treatment	Date Treatment Applied	Actual Growth Stage	Target Growth Stage	Comments
Cu/S, Mix, Stand	4 Nov 2010	5-5.5 TL	5 TL	
Cu/S, Mix, Stand	16 Nov 2010	6.5-7.5 TL	7 TL (pre bulbing)	
Cu/S, Enhance, Mix, Stand	30 Nov 2010	Bulbing	9 TL (post bulbing)	Signs of mildew
Cu/S, Enhance, Mix, Stand	14 Dec 2010	2-3 weeks after previous spray	2-3 weeks after previous spray	70% tops down in trial area

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 3.2 Results of the chelated nutrients and silica trial 1011 FC 108
Variety: 10-DR-161
Planted: 9 Jul 2010
Lifted: 28 Jan 2011

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Shoot ¼	Shoot ½	Shoot ¾	Shoot 1	Shoot >1
Control	20.4	9.5	20.2	1.7	5.7	0	2.5	32.3	65.2	0
Cu/S	18.6	17.1	25.6	1.3	4.9	0	0	33.7	66.3	0
Enhance	19.2	17.6	25.3	1.2	5.1	0	0.4	29.6	70.0	0
Mix	19.9	12.9	22.9	1.6	5.2	0.8	2.3	25.7	71.2	0
Stand	18.8	6.0	11.2	1.3	4.8	0	2.9	33.5	63.1	0.4
P	NS	NS	.002	NS	NS	NS	NS	NS	NS	NS
LSD 5%			6.73							

- The area where the trial was located had vigorous vegetative growth
- Stand (20% silica) significantly reduced skinning 90 days post harvest
- The treatments had no significant affect on yield, the level of skinning 30 days post lifting, weight loss or sprouting

1011 FC 108

Treatment	Date Treatment Applied	Actual Growth Stage	Target Growth Stage	Comments
Cu/S, Mix, Stand	25 Nov 2010	5-6.5 TL	5 TL	Showing uneven emergence
Cu/S, Mix, Stand	1 Dec 2010	6.5-7 TL	7 TL (pre bulbing)	Showing uneven emergence
Cu/S, Enhance, Mix, Stand	24 Dec 2010	Bulbing	9 TL (post bulbing)	
Cu/S, Enhance, Mix, Stand	5 Jan 2011	2-3 weeks after previous spray	2-3 weeks after previous spray	

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 3.3 Results of the chelated nutrients and silica trial 1011 FC 251
Variety: 10-SP-181A
Planted: 17 Sep 2010
Lifted: 13 Feb 2011

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Shoot ¼	Shoot ½	Shoot ¾	Shoot 1	Shoot >1
Control	16.3	5.3	18.2	3.2	6.8	0	0	40.2	59.8	0
Cu/S	16.1	6.4	16.0	3.3	6.9	0	0	25.8	74.2	0
Enhance	16.1	4.7	25.8	3.5	7.3	0	0	31.6	68.4	0
Mix	14.5	6.6	18.2	3.4	6.8	0	0.2	38.1	61.6	0
Stand	14.9	6.3	21.0	3.3	6.6	0	0.4	34.6	65.0	0
P	NS	NS	NS	NS	NS	-	NS	.037	.035	-
LSD 5%								9.30	9.29	

- Exceptionally fast growth at this site, not representative of standard growth rate
- The treatments had no significant affect on yield, the level of skinning 30 days post lifting, the level of skinning 90 days post lifting or weight loss
- Sprouting was significantly more advanced in the Cu/S treatment compared to the control, although no shoot was visible in any treatment

1011 FC 251

Treatment	Date Treatment Applied	Actual Growth Stage	Target Growth Stage	Comments
Cu/S, Mix, Stand	4 Dec 2010	4.5-5 TL	5 TL	
Cu/S, Mix, Stand	14 Dec 2010	5.5-6.5 TL	7 TL (pre bulbing)	
Cu/S, Enhance, Mix, Stand	5 Jan 2011	Bulbing	9 TL (post bulbing)	
Cu/S, Enhance, Mix, Stand	20 Jan 2011	2-3 weeks after previous spray	2-3 weeks after previous spray	

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 3.4 Results of the post bulbing nitrogen trial 1011 FN 333
Variety: Canterbury
Planted: 29 Sep 2010
Lifted: 28 Feb 2011

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Shoot ¼	Shoot ½	Shoot ¾	Shoot 1	Shoot >1
Control	11.0	2.6	8.4	2.8	7.6	0	0	35.8	60.1	1.8
Amm. Sul.	12.0	3.8	15.7	2.9	7.8	0	0.7	34.0	62.7	1.8
Cal. Nit.	10.8	3.2	18.2	3.1	8.0	0	2.5	30.1	63.5	3.0
Nitroph.	11.5	3.0	8.6	2.7	7.1	0	3.8	32.0	62.3	0
Urea	11.9	3.9	15.7	3.2	8.6	0	1.6	28.8	62.5	4.9
P	NS	NS	NS	NS	NS	-	NS	NS	NS	.043
LSD 5%										3.04

- Treatments applied 19 Jan 2011, bulbing
- Trial site was exposed to high mildew pressure late in the season
- The treatments had no significant affect on yield, the level of skinning 30 or 90 days post lifting, or weight loss
- Sprouting was significantly higher in the Urea treatment compared to the control

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 3.5 Results of the post bulbing nitrogen trial 1011 FN 334
Variety: Conan
Planted: 1 Oct 2010
Lifted: 27 Feb 2011

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Shoot ¼	Shoot ½	Shoot ¾	Shoot 1	Shoot >1
Control	14.2	10.2	27.5	2.7	8.1	0	0	24.5	72.4	1.8
Amm. Sul.	15.6	14.1	31.1	3.1	7.8	0	1.2	25.1	73.1	0.2
Cal. Nit.	14.5	9.5	14.4	3.3	8.6	0	0.2	28.0	66.2	2.7
Nitroph.	16.7	13.5	19.9	2.4	7.2	0	2.2	23.9	70.4	1.1
Urea	14.9	7.5	32.5	2.9	7.6	0	1.3	24.2	70.1	2.4
P	NS	NS	NS	NS	NS	-	NS	NS	NS	NS
LSD 5%										

- Treatments applied 19 Jan 2011, bulbing
- The treatments had no significant affect on yield, the level of skinning 30 or 90 days post lifting, weight loss or shoot development

Results Colour Key

Orange	Skinning >20% at either 30d post or 90d post lifting
Green	Skinning <20% at both 30d post and 90d post lifting

Table 3.6 Results of the post bulbing nitrogen trial 1011 FN 235
Variety: Canterbury
Planted: 9 Oct 2010
Lifted: 5 Mar 2011

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Shoot ¼	Shoot ½	Shoot ¾	Shoot 1	Shoot >1
Control	14.2	1.1	40.0	2.3	6.6	0	1.4	28.8	66.9	0.7
Amm. Sul.	12.3	4.0	50.7	2.8	7.0	0	0	28.6	67.6	1.3
Cal. Nit.	14.9	5.4	52.8	3.6	8.5	0	1.9	23.1	72.4	0.7
Nitroph.	13.8	2.8	48.6	2.1	6.1	0	0.9	22.1	76.1	0.8
Urea	13.4	3.2	53.0	2.0	6.6	0	1.0	24.2	70.6	2.4
P	NS	NS	NS	NS	NS	-	NS	NS	NS	NS
LSD 5%										

- Treatments applied 27 Jan 2011, bulbing
- Irrigation within 2hrs of treatment application
- This site was planted towards the end of the currently recognised planting window for this variety, in a season where the crop was maturing in cool conditions
  - Early growth was slower than expected
- The trial was lifted 14 days later than the current standard lifting time of 80% tops down, due to uneven maturity across the remainder of the paddock
  - Note that 80% tops down may not apply to the variety Canterbury
- The treatments had no significant affect on yield, the level of skinning 30 or 90 days post lifting, weight loss or shoot development

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 3.7 Results of the post bulbing boron trial 1011 FS 223
Variety: 10-DR-161
Planted: 18 Sep 2010
Lifted: 10 Mar 2011

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Shoot ¼	Shoot ½	Shoot ¾	Shoot 1	Shoot >1
Control	21.1	2.1	35.8	2.6	6.9	0	0.5	19.6	75.7	1.1
Bor	20.0	0.5	41.3	2.5	7.3	0	0.9	18.8	76.8	2.4
Mover	20.3	5.1	36.1	2.5	6.7	0	1.1	22.2	74.9	0.6
P	NS	NS	NS	NS	NS	-	NS	NS	NS	NS
LSD 5%										

- This site was planted towards the end of the currently recognised planting window for this variety, in a season where the crop was maturing in cool conditions
- The trial area was lifted 14-21 days later than the current standard lifting time of 80% tops down, due to uneven maturity across the remainder of the paddock
- The treatments had no significant affect on yield, the level of skinning 30 or 90 days post lifting, weight loss or shoot development

1011 FS 223

Treatment	Date Treatment Applied	Actual Growth Stage	Target Growth Stage	Comments
Bor, Mover	5 Jan 2011	Bulbing	Bulbing	
Bor, Mover	20 Jan 2011	2-3 weeks after previous spray	2-3 weeks after previous spray	Irrigated just prior to spray

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 3.8 Results of the post bulbing boron trial 1011 FS 112
Variety: 10-DR-161
Planted: 15 Sep 2010
Lifted: 21 Feb 2011

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Shoot ¼	Shoot ½	Shoot ¾	Shoot 1	Shoot >1
Control	11.8	21.6	45.8	3.9	8.1	0	5.9	43.9	48.6	1.5
Bor	10.4	25.5	48.2	3.8	7.3	0	5.1	41.9	52.1	0.8
Mover	11.5	22.4	42.0	3.8	8.0	0	0	27.3	71.3	1.4
P	NS	NS	NS	NS	NS	-	NS	NS	NS	NS
LSD 5%										

- Trial area had severe downy mildew by lifting
    - Tops were completely desiccated by the disease
- Crop canopy was free of downy mildew damage at 20th Jan 2011
    - ~2 weeks post bulbing
    - ~4 weeks before lifting
- The treatments had no significant affect on yield, the level of skinning 30 or 90 days post lifting, weight loss or shoot development

1011 FS 112

Treatment	Date Treatment Applied	Actual Growth Stage	Target Growth Stage	Comments
Bor, Mover	5 Jan 2011	Bulbing	Bulbing	
Bor, Mover	20 Jan 2011	2-3 weeks after previous spray	2-3 weeks after previous spray	

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 3.9 Results of early post emergence nitrogen and silica, and growth manipulation trial 1112 F 101
Variety: 11-SP-211
Planted: 16 May 2011
Lifted: 29 Dec 2011

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Not Skinned Shoot >1 %	Skinned Shoot >1 %
Control	11.4	4.0	14.7	69.3	2.2	2.9	0	0
Urea	11.5	2.2	23.5	75.2	2.3	2.9	0	0
DAP	13.1	5.6	20.4	66.8	2.3	3.2	0	0
Calcium Nitrate	10.1	4.9	12.4	64.7	2.3	3.0	0	0
Ammonium Sulphate	11.7	3.2	10.8	59.8	2.2	3.1	0	0
Rustica	11.7	5.1	14.7	65.5	2.3	3.2	0	0
Nitrophoska	11.6	5.6	21.4	63.9	2.4	3.5	0	0
3 x Urea	11.6	2.4	10.4	63.2	2.1	3.2	0	0
Maxsil	10.2	4.0	18.8	69.7	2.6	3.3	0	0
Supa Bor	10.4	2.6	14.4	52.1	2.2	3.2	0	0
Cut	10.3	2.8	1.6	43.5	2.2	2.9	0	0
Totril/Bladex	10.5	1.4	7.7	57.3	2.1	3.1	0	0
P	NS	NS	NS	.002	NS	NS	-	-
LSD 5%				15.19				

Target Treatment Application Timing	Date Applied	Actual Average Leaf Stage (TL)	Water (mm) 24hrs	Water (mm) 24-48hrs	Water (mm) 48-72hrs
1TL	15/8/11	1-1.25	12.8	0	15.8
3TL	19/9/11	2.75-3	6.4	1	3.6
6TL	25/10/11	5-6	0	0	3.8
Bulbing	23-24/11/11	Bulbing	0	0-14	14-30
Bulbing (+2wks)	8/12/11	Bulbing +2 weeks	0	0	2.4

- This site was not representative, due to severe herbicide burn early followed by late season fertiliser application
    - The crop's canopy grew more vigorously post bulbing than standard
- Rep 1, Cut treatment was not harvestable due to lifter damage
- There was considerable lifting damage in this trial requiring some treatments to be harvested from the buffer beds
- The treatments had no significant affect on yield, the level of skinning 30 days post lifting, the level of skinning 90 days post lifting, weight loss or sprouting
- The level of skinning 160 days post lifting was significantly reduced by the Cut and Totril/Bladex treatments compared to the control

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 3.10 Results of early post emergence nitrogen and silica, and growth manipulation trial 1112 F 102
Variety: 11-SP-211
Planted: 17 May 2011
Lifted: 28 Dec 2011

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Not Skinned Shoot >1 %	Skinned Shoot >1 %
Control	18.7	1.4	1.8	33.3	2.2	3.0	0	0
Urea	16.6	2.0	8.3	45.0	2.4	3.1	0	0
DAP	17.1	2.0	5.0	41.0	2.3	3.2	0	0
Calcium Nitrate	16.5	6.6	4.0	37.0	2.4	3.2	0	0
Ammonium Sulphate	15.5	1.6	3.5	47.3	2.6	3.2	0	0
Rustica	15.8	1.4	6.4	38.6	2.6	3.0	0	0
Nitrophoska	14.8	1.9	4.1	45.1	2.2	2.9	0	0
3 x Urea	15.4	2.1	5.7	30.5	2.1	2.8	0	0
Maxsil	17.6	0.8	6.6	32.3	2.2	3.1	0	0
Supa Bor	16.0	2.6	3.6	33.7	2.2	2.9	0	0
Cut	13.2	2.7	6.3	28.1	2.5	3.2	0	0
Totril/Bladex	14.7	1.7	2.9	31.9	2.5	2.8	0	0
P	<.001	NS	NS	<.001	NS	NS	-	-
LSD 5%	2.11			7.98				

Target Treatment Application Timing	Date Applied	Actual Average Leaf Stage (TL)	Water (mm) 24hrs	Water (mm) 24-48hrs	Water (mm) 48-72hrs
1TL	15/8/11	1	12.8	0	15.8
3TL	20/9/11	2.75-3	1	1	3.6
6TL	25/10/11	5-6	0	0	3.8
Bulbing	23-24/11/11	Bulbing	0	0-14	14-30
Bulbing (+2wks)	8/12/11	Bulbing +2 weeks	0	0	2.4

- This site had late season fertiliser application
- Yield was significantly reduced by all treatments other than DAP and Maxsil compared to the control; no treatments significantly increased yield compared to the control
- The treatments had no significant affect on the level of skinning 30 days post lifting, the level of skinning 90 days post lifting, weight loss or sprouting
- The level of skinning 160 days post lifting was significantly increased by the Urea, Ammonium Sulphate and Nitrophoska treatments compared to the control

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 3.11 Results of early post emergence nitrogen and silica, and growth manipulation trial 1112 F 201
Variety: 11-SP-211
Planted: 4 May 2011
Lifted: 3 Jan 2012

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Not Skinned Shoot >1 %	Skinned Shoot >1 %
Control	15.6	0	22.5	58.7	1.9	2.9	0	0
Urea	16.0	0	22.9	61.2	1.8	2.9	0	0
DAP	15.5	0	25.7	62.3	1.9	3.0	0	0
Calcium Nitrate	13.9	0	35.4	64.9	1.8	3.2	0	0
Ammonium Sulphate	15.5	0	24.6	55.4	1.9	3.2	0	0
Rustica	15.3	0	22.3	60.1	1.8	3.0	0	0
Nitrophoska	16.0	0.2	26.6	56.0	1.7	3.0	0	0
3 x Urea	14.1	0.3	26.2	60.0	1.9	3.0	0	0
Maxsil	16.2	0	19.9	57.1	1.9	3.1	0	0
Supa Bor	17.1	0	26.6	61.8	1.9	3.0	0	0
Cut	14.2	0	20.7	55.2	1.9	3.2	0	0
Totril/Bladex	16.8	0	20.3	61.0	1.7	2.7	0	0
P	NS	NS	NS	NS	NS	NS	-	-
LSD 5%								

Target Treatment Application Timing	Date Applied	Actual Average Leaf Stage (TL)	Water (mm) 24hrs	Water (mm) 24-48hrs	Water (mm) 48-72hrs
1TL	22/8/11	1.25	0	0	2.8
3TL	22/9/11	3	3.6	0	0
6TL	27/10/11	6-6.25	3.8	4	14
Bulbing	24/11/11	Bulbing	0	14	30
Bulbing (+2wks)	8/12/11	Bulbing +2 weeks	0	0	2.4

- This site had greater than standard fertiliser application
- The treatments had no significant affect on yield, the level of skinning 30 days post lifting, the level of skinning 90 days post lifting, the level of skinning 160 days post lifting, weight loss or sprouting

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 3.12 Results of early post emergence nitrogen and silica, and growth manipulation trial 1112 F 204
Variety: 11-SP-211
Planted: 7 May 2011
Lifted: 29 Dec 2011

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Not Skinned Shoot >1 %	Skinned Shoot >1 %
Control	20.4	6.2	18.7	60.7	1.8	2.8	0	0
Urea	18.1	9.6	15.0	62.9	1.7	3.0	0	0
DAP	17.4	6.2	24.0	68.4	1.7	2.9	0	0
Calcium Nitrate	18.2	7.7	19.7	69.0	1.7	2.8	0	0
Ammonium Sulphate	18.5	8.3	19.9	73.8	1.6	2.9	0	0
Rustica	18.7	7.5	19.5	63.3	1.6	2.5	0	0
Nitrophoska	19.3	6.5	26.9	67.2	1.7	2.8	0	0
3 x Urea	16.8	7.6	24.7	70.0	1.7	2.9	0	0
Maxsil	17.7	4.9	19.2	63.8	1.6	3.2	0	0
Supa Bor	18.4	5.0	12.3	67.6	1.7	3.1	0	0
Cut	15.3	4.6	9.1	46.6	1.7	2.7	0	0
Totril/Bladex	16.1	8.5	15.8	66.1	1.8	2.8	0	0
P	<.001	NS	NS (.054)	.02	NS	NS	-	-
LSD 5%	2.00			12.41				

Target Treatment Application Timing	Date Applied	Actual Average Leaf Stage (TL)	Water (mm) 24hrs	Water (mm) 24-48hrs	Water (mm) 48-72hrs
1TL	22/8/11	1.25	0	0	2.8
3TL	22/9/11	3	3.6	0	0
6TL	27/10/11	6	3.8	4	14
Bulbing	24/11/11	Bulbing	0	14	30
Bulbing (+2wks)	Not applied				

- The second application of Supa Bor was not applied
- Yield was significantly reduced by all treatments other than Entec Nitrophoska compared to the control; no treatments significantly increased yield compared to the control
- The treatments had no significant affect on the level of skinning 30 days post lifting, the level of skinning 90 days post lifting, weight loss or sprouting
- The level of skinning 160 days post lifting was significantly increased by the Ammonium Sulphate treatment, and significantly reduced by the Cut treatment compared to the control

Results Colour Key

Orange	Skinning >20% at either 30d post or 90d post lifting
Green	Skinning <20% at both 30d post and 90d post lifting

Table 3.13 Results of early post emergence nitrogen and silica, and growth manipulation trial 1112 F 350
Variety: 11-SP-211
Planted: 28 May 2011
Lifted: 3 Jan 2012

Treatment	Gross Yield/2m^2
Control	OWR
Urea	OWR
DAP	OWR
Calcium Nitrate	OWR
Ammonium Sulphate	OWR
Rustica	OWR
Nitrophoska	OWR
3 x Urea	OWR
Maxsil	OWR
Supa Bor	OWR
Cut	OWR
Totril/Bladex	OWR
P	
LSD 5%	

Target Treatment Application Timing	Date Applied	Actual Average Leaf Stage (TL)	Water (mm) 24hrs	Water (mm) 24-48hrs	Water (mm) 48-72hrs
1TL	23/8/11	1-1.25	0.8	0	4.6
3TL	3/10/11	2.75-3	0	0	0
6TL	31/10/11	5.75-6	0.6	0.4	0.2
Bulbing	28/11/11	Bulbing	0.4	13	4.2
Bulbing (+2wks)	12/12/11	Bulbing + s weeks	0	0.2	0

- This entire trial was not harvestable, due to late onset of onion white rot

Table 3.14 Results of early post emergence nitrogen and silica, and growth manipulation trial 1112 F 355
Variety: 11-SP-211
Planted: 30 May 2011
Lifted: 16 Jan 2012

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Not Skinned Shoot >1 %	Skinned Shoot >1 %
Control	21.4	5.9	33.3	59.2	2.4	3.4	0	0
Urea	20.7	6.1	27.8	66.2	2.1	3.7	0	0
DAP	20.4	7.0	34.3	69.1	2.4	4.0	0	0
Calcium Nitrate	19.9	8.2	42.2	67.9	2.2	4.1	0	1.0
Ammonium Sulphate	19.9	7.4	36.6	65.1	2.2	3.9	0	1.5
Rustica	21.3	8.1	31.9	67.8	2.4	4.1	0	0
Nitrophoska	21.7	4.2	38.5	70.6	2.3	3.6	0	0
3 x Urea	20.1	7.0	35.4	71.2	2.4	3.6	0	0
Maxsil	21.4	4.8	40.0	63.6	2.3	3.7	0	0
Supa Bor	19.3	7.0	36.3	71.6	2.3	3.8	0	0
Cut	19.5	3.6	18.4	59.8	2.1	3.8	0	0
Totril/Bladex	20.3	5.7	32.6	59.9	2.5	3.8	0	0
P	NS	NS	<.001	NS	NS	NS	-	NS
LSD 5%			8.75					

Target Treatment Application Timing	Date Applied	Actual Average Leaf Stage (TL)	Water (mm) 24hrs	Water (mm) 24-48hrs	Water (mm) 48-72hrs
1TL	23/8/11	1-1.25	0.8	0	4.6
3TL	3/10/11	2.75-3	0	0	0
6TL	31/10/11	5.75-6	0.6	0.4	0.2
Bulbing	28/11/11	Bulbing	0.4	13	4.2
Bulbing (+2wks)	12/12/11	Bulbing + s weeks	0	0.2	0

- The treatments had no significant affect on yield, the level of skinning 30 days post lifting, the level of skinning 160 days post lifting, weight loss or sprouting
- The level of skinning 90 days post lifting was significantly reduced by the Cut treatment compared to the control, and significantly increased by the Calcium Nitrate treatment compared to the control

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 3.15 Results of growth manipulation and silica, and growth manipulation trial 1112 F 105
Variety: 10-DR-161
Planted: 13 Jul 2011
Lifted: 25 Jan 2012

Treatment	Gross Yield/2m^2
Control	OWR
3 x Urea	OWR
Maxsil	OWR
Supa Bor	OWR
Cut	OWR
Totril/Bladex	OWR
P	
LSD 5%	

Target Treatment Application Timing	Date Applied	Actual Average Leaf Stage (TL)	Water (mm) 24hrs	Water (mm) 24-48hrs	Water (mm) 48-72hrs
1TL	4/10/11	1.25	0	0	1.8
3TL	2/11/11	3-4	0	0	0
6TL	9/12/11	6.5	0	2.4	0
Bulbing	28/12/11	Bulbing	15	0	0
Bulbing (+2wks)	13/1/12	Bulbing + 2 weeks	0	0	0

- This entire trial was not harvestable, due to late onset of onion white rot

Table 3.16 Results of growth manipulation and silica, and growth manipulation trial 1112 F 109
Variety: Baron
Planted: 17 Jul 2011
Lifted: 20 Jan 2012

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Not Skinned Shoot >1 %	Skinned Shoot >1 %
Control	19.1	0	3.8	41.1	2.2	3.4	0	0
3 x Urea	18.5	1.9	11.0	49.0	2.0	3.3	0	0
Maxsil	17.4	0.3	0.9	38.4	2.1	3.3	0	0
Supa Bor	16.9	0.4	2.4	47.9	2.0	3.3	0	0
Cut	14.4	0.3	0.7	37.7	2.1	3.3	0	0
Totril/Bladex	14.9	0	2.6	42.1	2.1	3.3	0	0
P	.002	NS	.010	NS	NS	NS	-	-
LSD 5%	2.25		5.72					

Target Treatment Application Timing	Date Applied	Actual Average Leaf Stage (TL)	Water (mm) 24hrs	Water (mm) 24-48hrs	Water (mm) 48-72hrs
1TL	4/10/11	1.25	0	0	1.8
3TL	2/11/11	3-4	0	0	0
6TL	9/12/11	6.75-7.25	0	2.4	0
Bulbing	19/12/11	Bulbing	0	0.2	0.2
Bulbing (+2wks)	30/12/11	Bulbing + 2 weeks	0	0	0

- Rep 4, Supa Bor, Cut and Totril/Bladex not harvested due to lifting damage
- Yield was significantly reduced by the Cut and Totril/Bladex treatments compared to the control; no treatments significantly increased yield compared to the control
- The treatments had no significant affect on the level of skinning 30 days post lifting, the level of skinning 160 days post lifting, weight loss or sprouting
- The level of skinning 90 days post lifting was significantly increased by the 3 x Urea treatment compared to the control

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 3.17 Results of early post emergence nitrogen and silica, and growth manipulation trial 1112 F 230 (Canterbury)
Variety: Canterbury
Planted: 15 Sep 2011
Lifted: 13 Feb 2012

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Not Skinned Shoot >1 %	Skinned Shoot >1 %
Control	15.8	0	15.4	57.0	2.4	2.8	0	0
Urea	16.7	0.3	16.7	55.3	2.4	2.8	0	0.6
DAP	16.8	1.4	17.5	53.9	2.3	2.9	0	0
Calcium Nitrate	17.1	0.4	19.2	62.0	2.5	3.0	0	0
Ammonium Sulphate	17.8	0.8	25.3	51.3	2.3	2.8	0	0
Rustica	16.5	0	14.6	59.9	2.3	2.7	0	0
Nitrophoska	18.3	0.5	13.7	58.7	2.3	2.8	0	0
3 x Urea	17.5	2.9	18.8	62.2	2.3	3.0	0	0
Maxsil	15.0	0.5	16.6	49.1	2.2	2.8	0	0
Supa Bor	18.4	1.8	18.9	58.9	2.6	2.6	0	0
Cut	12.1	0.5	5.0	50.1	2.3	2.6	0	0
Totril/Bladex	10.8	0.4	11.5	44.4	2.4	2.8	0	0
P	<.001	NS	.002	NS	NS	NS	-	NS
LSD 5%	2.45		7.53					

Target Treatment Application Timing	Date Applied	Actual Average Leaf Stage (TL)	Water (mm) 24hrs	Water (mm) 24-48hrs	Water (mm) 48-72hrs
1TL	4/11/11	1	0	0	0
3TL	30/11/11	3-3.25	13.8	0.2	0
6TL	19/12/11	6-6.25	4	0	0.2
Bulbing	23/1/12	Bulbing	0	0	0
Bulbing (+2wks)	Not applied				

- The second application of Supa Bor was not applied
- This trial experienced severe downy mildew infection towards the end of the crop, which may have influenced the timing of tops down
- Yield was significantly reduced by the Cut and Totril/Bladex treatments compared the control; yield was significantly increased by the Entec Nitrophoska and Supa Bor treatments compared to the control
- The treatments had no significant affect on the level of skinning 30 days post lifting, the level of skinning 160 days post lifting, weight loss or sprouting
- The level of skinning 90 days post lifting was significantly reduced by the Cut treatment compared to the control, and significantly increased by the Ammonium Sulphate treatment compared to the control

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 3.18 Results of early post emergence nitrogen and silica, and growth manipulation trial 1112 F 230 (161)
Variety: 161
Planted: 15 Sep 2011
Lifted: 26 Feb 2012

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Not Skinned Shoot >1 %	Skinned Shoot >1 %
Control	15.6	3.9	12.0	57.4	2.8	3.2	0	0
Urea	15.8	1.9	24.6	51.0	2.4	3.3	0	0
DAP	16.1	5.9	27.3	52.3	2.7	3.2	0	2.2
Calcium Nitrate	17.9	4.4	27.5	62.8	2.7	3.4	0	1.4
Ammonium Sulphate	17.3	0.6	29.8	50.6	2.9	3.2	0	0
Rustica	17.2	3.4	29.1	64.3	2.6	3.3	0	0
Nitrophoska	16.4	4.5	26.1	55.2	2.5	3.5	0	0
3 x Urea	16.4	8.9	27.0	63.6	2.7	3.2	0	0
Maxsil	19.9	1.4	21.1	57.3	2.9	3.3	0	0
Supa Bor	15.8	2.2	13.1	51.4	2.7	3.4	0	0
Cut	11.9	1.5	6.6	36.0	2.8	3.2	0	0
Totril/Bladex	11.6	1.3	14.1	40.8	2.8	3.2	0	0
P	NS (.051)	NS	<.001	.019	.042	NS	-	NS
LSD 5%	4.61		8.30	15.73	0.31			

Target Treatment Application Timing	Date Applied	Actual Average Leaf Stage (TL)	Water (mm) 24hrs	Water (mm) 24-48hrs	Water (mm) 48-72hrs
1TL	4/11/11	.75-1	0	0	0
3TL	30/11/11	2.75-3	13.8	0.2	0
6TL	19/12/11	5.75-6	4	0	0.2
Bulbing	23/1/12	Bulbing	0	0	0
Bulbing (+2wks)	6/2/12	Bulbing + 2 weeks	5	0	0

- The treatments had no significant affect on yield, the level of skinning 30 days post lifting, weight loss 90-160 days post lifting or sprouting
- The level of skinning 90 days post lifting was significantly increased by all fertiliser treatments other than the Supa Bor treatment compared to the control
- Weight loss was significantly reduced by the Urea treatment 30-90 days post lifting compared to the control
- The level of skinning 160 days post lifting was significantly reduced by the Cut and Totril/Bladex treatments compared to the control

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 3.19 Results of planting phosphorous and nitrogen interaction trial 1213 F 104
Variety: 12-DR-317
Planted: 30 Jul 2012
Lifted: 12 Feb 2013

Drill MAP Treatment	Foliar Urea Treatment	Density Plants/m^2	Gross Yield/2m^2	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160D Weight Loss %	160d Shoot %				
									¼	½	¾	1	>1
MAP	All	85.9	16.2	5.1	56.3	94.0	3.1	3.2	0	3.2	14.7	78.8	3.2
Nil	All	86.6	15.0	3.2	51.8	90.5	3.1	3.2	0	1.9	19.4	75.7	2.8
P		NS	.047	NS	NS	NS	NS	NS	-	NS	NS	NS	NS
LSD 5%			1.15										
All	Nil	87.0	13.5	0.5	48.6	87.3	3.1	2.9	0	2.4	17.9	75.4	4.1
All	1TL	87.0	15.6	3.9	50.6	93.4	3.2	3.1	0	2.9	16.9	76.9	3.2
All	1&3TL	85.3	15.8	5.9	56.1	94.7	3.2	3.4	0	1.3	18.4	79.0	1.2
All	1&3&6TL	85.9	17.5	6.3	60.9	93.5	3.1	3.4	0	3.7	15.0	77.8	3.4
P		NS	<.001	.006	.032	NS	NS	NS	-	NS	NS	NS	NS
LSD 5%			1.63	3.39	8.82								
MAP	Nil	87.2	13.9	0.8	53.0	88.7	3.0	2.7	0	3.7	17.0	73.2	6.0
Nil	Nil	86.8	13.0	0.3	44.2	85.9	3.2	3.2	0	1.1	18.8	77.6	2.3
MAP	1TL	87.6	16.7	4.5	49.8	94.3	3.3	2.9	0	2.7	16.8	77.4	2.9
Nil	1TL	86.4	14.6	3.3	51.4	92.4	3.1	3.3	0	3.1	17.0	76.3	3.5
MAP	1&3TL	83.0	16.4	8.1	58.5	100	3.2	3.3	0	2.3	12.9	83.3	1.4
Nil	1&3TL	87.6	15.2	3.6	53.8	89.4	3.2	3.4	0	0.3	23.9	74.6	1.1
MAP	1&3&6TL	86.0	17.8	6.9	64.0	92.8	3.2	3.9	0	4.1	12.1	81.2	2.5
Nil	1&3&6TL	85.8	17.2	5.7	57.9	94.3	3.1	2.9	0	3.2	17.9	74.4	4.3
P		NS	NS	NS	NS	NS	NS	NS	-	NS	NS	NS	NS
LSD 5%													

- The presence of moderate downy mildew in this site may have influenced the level of skinning, potentially masking treatment affects
- Density was not significantly affected by any treatment
- Yield was significantly increased by the application of MAP at planting or by the applications of Urea
- The level of skinning 30days and 90 days post lifting was significantly increased by the application of Urea
- The treatments had no significant affect on weight loss
- The treatments had no significant affect on shoot development

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 3.20 Results of planting phosphorous and nitrogen interaction trial 1213 F 107
Variety: 12-DR-161
Planted: 19 Aug 2012
Lifted: 5 Feb 2013

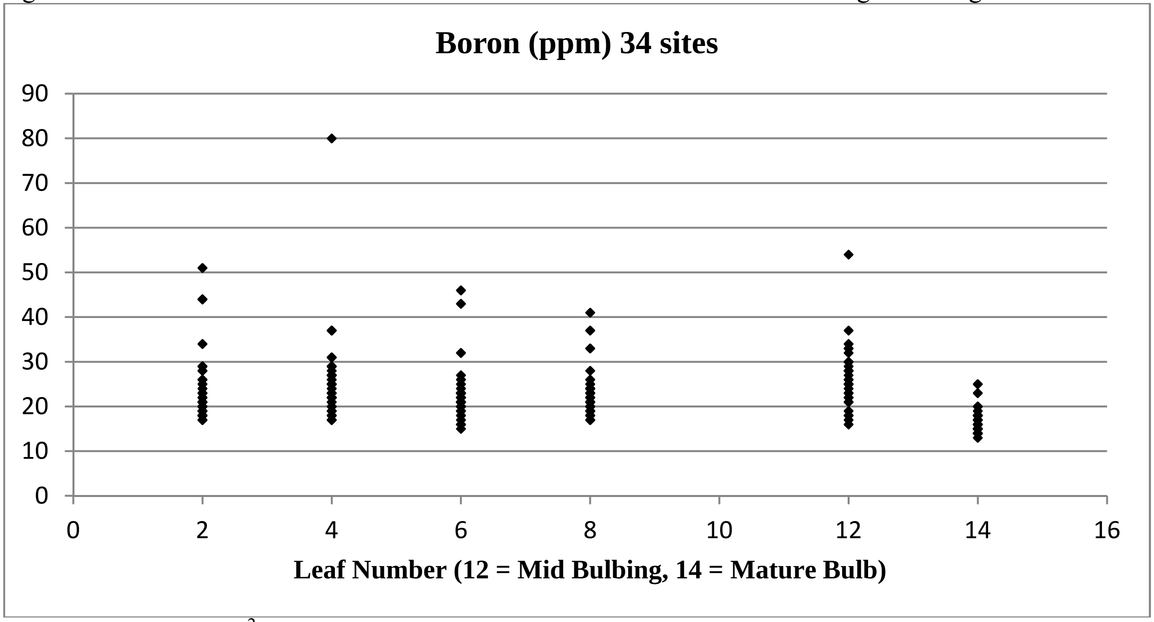
Drill MAP Treatment	Foliar Urea Treatment	Density Plants/m^2	Gross Yield/$2m^2$	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
									¼	½	¾	1	>1
MAP	All	103.9	16.9	5.4	13.2	31.3	2.6	2.1	0	1.6	18.9	79.4	0
Nil	All	103.3	16.5	3.0	13.6	33.5	2.6	2.0	0	1.9	20.9	77.1	0
P		NS	NS	<.001	NS	NS	NS	NS	-	NS	NS	NS	-
LSD 5%				1.24									
All	Nil	104.9	16.2	1.5	6.2	28.0	2.7	2.1	0	1.9	22.9	75.0	0
All	1TL	103.6	18.3	4.0	11.1	25.4	2.7	2.0	0	1.9	20.9	77.0	0
All	1&3TL	104.1	15.8	4.8	17.2	37.6	2.6	2.0	0	1.9	18.4	79.6	0
All	1&3&6TL	101.9	16.7	6.3	18.1	37.4	2.5	1.9	0	1.3	17.6	81.0	0
P		NS	NS	<.001	0.007	<.001	NS	NS	-	NS	NS	NS	-
LSD 5%				1.76	7.15	6.53							
MAP	Nil	103.4	16.3	2.2	7.5	26.7	2.6	2.1	0	1.5	22.4	76.0	0
Nil	Nil	106.5	16.1	0.7	4.9	29.2	2.7	2.1	0	2.3	23.5	74.0	0
MAP	1TL	104.0	18.6	7.2	11.4	24.0	2.7	2.0	0	1.0	19.9	78.9	0
Nil	1TL	103.2	18.0	0.8	10.8	26.8	2.6	2.0	0	2.7	22.0	75.2	0
MAP	1&3TL	104.8	15.6	4.7	16.7	36.6	2.6	2.1	0	3.2	17.3	79.3	0
Nil	1&3TL	103.4	16.1	4.8	17.6	38.6	2.5	1.9	0	0.6	19.4	79.9	0
MAP	1&3&6TL	103.2	17.4	7.3	16.3	36.7	2.6	2.1	0	0.5	16.3	83.0	0
Nil	1&3&6TL	100.6	16.1	5.4	19.9	38.1	2.4	1.8	0	2.0	18.9	78.9	0
P		NS	NS	<.001	NS	NS	NS	NS	-	NS	NS	NS	-
LSD 5%				2.50									

- OWR was present throughout the trial area; potentially masking treatment affects, no yield data was collected for 1 of the 5 blocks due to the level of OWR
- Treatment Nil/1TL and MAP/1&3TL were deleted from 1 block due to treatment application error
- The treatments had no significant affect on density or yield
- The level of skinning 30days post lifting was significantly increased by the application of MAP at planting
- The level of skinning 30 days, 90days and 160 days post lifting was significantly increased by the application of Urea
- There was a significant interaction between the application of MAP at drilling and Urea on the level of skinning 30 days post lifting
- The treatments had no significant affect on weight loss or shoot development

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

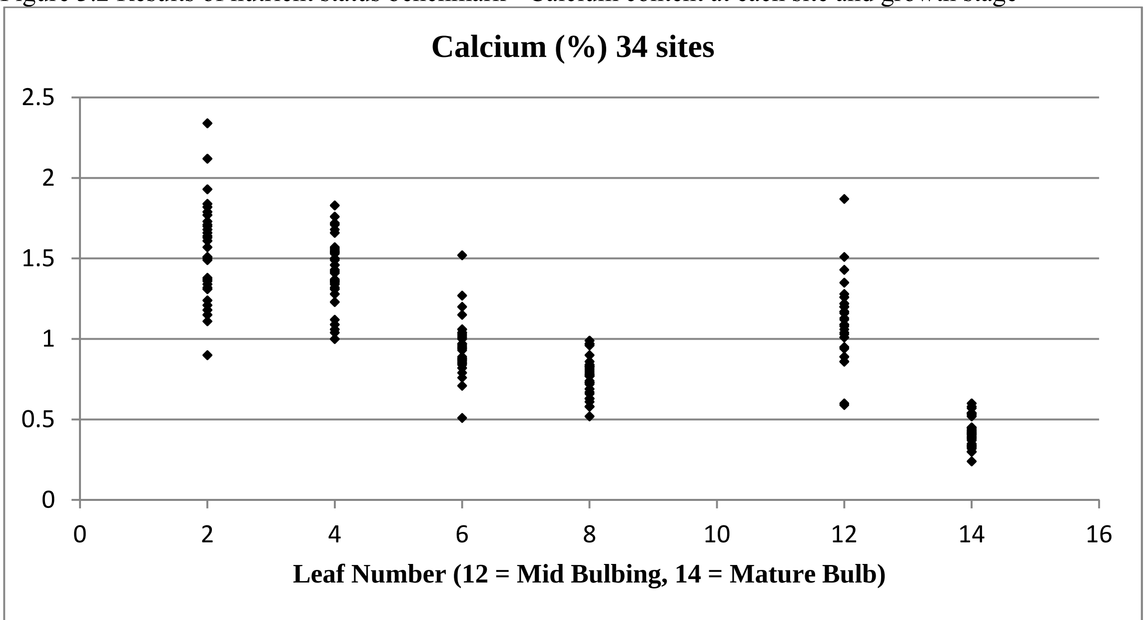
Figure 3.1 Results of nutrient status benchmark - Boron content at each site and growth stage



Correlation analysis (R^2) between each skin assessment and nutrient content at each growth stage

	2TL	4TL	6TL	8TL	12 Mid Bulbing	14 Mature Bulb
30d Skin	.01	0	0	0	.03	.01
90d Skin	0	0	0	0	.02	.01
160d Skin	0	0	.01	.01	.03	0

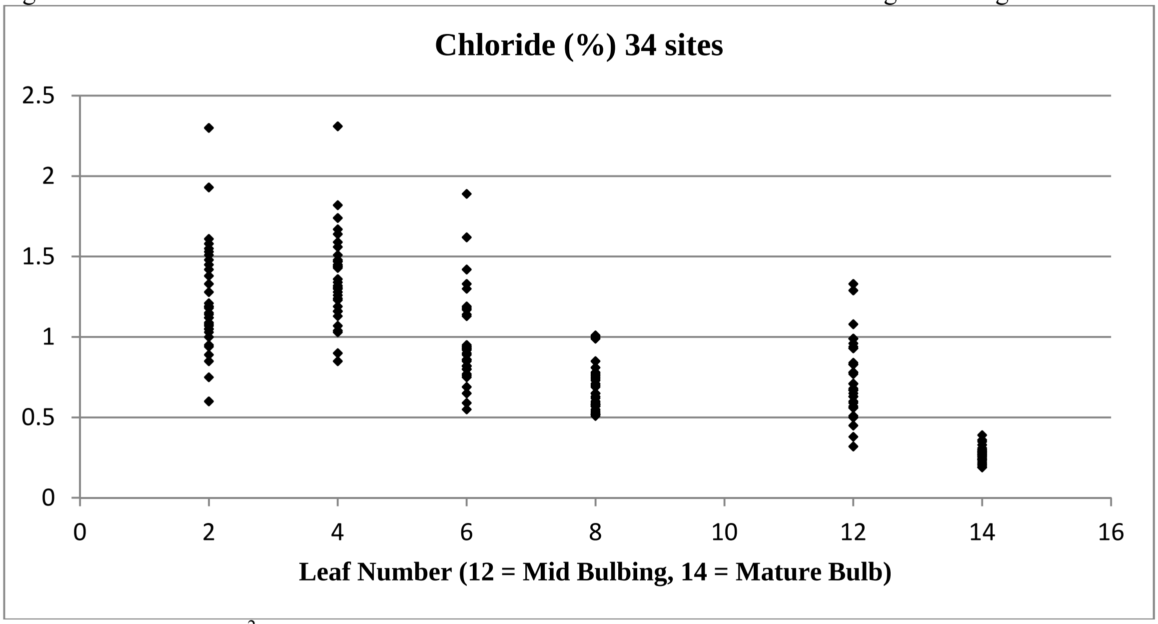
Figure 3.2 Results of nutrient status benchmark - Calcium content at each site and growth stage



Correlation analysis (R^2) between each skin assessment and nutrient content at each growth stage

	2TL	4TL	6TL	8TL	12 Mid Bulbing	14 Mature Bulb
30d Skin	.20	.08	.07	0	.26	.12
90d Skin	.06	.06	.05	.01	.07	0
160d Skin	.01	.04	.03	.01	.25	0

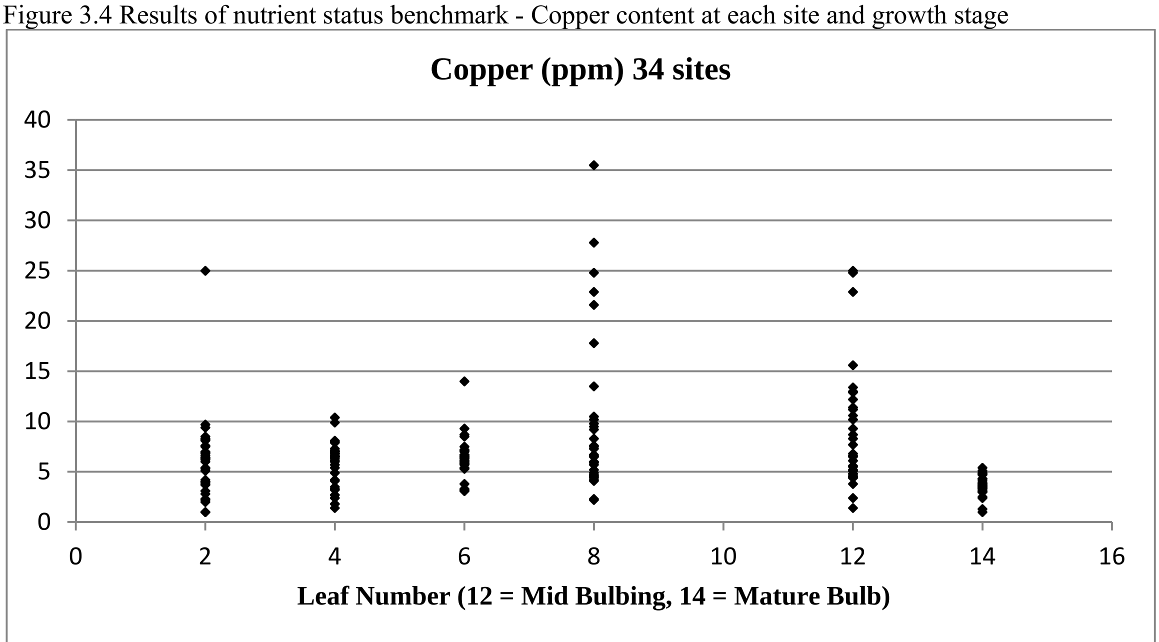
Figure 3.3 Results of nutrient status benchmark - Chloride content at each site and growth stage



Correlation analysis (R^2) between each skin assessment and nutrient content at each growth stage

	2TL	4TL	6TL	8TL	12 Mid Bulbing	14 Mature Bulb
30d Skin	.04	.05	.06	.05	.04	.01
90d Skin	0	.02	.03	0	0	.04
160d Skin	.01	.01	.04	0	.07	.16

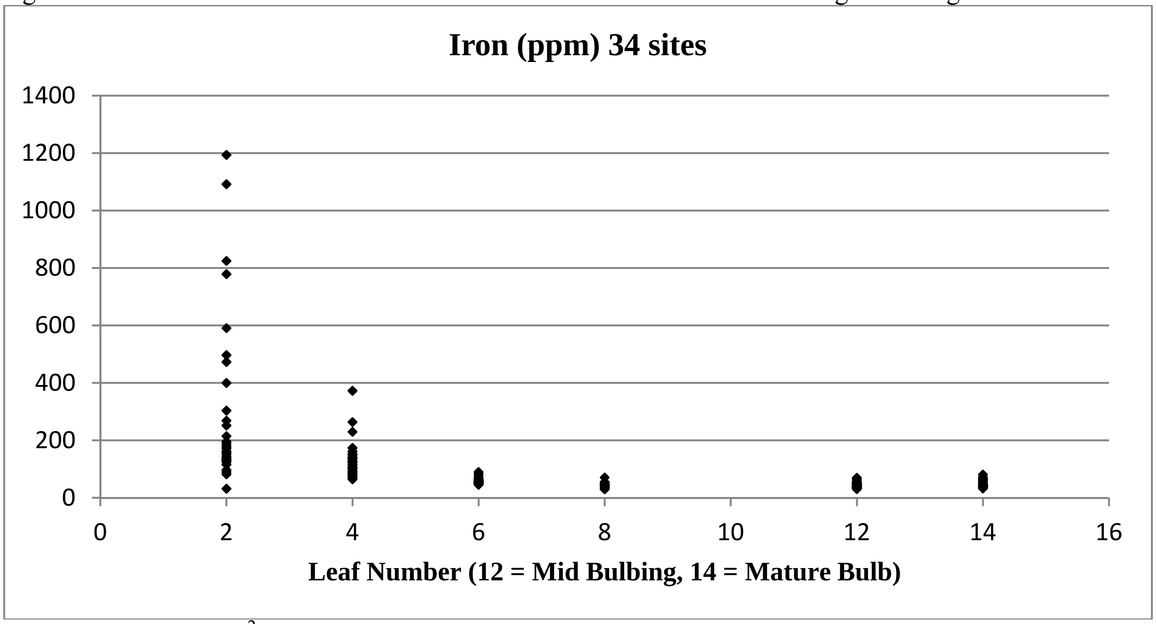
Figure 3.4 Results of nutrient status benchmark - Copper content at each site and growth stage



Correlation analysis (R^2) between each skin assessment and nutrient content at each growth stage

	2TL	4TL	6TL	8TL	12 Mid Bulbing	14 Mature Bulb
30d Skin	.02	.07	.05	0	.21	.04
90d Skin	.01	.12	.01	0	.06	.08
160d Skin	.06	.15	.03	0	.01	.12

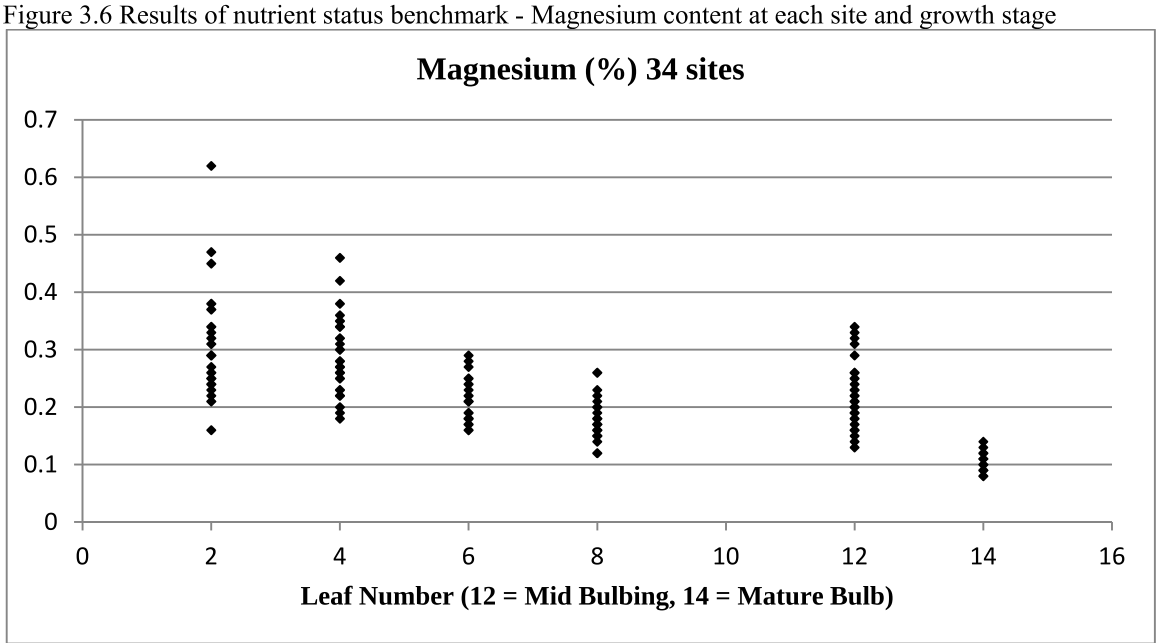
Figure 3.5 Results of nutrient status benchmark - Iron content at each site and growth stage



Correlation analysis (R^2) between each skin assessment and nutrient content at each growth stage

	2TL	4TL	6TL	8TL	12 Mid Bulbing	14 Mature Bulb
30d Skin	.04	.01	.02	0	.09	.20
90d Skin	.03	.02	.03	0	.08	.09
160d Skin	.10	.07	0	.06	.28	.05

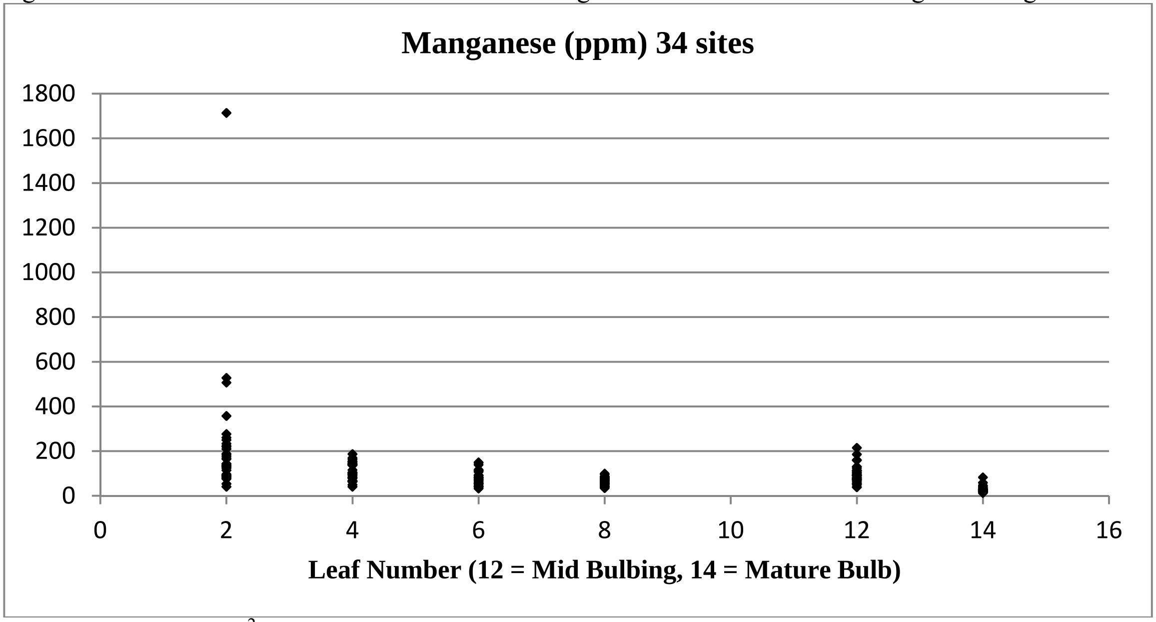
Figure 3.6 Results of nutrient status benchmark - Magnesium content at each site and growth stage



Correlation analysis (R^2) between each skin assessment and nutrient content at each growth stage

	2TL	4TL	6TL	8TL	12 Mid Bulbing	14 Mature Bulb
30d Skin	.03	.01	.02	.01	.03	.02
90d Skin	.02	.07	.07	0	.03	.01
160d Skin	.03	.05	.09	.07	.27	.16

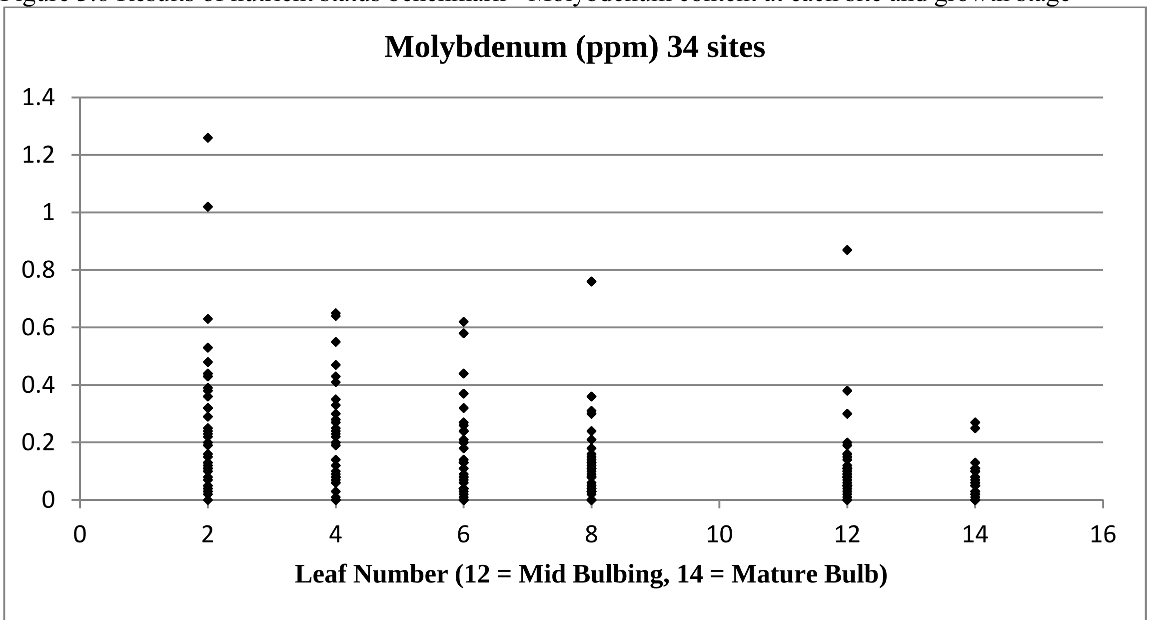
Figure 3.7 Results of nutrient status benchmark - Manganese content at each site and growth stage



Correlation analysis (R^2) between each skin assessment and nutrient content at each growth stage

	2TL	4TL	6TL	8TL	12 Mid Bulbing	14 Mature Bulb
30d Skin	.01	.01	0	0	.04	0
90d Skin	0	.02	.02	0	.08	.03
160d Skin	.01	.01	0	.01	.08	0

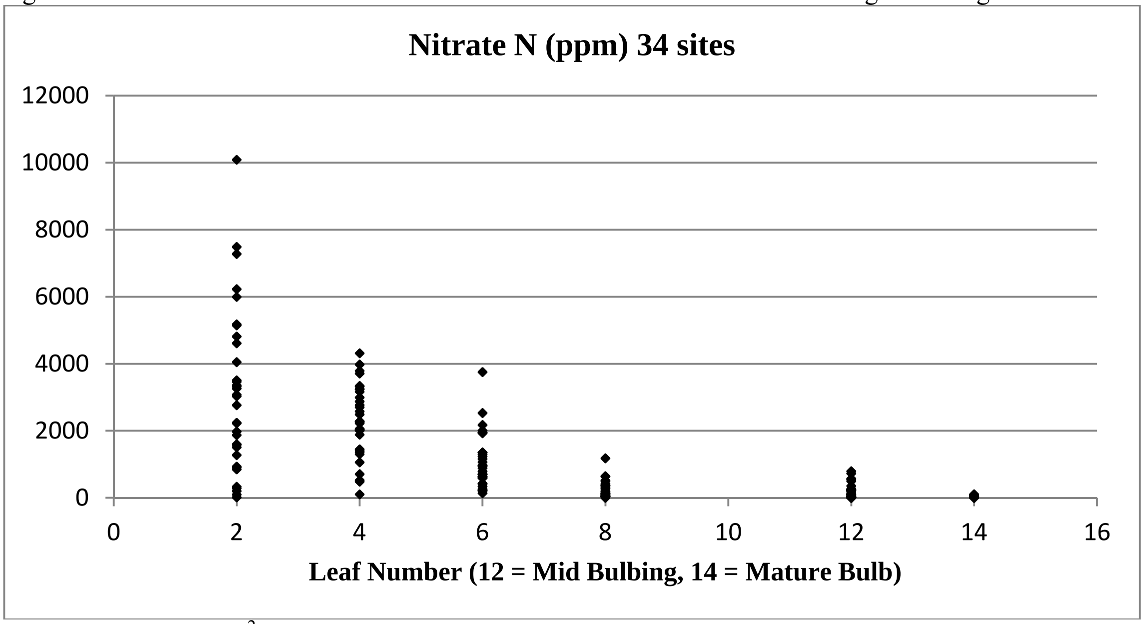
Figure 3.8 Results of nutrient status benchmark - Molybdenum content at each site and growth stage



Correlation analysis (R^2) between each skin assessment and nutrient content at each growth stage

	2TL	4TL	6TL	8TL	12 Mid Bulbing	14 Mature Bulb
30d Skin	0	.01	.03	0	.11	.01
90d Skin	.02	.07	.04	.07	.13	.02
160d Skin	.01	0	.01	.01	.01	.02

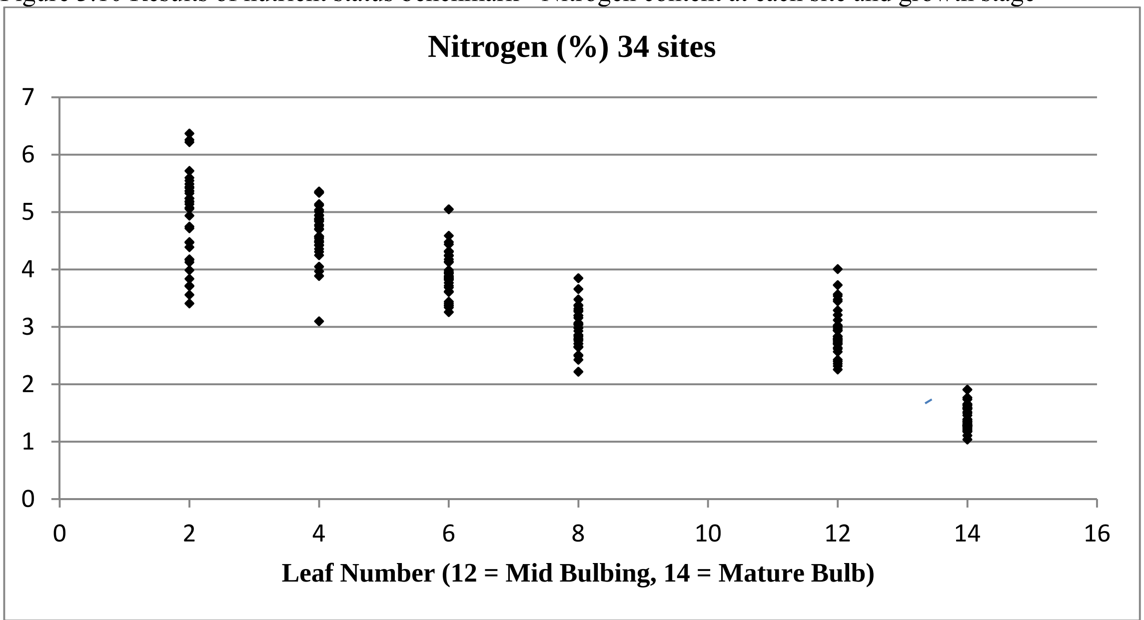
Figure 3.9 Results of nutrient status benchmark - Nitrate content at each site and growth stage



Correlation analysis (R^2) between each skin assessment and nutrient content at each growth stage

	2TL	4TL	6TL	8TL	12 Mid Bulbing	14 Mature Bulb
30d Skin	0	.02	.02	.02	.03	.52
90d Skin	.01	.04	.07	0	.04	.39
160d Skin	.09	.13	.12	.02	.06	.22

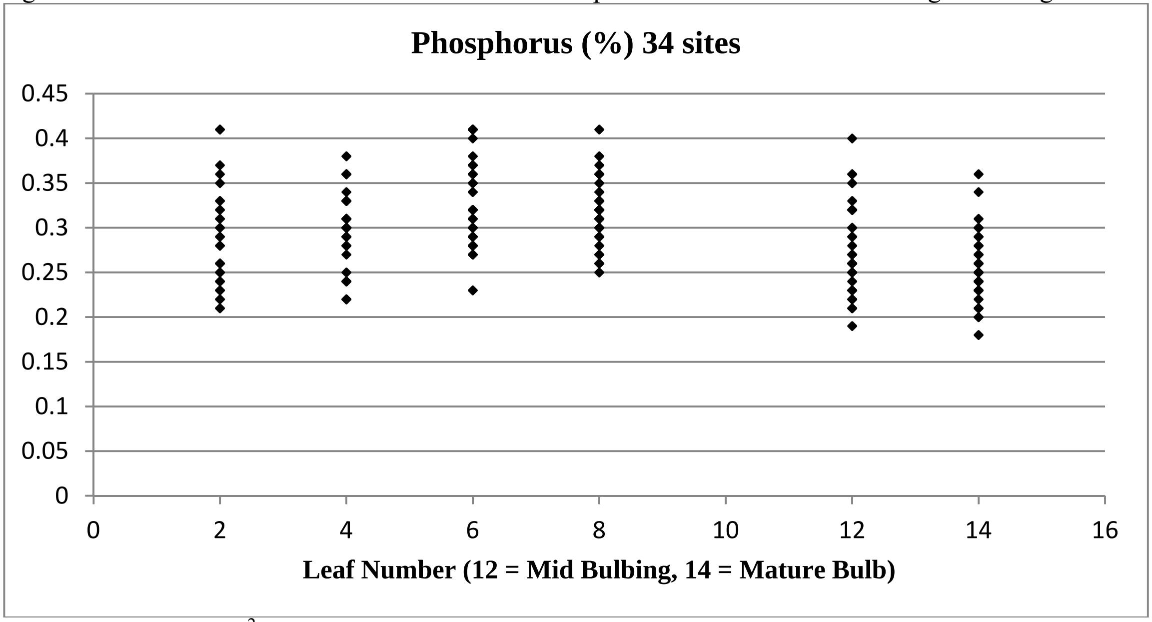
Figure 3.10 Results of nutrient status benchmark - Nitrogen content at each site and growth stage



Correlation analysis (R^2) between each skin assessment and nutrient content at each growth stage

	2TL	4TL	6TL	8TL	12 Mid Bulbing	14 Mature Bulb
30d Skin	0	0	0	.02	.27	.09
90d Skin	0	0	.01	0	.15	.08
160d Skin	.06	.02	.01	0	.25	.02

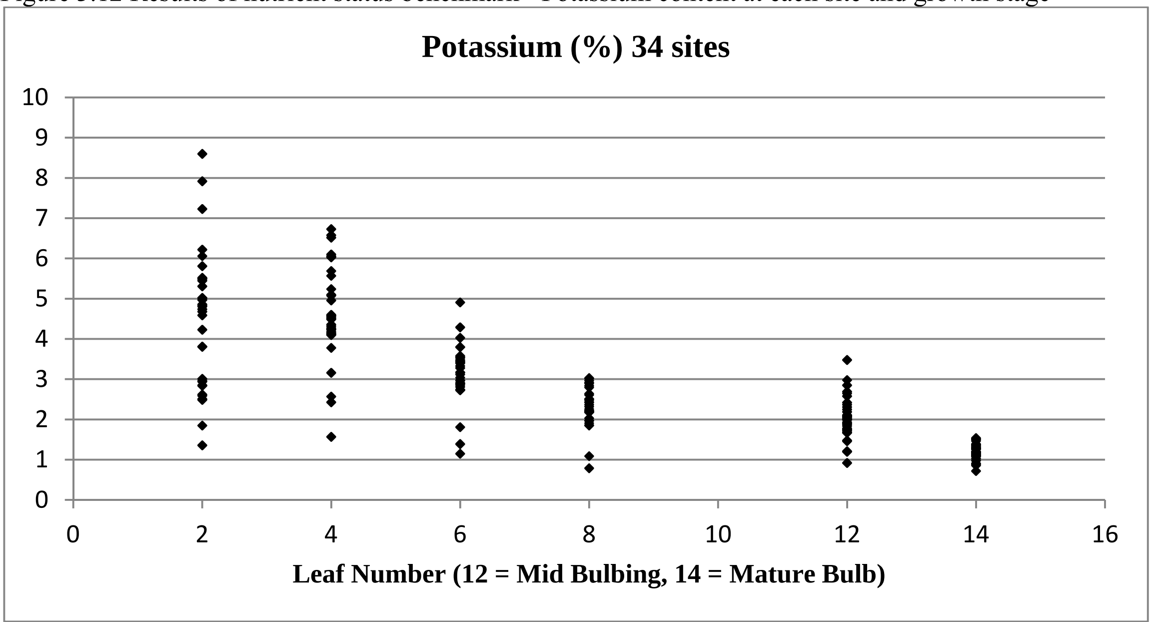
Figure 3.11 Results of nutrient status benchmark - Phosphorus content at each site and growth stage



Correlation analysis (R^2) between each skin assessment and nutrient content at each growth stage

	2TL	4TL	6TL	8TL	12 Mid Bulbing	14 Mature Bulb
30d Skin	.01	.12	.09	.03	.18	.32
90d Skin	.02	.08	.04	.01	.11	.09
160d Skin	.04	.18	.01	0	.03	.01

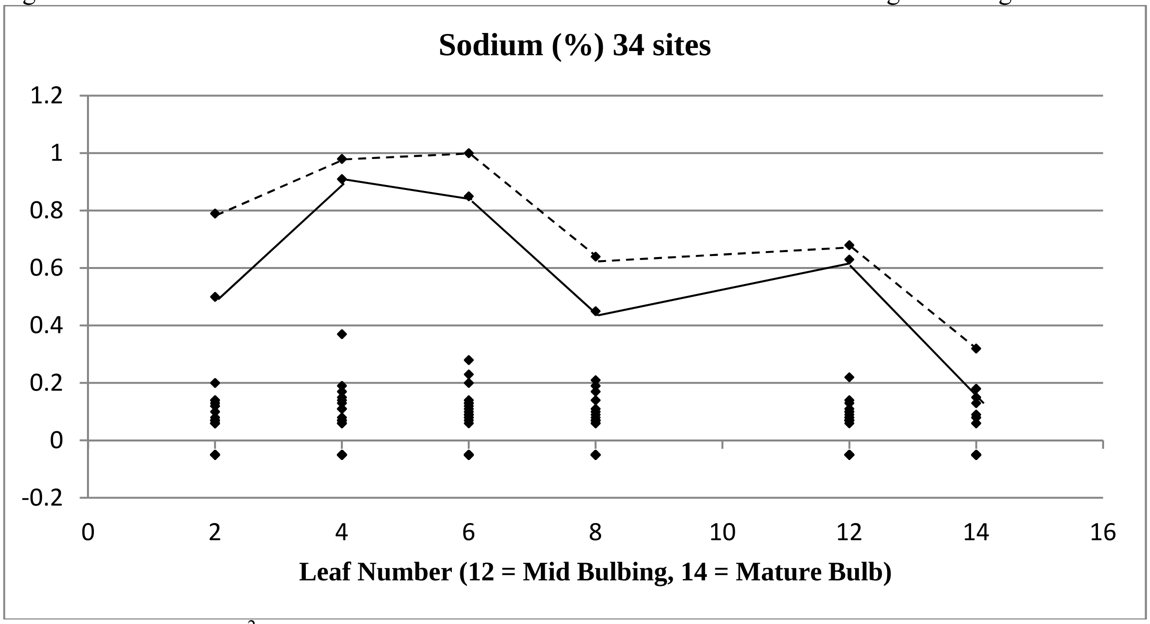
Figure 3.12 Results of nutrient status benchmark - Potassium content at each site and growth stage



Correlation analysis (R^2) between each skin assessment and nutrient content at each growth stage

	2TL	4TL	6TL	8TL	12 Mid Bulbing	14 Mature Bulb
30d Skin	.04	.14	.30	.41	.15	.20
90d Skin	0	.07	.05	.07	.02	0
160d Skin	.02	0	.02	.03	.02	0

Figure 3.13 Results of nutrient status benchmark - Sodium content at each site and growth stage

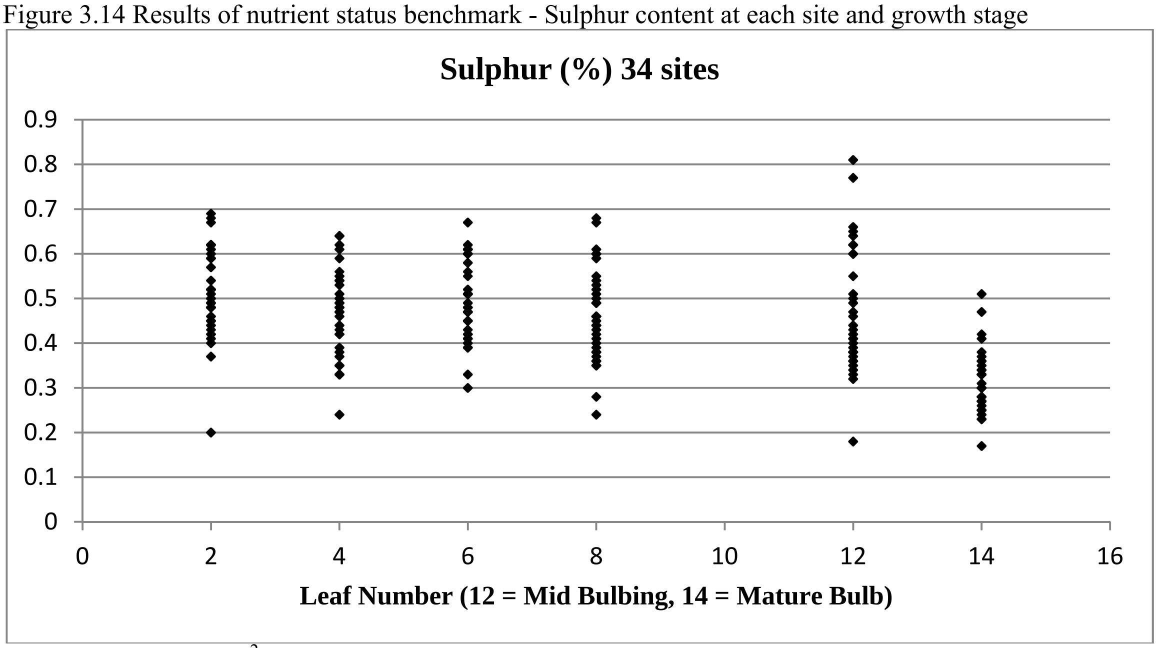


Correlation analysis (R^2) between each skin assessment and nutrient content at each growth stage

	2TL	4TL	6TL	8TL	12 Mid Bulbing	14 Mature Bulb
30d Skin	.62	.65	.70	.64	.71	.44
90d Skin	.18	.28	.29	.22	.28	.14
160d Skin	.14	.18	.21	.16	.21	.12

- Sodium levels that were too low to be detected were treated as “0” in this analysis.
- The data points connected by the lines show the progression of results within two of the sample sites; note that both sites were in the same paddock but were from different varieties

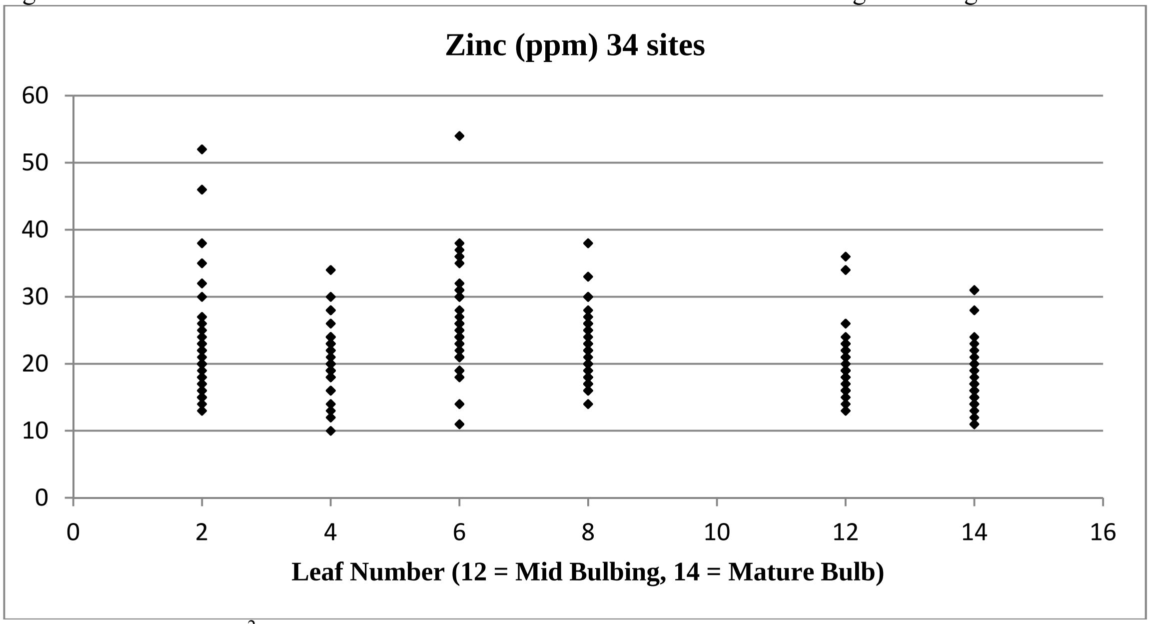
Figure 3.14 Results of nutrient status benchmark - Sulphur content at each site and growth stage



Correlation analysis (R^2) between each skin assessment and nutrient content at each growth stage

	2TL	4TL	6TL	8TL	12 Mid Bulbing	14 Mature Bulb
30d Skin	.04	.08	.06	.12	.42	.45
90d Skin	0	.02	.07	.16	.33	.35
160d Skin	0	.03	.25	.13	.30	.30

Figure 3.15 Results of nutrient status benchmark - Zinc content at each site and growth stage



Correlation analysis (R^2) between each skin assessment and nutrient content at each growth stage

	2TL	4TL	6TL	8TL	12 Mid Bulbing	14 Mature Bulb
30d Skin	0	0	.02	.06	.01	.11
90d Skin	.01	0	.03	.01	.01	.13
160d Skin	0	0	.01	.05	0	.08

Figure 3.16 Results of nutrient status benchmark - Skinning level at each site at 30 d, 90d and 160d post lifting

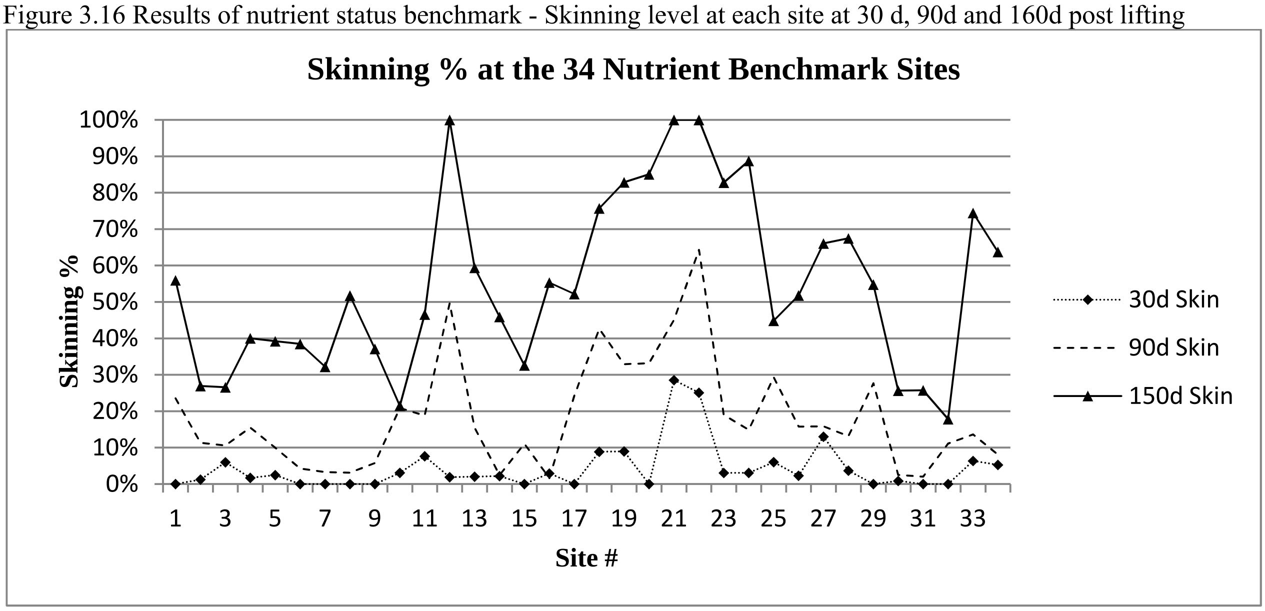


Table 3.21 Results of sulphur, nitrogen and molybdenum interaction trial 1314 TS Fert 10
Variety: 11-DR-211
Planted: 7 May 2013
Lifted: 3 Jan 2014

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Not Skinned Shoot >1%	160d Skinned Shoot >1%	Pyruvate µmol/ml
Control	21.4	19.3	10.2	48.2	1.8	1.9	0	0.2	4.5
Mo	21.3	18.5	8.1	50.1	1.9	1.8	0	0	4.9
S	22.8	17.7	6.3	46.3	2.4	1.9	0	0	5.1
S & Mo	25.0	19.4	4.6	44.3	1.9	2.2	0.7	0	5.2
S & N	22.1	21.9	11.3	58.1	1.8	2.1	0.3	0.7	5.2
P	NS	NS	NS	NS	NS	NS	NS	NS	NS
LSD 5%									

- This site had a high level of bolters and was lifted earlier than standard to try and reduce the final level of bolters
- The treatments had no significant affect on yield
- The level of skinning 30 days, 90days and 160 days post lifting was not significantly affected by any treatment
- The treatments had no significant affect on weight loss or shoot development
- The treatments had no significant affect on pyruvate level, although all treatments involving sulphur had higher levels than the control

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 3.22 Results of sulphur, nitrogen and molybdenum interaction trial 1314 TS Fert 20
Variety: 11-DR-211
Planted: 8 May 2013
Lifted: 4 Jan 2014

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Not Skinned Shoot >1%	160d Skinned Shoot >1%	Pyruvate µmol/ml
Control	20.3	9.8	3.9	43.7	1.8	1.9	0	0	5.0
Mo	20.9	8.8	3.9	44.6	1.9	1.9	0.5	0	5.3
S	21.2	12.0	6.3	51.3	1.6	2.3	0	0	5.3
S & Mo	18.9	11.2	6.6	41.6	1.9	1.9	0.5	0	5.9
S & N	19.9	8.3	4.1	52.2	1.7	1.8	0.5	0.6	5.6
P	NS	NS	NS	NS	NS	NS	NS	NS	NS
LSD 5%									

- The treatments had no significant affect on yield
- The level of skinning 30 days, 90days and 160 days post lifting was not significantly affected by any treatment
- The treatments had no significant affect on weight loss or shoot development
- The treatments had no significant affect on pyruvate level, although all treatments involving sulphur had higher levels than the control

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 3.23 Results of sulphur, nitrogen and molybdenum interaction trial 1314 TS Fert 50
Variety: 12-RC-181
Planted: 7 Sep 2013
Lifted: 12 Feb 2014

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Not Skinned Shoot >1%	160d Skinned Shoot >1%	Pyruvate µmol/ml
Control	19.3	7.3	7.0	58.8	1.5	2.2	0	0.4	3.6
Mo	20.0	6.5	10.7	61.5	1.5	2.2	0	2.0	2.8
S	19.9	8.5	8.7	62.2	1.6	2.2	0.4	0	4.1
S & Mo	20.5	8.0	9.5	60.2	1.5	2.2	0	0.3	4.0
S & N	19.8	5.7	11.8	59.8	1.6	2.1	0.2	0	5.7
P	NS	NS	NS	NS	NS	NS	NS	NS	<.001
LSD 5%									0.86

- The treatments had no significant affect on yield
- The level of skinning 30 days, 90days and 160 days post lifting was not significantly affected by any treatment
- The treatments had no significant affect on weight loss or shoot development
- The pyruvate level was significantly increased by the S & N treatment compared to the control, and all other treatments involving sulphur also had higher levels than the control
    - The pyruvate level from the Mo treatment was significantly lower than all the treatments involving sulphur

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 3.24 Results of sulphur, nitrogen and molybdenum interaction trial 1314 TS Fert 60
Variety: 12-RC-181
Planted: 12 Sep 2013
Lifted: 18 Feb 2014

Treatment	Gross Yield/2m^2	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Not Skinned Shoot >1%	160d Skinned Shoot >1%	Pyruvate µmol/ml
Control	16.5	5.9	6.6	71.7	1.5	2.4	0	0	5.3
Mo	17.5	4.5	7.6	67.9	1.4	2.5	0	0	5.5
S	14.8	5.6	3.4	69.2	1.5	2.6	0	0	6.6
S & Mo	16.7	5.7	9.2	67.9	1.4	2.5	0	0	5.4
S & N	16.6	5.1	9.7	73.4	1.5	2.5	0	0	7.3
P	NS	NS	NS	NS	NS	NS	NS	NS	.006
LSD 5%									1.13

- The treatments had no significant affect on yield
- The level of skinning 30 days, 90days and 160 days post lifting was not significantly affected by any treatment
- The treatments had no significant affect on weight loss or shoot development
- The pyruvate level was significantly increased by the S and the S & N treatment compared to the control

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

4. Curing Strategies

Materials & Methods

Methods common to all curing trials
The Standard Onion Assessment Protocol (SOAP) developed in this project (Chapter 1) was used throughout the curing trials for consistency of assessment. The SOAP was designed to be representative of industry practices, so that curing trial data could be directly extrapolated to commercial outcomes. All trials were located within commercial onion crops and were subjected to standard onion agronomy inputs.

Gross yield was measured in 2m^2 of each windrow once onions were fully cured; typically 14-21 days after lifting if May/Jun sown and 21-28 days after lifting if Jul/Aug or Sep/Oct sown. 20L (10-11kg) samples of hand topped bulbs from each plot were then sampled and removed to the controlled atmosphere storage facility for post harvest evaluation of skins, weight loss and sprouting, where the following conditions were maintained: 6am to 6pm 21^{o}C and 60% RH, 6pm to 6am: 11^{o}C and 80% RH.

Skins were put under mechanical pressure using a method adapted from Hole et al. (2002). Our system used a 200L drum with two rubber ribs attached to the inside of the drum as per Gracie et al. (2006), rotating at 40rpm for 10 minutes for cream gold onions or 5 minutes for red onions. Two 20L (10-11kg) bags of samples were placed in the drum at a time. The measurement of skinning was defined to be representative of European customer standards where any amount of visible scale is classified as skinning, regardless of the cause (includes splits, cracks or shelling). Onion samples were put under mechanical pressure in the drum at strategic times to replicate standard times commercial onions are exposed to skin pressure; namely 30-40 days post lifting which is representative of standard packing time, and 90-100 days post lifting which is representative of standard repacking time after arrival in Europe. In the 2011/12 season, skins were further evaluated at 160-170 days after lifting representative of long term storage and multiple handling of onions that occurs in difficult market seasons.

Weight loss was recorded at 90-100 days and 160-170 days post lifting, taking into account any losses due to disease.

Shoot development was measured at 160-170 days post lifting by cutting all onions in half and recording whether a shoot was visible beyond the shoulder of the bulb.

The data presented in the results tables is the average of the replicates plus the outcome of the analysis of variance, using Genstat 13.

All curing trials are named with a four digit number for the year of the trial, such as 1011 for 2010/11, a letter for the type of trial such as L for lifting trial, and a three digit code for the location, such as 106. Location codes represent the following areas in Tasmania

- 100-199 = Devonport
- 200-249 = Deloraine to Westbury/Hagley
- 250-299 = Longford
- 300-349 = Wynyard
- 350-399 = Forest/Smithton

Time of Lifting
Purpose: To determine the impact of time of lifting on yield, skins and shelf life

Time of lifting was compared in nineteen standard randomized block trials over two seasons, with 4 replicates, in trials superimposed in already established commercial onion crops. 2.5m plots were hand lifted at each of the 6 designated lifting times. The lifting times were established around the forecast or predicted lifting time based on historical crop performance.

Lifting Times

- (14d Post) 14 days after predicted lifting date
- (7d Post) 7 days after predicted lifting date
- (Predicted) Predicted lifting date from Agronomist
- (7d Pre) 7 days before predicted lifting date
- (14d Pre) 14 days before predicted lifting date
- (21d Pre) 21 days before predicted lifting date

Soil moisture was recorded in each plot at the time of hand lifting with an Aquaterr 200 capacitive sensor (range 0-100%). Plots were field cured in the paddock as per standard industry practice.

The proportion of tops down was estimated in each plot at the time of hand lifting.

Time on Ground
Purpose: To determine the impact of leaving lifted onions on soil 30 days longer than standard, on skins and shelf life

A survey of eight commercial crops was implemented by sampling 2 x standard 20L of bulbs per crop from the commercial windrow at the standard time of harvest; typically 14-21 days after lifting if May/Jun sown and 21-28 days after lifting if Jul/Aug or Sep/Oct sown.

One bag was placed on bare soil away from the commercial crop for 30 days to simulate a crop being left on the ground for an extra month, while the other bag was located in the controlled atmosphere storage facility for post harvest evaluation of skins, weight loss and sprouting, where the following conditions were maintained: 6am to 6pm 21^{o}C and 60% RH, 6pm to 6am: 11^{o}C and 80% RH. After the extra 30 days on bare soil, these bags were also located in the controlled atmosphere storage facility.

A modified version of the Standard Onion Assessment Protocol (SOAP) was implemented where assessments for skinning were done at 60 days and 120 days post lifting instead of the standard 30 days and 90 days post lifting. Weight loss was measured at 60-120 days and 120-160 days post lifting instead of the standard 30-90 days and 90-160 days post lifting. The final SOAP assessments for shoot development and skinning were still done at 160 days post lifting.

Windrow Depth
Purpose: To determine the impact of windrow depth on skins and shelf life

Three windrow depths were formed in non replicated trials in ten commercial crops in the 2012/13 season. Windrows were formed by hand lifting crop within 1week of 80% tops down and forming a single layer standard windrow, a double layer windrow and a triple layer windrow. The width of each windrow remained the same, so only the depth changed.

A temperature and humidity logger was placed amongst the top onions in each base layer of the windrow. A standard 20L sample of bulbs was taken from a cross section of the entire windrow, at the standard time of harvest; typically 14-21 days after lifting if May/Jun sown and 21-28 days after lifting if Jul/Aug or Sep/Oct sown.

Soil Moisture
Purpose: To determine the impact of soil moisture at the time of lifting on skins and shelf life

Soil moisture data collected during the time of lifting trials was analysed for any correlations with skinning. In this analysis the time of lifting was standardised to lifting during the week crops reached 80% tops down, and the soil moisture was measured at the time of lifting.

A modified version of the time of lifting trials was established in four commercial crops. Trials were started 1 day after a rain event that was sufficient to wet the soil to at least 10cm, in a crop that had been 80% tops down for less than 1 week. Trials were abandoned if there was any follow up rain prior to lifting. A standard block design with 4 replicates and 4 lifting times was established by hand lifting and forming the windrows.

Lifting Times

- (1d Post) Lift 1 day after rain
- (3/4d Post) Lift 3/4 days after rain
- (7d Post) Lift 7 days after rain
- (14d Post) Lift 14 days after rain

Soil moisture was recorded in each plot at the time of hand lifting with an Aquaterr 200 capacitive sensor (range 0-100%). Plots were field cured in the paddock as per standard industry practice.

In addition to the above four trials, another standard block design trial with 4 replicates was established in a commercial crop to evaluate the impact of irrigation applied at different intervals prior to lifting. In this trial all treatments were lifted at the same time. The final crop irrigation was applied 12 days prior to lifting. Three irrigation treatments were evaluated; the equivalent of 70ml of irrigation was applied either 1 day or 5 days prior to lifting or at both timings. All treatments were hand lifted and formed into windrows to cure in the paddock.

A standard 20L sample of bulbs was taken from the windrows, at the standard time of harvest; typically 14-21 days after lifting if May/Jun sown and 21-28 days after lifting if Jul/Aug or Sep/Oct sown.

Senescence

Purpose: To evaluate treatments to manipulate senescence to force the crop to senesce more evenly to improve skins and shelf life

Two approaches to influencing senescence were evaluated in non replicated trials in ten commercial crops. The first approach involved the use of the growth regulator Ethrel, which is registered on some crops in Australia to assist with uniform ripening or maturity. The other approach involved the use of a herbicide mix to burn the onion leaves to try and stress the crop into senescing evenly.

Treatments

- Control
- Ethrel (720g/L ethephon)
  - 1,200ml//ha Ethrel + 400ml/ha Activator applied in 440L/ha water
- Herbicide Mix: Totril (250g/L ioxynil), Bladex (900g/kg cyanazine), Activator (900g/L non-ionic surfactants)
  - 1L/ha Totril + 0.65kg/ha Bladex + 400ml/ha Activator applied in 220L/ha water

Treatments were applied 1 week before predicted lifting date, based on historical crop performance. Treated plots were hand lifted as split plots; first split plot within 1 week of reaching 80% tops down, second split plot 1 week later.

A standard 20L sample of bulbs was taken from the windrows, at the standard time of harvest; typically 14-21 days after lifting if May/Jun sown and 21-28 days after lifting if Jul/Aug or Sep/Oct sown.

Results

The data profiles presented in this report are the first time curing trials have been evaluated using the new assessment method developed in this project (Chapter 1). Every curing treatment has a complete production profile generally consisting of data including gross yield, skinning, weight loss and shoot development. Information regarding trial site conditions and observations from the statistical analysis are located beneath each table, for ease of reference.

Time of Lifting

Results for the eight sites in the 2010/11 season are summarised in Tables 4.1-4.8. Yield increased significantly with later lifting, in all eight trial sites, however yield only increased significantly in 25% of the trial sites when lifted after 80% tops down. When the crop was lifted before 80% tops down the level of skinning 30 days post lifting increased significantly in 1 trial site (Table 4.1) and decreased significantly in 3 trial sites (Tables 4.4, 4.5, 4.8). When the crop was lifted after 80% tops down the level of skinning 30 days post lifting increased significantly in 2 trial sites (Tables 4.2, 4.6) and decreased significantly in 2 trial sites (Tables 4.7, 4.8). When the crop was lifted before 80% tops down the level of skinning 90 days post lifting did not increase significantly in any trial site and decreased significantly in 3 trial sites (Tables 4.1, 4.4, 4.5). When the crop was lifted after 80% tops down the level of skinning 90 days post lifting increased significantly in 5 trial sites (Table 4.1, 4.2, 4.6, 4.7, 4.8) and did not decrease in any site. In some crops the time of lifting did have an impact on weight loss, with weight loss generally increasing with either very early or very late lifting. Visible shoot development (>1) was not significantly different between lifting times.

Results for the eleven sites in the 2011/12 season are summarised in Tables 4.9-4.19. Yield increased significantly with later lifting, in all eleven trial sites, however yield only increased significantly in 45% of the trial sites when lifted after 80% tops down. When the crop was lifted before 80% tops down the level of skinning 30 days post lifting increased significantly in all trial sites (Tables 4.9-4.19). When the crop was lifted after 80% tops down the level of skinning 30 days post lifting increased significantly in 3 trial sites (Tables 4.14, 4.17, 4.19) and did not decrease significantly in any trial sites. When the crop was lifted before 80% tops down the level of skinning 90 days post lifting increased significantly in 3 trial sites (Tables 4.15, 4.18, 4.19) and did not decrease significantly in any trial sites. When the crop was lifted after 80% tops down the level of skinning 90 days post lifting increased significantly in 8 trial sites (Tables 4.9, 4.10, 4.11, 4.12, 4.14, 4.17, 4.18, 4.19) and did not decrease significantly in any trial sites. The level of skinning 160 days post lifting was very high in all sites and lifting times, with one exception (Table 4.17). The level of skinning 160 days post lifting increased significantly when the crop was lifted <80% tops down in four of the trial sites, decreased significantly in one site, and did not change in the other sites. The level of skinning 160 days post lifting increased significantly when the crop was lifted >80% tops down in four of the trials sites and did not change in the other sites. Weight loss was significantly affected in four of the trial sites (Tables 4.12, 4.14, 4.17, 4.19).

Skinning results were consistent between the 2 seasons at 90 days post lifting where crops lifted before 80% tops down either had significantly reduced skinning or no change in skinning, and crops lifted after 80% tops down either had significantly increased skinning or no change in skinning. Results for skinning at 30 day post lifting however were not consistent between the 2 seasons. There were some limitations in the data set from the first year due to a number of sites not having at least one lifting time either side of 80% tops down, resulting in skewed lifting ranges which may have influence interpretation of the results (Tables 4.2, 4.3, 4.4, 4.5).

Results for all nineteen sites for the two seasons are aggregated in Table 4.20. 100% of the sites recorded skinning <20% at 30 days post lifting when lifted either 0, 1 or 2 weeks from 80% tops down (Table 4.20). The number of sites with skinning <20% at 90 days post lifting decreased progressively with later lifting from a maximum of 90% to a minimum of 22% (Table 4.20). The optimum time of lifting in terms of the timing with the greatest number of sites with skinning <20% at both 30 days and 90 days post lifting was 0 weeks within 80% tops down (Table 4.20), however this only occurred in 76% of sites. There were four sites that did not record skinning levels <20% at both 30 days and 90 days post lifting when lifted 0 weeks from 80% tops down, although one of these did still record the lowest level of skinning at this lifting time of 15.1% at 30 days post lifting and 26.8% at 90 days post lifting (Table 4.9). The remaining three sites all shared a common maturity pattern where the time taken from <25% tops down to >75% tops down was at least three weeks (Tables 4.5, 4.15, 4.16), whereas in all the other sites the same maturity progression took no more than one week. In all three of these sites, the lowest skinning levels at both 30 days and 90 days post lifting were recorded when lifted within three weeks of the commencement of tops down, as measure by tops down >25%.

Time on Ground

Leaving onions on the ground for an additional 30 days was generally detrimental to skin quality (Table 4.21). The level of skinning in onions left on soil for an extra 30 days was higher at each assessment time than onions put into standard storage conditions. The extra time on the ground increased the level of skinning from an average of 2.0% to 9.3% at 60 days post lifting, 22.8% to 35.7% at 120 days post lifting and 49.7 % to 66.7% at 160 days post lifting (Table 4.21). The extra time on the ground did not affect weight loss up to 120 days post lifting, but weight loss did increase from an average of 3.3% to 3.8% at 120-160 days post lifting with the extra time on the ground (Table 4.21). Sprouting was not affected by the extra time on the ground.

Four of the eight sites had skinning levels <20% at both 60 days and 120 days post lifting when onions were harvested at the standard time, but only one out of the eight sites had skinning levels <20% at both 60 days and 120 days post lifting when onions were left on the ground for an extra 30 days (Table 4.21). When the control samples from adjacent fertiliser trials (Chapter 3, Tables 3.9-3.12, 3.14, 3.16-3.18) are compared, six out of the eight sites had skinning levels <20% at both 30 days and 90 days post lifting when onions were harvested at the standard time and assessed at the normal SOAP timings of 30 days and 90 days post lifting; indicating that the extra 30 days storage even under controlled conditions is long enough to contribute to skin quality deterioration.

Windrow Depth

The average number of days from lifting and windrow formation to harvest was 17, with a minimum of 13 and maximum of 22 (Table 4.22). The level of skinning averaged 4.0% in the single layer windrow, 4.1% in the double layer windrow and 4.6% in the triple layer windrow 30 days post lifting (Table 4.22). While at 90 days post lifting, the level of skinning averaged 7.0% in the single layer windrow, 8.5% in the double layer windrow and 9.0% in the triple layer windrow (Table 4.22). Similarly, the level of skinning 160 days post lifting was very consistent between the windrow depths, averaging 33.6% in the single layer windrow, 33.4% in the double layer windrow and 34.5% in the triple layer windrow (Table 4.22). Note that onions were sampled from a cross section through the entire windrow, not solely from the base layer. Overall, the number of layers in the windrow did not have any consistent impact on the level of skinning. It was observed that onions from windrows with 2 or 3 layers were greener and less cured than onions from a single layer windrow; however this has not had a measureable impact on skinning level. Seasonal conditions during 2012/13 were very favourable for windrow curing, and different results may occur under less favourable conditions.

The level of weight loss averaged 2.7% in the single layer windrow, 2.8% in the double layer windrow and 2.9% in the triple layer windrow 30-90 days post lifting (Table 4.23). While at 90-160 days post lifting, the level of weight loss averaged 2.3% in the single layer windrow, 2.3% in the double layer windrow and 2.5% in the triple layer windrow (Table 4.23). Examining individual trial sites reveals a consistent pattern of generally increasing weight loss with increased number of layers in the windrow (Table 4.23). This is consistent with the observation made that onions from windrows with 2 or 3 layers were greener and less cured than onions from a single layer windrow. It would be expected that less cured onions would lose more weight post harvest in the controlled atmosphere storage facility as they complete the curing process.

Shoot development was not impacted by the number of layers in the windrow (Table 4.24) however results may be different under different seasonal conditions.

The temperature and humidity conditions were monitored in all windrows; a representative sample of this data has been presented in Figures 4.1-4.4. Loggers were located within one bulb of the top of each base layer; in a 1 layer windrow the logger was located within one bulb of the top of the windrow, in a 2 layer windrow the logger was located in the middle of the windrow and in a 3 layer windrow the logger was located a third of the way up from the base of the windrow. The differences in temperature within the different depths of the windrow and the temperature differences between a coastal and an inland location for late December lifting varied as expected; that is the temperatures were lower on the coast and were lower deeper in the windrow regardless of the location (Figure 4.1). The temperature towards the top of the single layer windrow exceeded 40^{o}C on 4 days at the inland site but never exceeded 40^{o}C at the coastal site during the same time frame (Figure 4.1). The temperature towards the top of the single layer windrow exceeded 30^{o}C on 17 days at the inland site and only 4 days at the coastal site (Figure 4.1). The third layer never exceeded 40^{o}C, and only exceeded 30^{o}C on 1 day at the inland site and not at all at the coastal site (Figure 4.1).

The differences in humidity within the different depths of the windrow and the humidity differences between a coastal and an inland location for late December lifting varied as expected; that is the humidity was lower at the inland site and was higher deeper in the windrow regardless of the location (Figure 4.2). The humidity towards the top of the single layer windrow fell below 20% on 9 days at the inland site and only 1 day at the coastal site (Figure 4.2). The humidity one third of the way up from the base of the 3 layer windrow did not fall below 70% for the first 7 days at the coastal site, but fell below 70% every day at the inland site (Figure 4.2).

The differences in temperature within the different depths of the windrow between early January and late February lifting at inland sites did not vary as expected, but the results may have been influenced by canopy density and yield especially at the late February lifting site where temperatures were often very similar in all 3 windrow depths (Figure 4.3); this site had the lowest yield. The temperatures were lower for the February lifting and were lower deeper in the windrow regardless of the lifting time (Figure 4.3). The temperature towards the top of the single layer windrow exceeded 30^{o}C on ~85% of the days for the January lifting and ~45% of the days for the February lifting (Figure 4.3). The data also shows the impact of 5mm of rain on windrow curing around the 26-27 Feb where the temperature was a constant 19-20^{o}C day and night and at all depths of the windrow (Figure 4.3).

The differences in humidity within the different depths of the windrow between early January and late February lifting at inland sites may also have been influenced by canopy density and yield, especially at the late February lifting site where humidity was often very similar in all 3 windrow depths particularly later in the curing process (Figure 4.4). The humidity level range was generally fairly similar between the 2 lifting times with a typical diurnal fluctuation range from 30-90% for single layer (Figure 4.4). The data also shows the impact of 5mm rain on windrow curing around the 26-27 Feb where the humidity became saturated day and night and at all depths of the windrow (Figure 4.3).

Soil Moisture

Soil moisture data collected during the time of lifting trials was analysed for any correlations with skinning. There was no correlation between soil moisture and the level of skinning 30 days post lifting (Figure 4.5) or 90 days post lifting (Figure 4.6). In this analysis the time of lifting was standardised to lifting during the week crops reached 80% tops down, and the soil moisture was measured at the time of lifting. From the graphs it is apparent that there is no trend linking soil moisture at the time of lifting with skinning, confirmed by the exceptionally low R^2 values of 0.0016 for 30 days post lifting (Figure 4.5) and 0.0106 for 90 days post lifting (Figure 4.6). All seventeen sites recorded skinning levels <20% at 30 days post lifting (Figure 4.5), and only four sites recorded skinning levels >20% at 90 days post lifting (Figure 4.6).

The modified version of the time of lifting trials started 1 day after a rain event that was sufficient to wet the soil to at least 10cm, in a crop that had been 80% tops down for less than 1 week, also showed no link with soil moisture and skinning (Tables 4.25-4.28). The first site received 14mm of rain and while the level of skinning was significantly lower with later lifting at 30 days post lifting all skinning levels were very low at <6% (Table 4.25). Skinning levels 90 days and 160 days post lifting were not significantly different; nor was weight loss or shoot development significantly different (Table 4.25). The second site also received 14mm of rain and had skinning levels <2% at both 30 days and 90 days post lifting and even at 160 days post lifting all skinning levels remained low at <16% (Table 4.26); skinning, weight loss and shoot development were not significantly different. The level of skinning at the third site, which received 12 mm of rain, increased significantly with later lifting at 30 days and 90 days post lifting, but decreased significantly at 160 days post lifting (Table 4.27), while weight loss and shoot development were largely unaffected. The level of skinning at the final site, which received 8mm of rain, decreased significantly with later lifting at 30 days post lifting but was not significantly affected at 90 day or 160 days post lifting (Table 4.28), while weight loss and shoot development were largely unaffected. The level of skinning 30 days post lifting was >20% in 1/4 sites, while the level of skinning 90 days and 160 days post lifting was >20% in 3/4 sites.

The final soil moisture trial to evaluate the impact of 70ml of irrigation applied at either 1 day or 5 days prior to lifting or at both timings also revealed no impact of soil moisture on skinning (Table 4.29). In this trial all treatments were lifted at the same time. The level of skinning at both 30 days and 90 days post lifting was unusually low with all results <6% and there were no significant differences between any treatments and the control (Table 4.29).

Senescence

The application of Ethrel consistently increased the level of skinning (Table 4.30). At some sites the application of Ethrel resulted in yellowing of the tops; the application of Ethrel had no visible impact on root senescence relative to the control. The application of herbicide had no consistent impact on the level of skinning (Table 4.30). At all sites the application of herbicide resulted in yellowing of the tops, and resulted in increased senescence of the roots compared to the control. The application of Ethrel or herbicide reduced yield and increased weight loss in most trials (Table 4.31). The application of Ethrel or herbicide had no consistent impact on shoot development (Table 4.32).

Later lifting of the Ethrel and herbicide treatments resulted in increased average skinning at 90 days post lifting; otherwise average skinning levels were generally consistent between the two lifting times. Average yield increased with later lifting in both the control and Ethrel treatment but the herbicide treatment resulted in no change in average yield with later lifting (Table 4.31). Later lifting mostly resulted in reduced average weight loss in all treatments and the control (Table 4.31).

Discussion

The influence of curing practices on skin quality revealed that the greatest impact came from the time of lifting. The time on ground also impacted on skin quality, but to a lesser extent than time of lifting. Soil moisture at the time of lifting and windrow depth had no measurable impact on skin quality. Attempts to try and influence senescence failed to improve skin quality, and in the case of Ethrel decreased skin quality.

The data profiles presented in this report are the first time curing trials have been evaluated using the new assessment method developed in this project (Chapter 1).

Time of Lifting

Lifting within one week of 80% tops down produced the highest frequency of successful outcomes in terms of skinning; earlier lifting had a higher risk of skinning at initial handling 30 days post lifting (although low risk of skinning upon re handling 90 days post lifting), while later lifting had a higher risk of skinning upon re handling 90 days post lifting (Table 4.20). Note that sensitivity to time of lifting did vary considerably between paddocks.

In the context of managing risk for exports to Europe, the data supports earlier lifting rather than later lifting. While this reduced the yield potential in some cases and increased skinning risk at packing 30 days post lifting, it reduced the subsequent risk of skinning 90 days post lifting. In other words, earlier lifting increased skinning risk for the Grower/Packer but reduced the skinning risk for the European customer, while later lifting reduced skinning risk for the Grower/Packer but increased the skinning risk for the European customer. In order to reduce the risk of incurring a skinning claim with a customer in Europe, earlier lifting is the preferred management strategy.

Note that early lifting may increase the time needed to field cure or increase the level of green necks present at topping, which carries the risk of increasing the level of staining and possibly disease transfer.

The data indicates that in some cases there will be a trade off between yield and quality, however the yield increase was not significantly higher with later lifting in 63% of trial sites; yield alone should not be given first priority when specifically growing high quality crops for export to Europe.

The major limitation with implementation of the results for the time of lifting trials is that paddock tops do not always go down evenly. Sometimes this can be related to paddock history, such as when two smaller paddocks are combined, but sometimes variable maturity is randomly distributed within a paddock, or sometimes variances occur within a bed; notably outer rows maturing later than inner rows.

Given that paddocks do not always mature evenly, it is recommended that the date the first part of a paddock reaches 80% tops down as well as the date the last part of the paddock reaches 80% tops down be noted, and used to prioritise paddocks for lifting, and for establishing a skinning risk profile. The cause of this uneven maturity is not clear from the data gathered.

Another complication seen occasionally occurs when the tops are blown down prematurely by severe winds. In some instances the tops will stand up again but it is not unusual for the tops to remain down. In this situation the timing of lifting becomes confusing; however an additional consideration in this situation is translucent scale. Under the right conditions, potentially including tops blown down prematurely it may be possible for one or several of the scales to become translucent, resembling bacterial soft rot. This condition is associated with elevated levels of carbon dioxide which can occur if the bulb tissue is actively respiring but the carbon dioxide produced within the bulb tissue is unable to pass through the neck and builds up to toxic levels (Brewster, 2004). Translucent scale will ultimately lead to bulb breakdown or rejection by the end customer.

Time on Ground

The second curing factor affecting skin quality was time on ground; however the impact of an extra 30 days on the ground only increased average skinning by 7-16 percentage points (Table 4.21). Although not measured in this research project, another factor to be considered with time on ground is skin staining, which may not necessarily result in skinning, but could still result in customer rejections to due unacceptable appearance.

Windrow Depth
Perhaps surprisingly, windrow depth did not have a measureable impact on skinning, although it is worth noting the observation made that onions in the deeper windrows were less well cured, which was also supported by the weight loss data.

The temperature and humidity conditions recorded within the windrow depths largely confirmed expectations that temperatures were lower at greater depths while humidity was higher at greater depths, and that coastal windrows were cooler and more humid that inland windrows. The impact of only 5mm of rain on windrow conditions was concerning as humidity remained saturated at all depths for at least 2 days (Figure 4.4), potentially providing ideal conditions for disease proliferation.

Although no negative data was recorded, it is still recommended that windrow depth be kept to a minimum to reduce the risk of development of conditions conducive for disease development that could occur or prevail for longer in deeper windrows.

Soil Moisture
The impact of soil moisture at the time of lifting on skinning has long been questioned by industry; however the trial results indicated that the actual level of soil moisture at the time of lifting did not adversely affect skinning. The relevance of soil moisture at the time of lifting has been challenging to clarify, owing to the difficulty of being able to separate the impact of time of lifting from the impact of soil moisture.

Whether or not the soil moisture levels leading up to the time of lifting influence skinning were not evaluated in this project, however it has been demonstrated that increases in soil moisture at the time of lifting whether caused by rain or irrigation did not appear to affect skinning, other than when the increase in soil moisture delays the time of lifting.

This finding vindicates the current industry practice of applying a light irrigation immediately prior to lifting to soften the soil and clods to reduce damage, as not adding to skinning risk. However, the practice may increase the risk of disease development in the newly formed windrow.

It is interesting to note that even extreme amounts of water applied close to lifting, such as 70mm, were unable to influence the level of skinning (Table 4.29).

Findings from the crop surveys in both the 2010/11 and 2011/12 seasons presented in Chapter 1, further support the finding regarding the lack of influence of soil moisture on skinning. In both these seasons crops that were mature (80% tops down) but not yet lifted at the time of a substantial rain event, showed an interaction with time of lifting but not soil moisture. Those lifted immediately after the rain event did not have elevated levels of skinning, whilst those crops where lifting was substantially delayed developed elevated skinning levels.

Senescence
The application of herbicide one week from forecast lifting successfully turned the leaves yellow, and appeared to enhance root senescence; however it did not reduce skinning. Unfortunately, this result likely reflects the importance of the natural senescence pathway to produce high quality skins, which was not replicated by prematurely killing the crop with the herbicide mix used in these trials. The application of Ethrel also turned the leaves yellow in some trials but no effect on the roots was observed, however skinning was actually increased. Once again the results likely reflect the importance of the natural crop maturity processes. The trend of increasing weight loss with the herbicide and Ethrel treatments is consistent with the bulbs from these treatments not being as well cured as the control.

A review of literature specific to the topic of onion senescence was compiled by the University of Tasmania in support of this project (Lambert et al, 2012). The review highlighted the overall lack of knowledge regarding onion senescence “A significant gap remains within the scientific literature as to the biochemical and hormonal mechanisms that regulate onion senescence”. To complement this project, financial support from the project and access to field trial sites was provided to the University of Tasmania in support of a PhD candidate to conduct research on onion senescence; this work will be reported separately in the final PhD thesis.

Recommendations
Two lifting protocols to reduce the risk of skinning once crops are repacked in Europe are recommended as a result of this research. For crops with standard maturity, as measured by the progression of tops down taking one week or less from <25% tops down to >75% tops down; lift within 1 week of 80% tops down. For crops with delayed maturity, as measured by the progression of tops down taking greater than one week from <25% tops down to >75% tops down; lift within 3 weeks of >25% tops down. These recommendations can be combined in a composite recommendation as follows:

- lift within 1 week of 80% down, or within 3 weeks of 25% tops down, whichever occurs first

Further work is recommended to try and understand and define the reasons for uneven maturity within paddocks, otherwise implementation of either time of lifting protocols could be compromised.

In order to reduce the risk of skinning, especially once crops are repacked in Europe, it is recommended that crops be harvested within 30 days of lifting, which is consistent with current industry practice where May/Jun sown crops are typically harvested 14-21 days after lifting and Jul/Aug or Sep/Oct sown crops are typically harvested 21-28 days after lifting.

In order to reduce the risk of disease and minimise the time on ground, it is recommended that single windrows be formed; this should allow crops to fully cure but still be harvested well within the 30 days recommended between lifting and harvest.

In order to reduce the risk of disease developing in windrows it is recommended that paddocks are not watered close to the time of lifting, however results showed that rain or irrigation at this time did not influence the level of skinning, other than if the increase in soil moisture delayed the time of lifting. The current industry practice of applying a light irrigation immediately prior to lifting to soften the soil and clods to reduce damage at lifting is not expected to increase the skinning risk, but may increase the risk of disease development in the newly formed windrow.

Further work is recommended to further explore the opportunity to influence crop senescence, to either improve the uniformity of crop maturity or to extend the length of the lifting window; either avenue of research could yield potential benefits for commercial application.

Table 4.1 Results for Time of Lifting trial 1011 L 106 (211)
Variety: 10-SP-211
Planted: 26 May 2010
Commercial Crop Lifted: 9 Jan 2011

Treatment	Lifting Date	Tops Down %	Soil Moisture at 10cm	Gross Yield/2m^2	# Weeks from ≥80% Tops Down	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
										¼	½	¾	1	>1
14d post	15/1/11	100	89	11.0	+1	8.4	25.0	2.5	6.3	0	1.9	29.6	68.4	0
7d post	6/1/11	100	60	13.1	0	0.9	9.4	2.2	5.0	0	4.4	17.8	77.8	0
Predicted	30/12/10	78	59	12.9	-1	3.7	5.3	1.2	3.9	0	0.3	21.3	77.9	0.4
7d pre	23/12/10	11	61	9.1	-2	13.2	3.9	1.8	4.2	0	0.7	8.6	90.6	0
14d pre	16/12/10	0	86	7.7	-3	27.1	1.6	3.7	6.0	0	1.0	12.9	86.0	0
21d pre	10/12/10	0	81	6.0	-4	29.6	3.9	4.2	6.6	0	0	19.0	81.0	0
P				<.001		<.001	<.001	<.001	.007	-	.049	.001	<.001	NS
LSD 5%				0.99		8.25	4.80	0.99	1.55	-	2.85	8.44	8.51	

- Yield increased significantly with later lifting
- The level of skinning 30 days post lifting increased significantly when the crop was lifted <80% tops down, but did not change significantly when lifted >80% tops down
- The level of skinning 90 days post lifting did not change significantly when the crop was lifted <80% tops down, but did increase significantly when lifted >80% tops down
    - Note that onions that skinned at the 30 day assessment were removed from the sample and not re assessed at the 90 day assessment
- Overall, weight loss decreased significantly as the crop approached 80% tops down, but then increased with later lifting
- The time of lifting did have a significant affect on internal shoot development, however the affect was inconsistent
- Visible shoot development (>1) was not significantly different between lifting times

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 4.2 Results for Time of Lifting trial 1011 L 106 (Python)
Variety: Python (main crop 10-SP-211)
Planted: 26 May 2010
Commercial Crop Lifted: 9 Jan 2011

Treatment	Lifting Date	Tops Down %	Soil Moisture at 10cm	Gross Yield/2m^2	# Weeks from ≥80% Tops Down	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
										¼	½	¾	1	>1
14d post	15/1/11	100	87	13.6	+5	38.2	73.6	4.3	10.9	0	13.0	38.8	48.2	0
7d post	6/1/11	100	57	14.5	+4	16.5	49.3	1.1	4.1	0	1.0	32.3	65.1	1.5
Predicted	30/12/10	100	59	14.4	+3	13.4	55.4	1.7	4.8	0	6.2	37.6	56.2	0
7d pre	23/12/10	100	63	12.0	+2	6.7	21.7	1.4	4.4	0	2.0	21.9	76.1	0
14d pre	16/12/10	100	82	10.1	+1	9.6	20.8	2.8	6.3	0	1.4	19.2	79.4	0
21d pre	10/12/10	100	75	9.2	0	10.4	18.7	3.2	6.5	0	0.9	13.6	85.5	0
P				<.001		<.001	<.001	.002	<.001	-	.028	<.001	<.001	NS
LSD 5%				1.15		8.22	15.75	1.45	1.49	-	7.88	11.77	13.23	

- This trial began after 100% tops were down owing to the unexpected very early maturity of this variety
- Yield increased significantly with later lifting
- The level of skinning 30 days post lifting increased significantly with later lifting
- The level of skinning 90 days post lifting increased significantly with later lifting
    - Note that onions that skinned at the 30 day assessment were removed from the sample and not re assessed at the 90 day assessment
- Overall, weight loss decreased significantly as the crop approached the predicted lifting date, but then increased with later lifting
- Visible shoot development (>1) was not significantly different between lifting times
- The trial may have commenced too late to draw any conclusions, as the tops were already 100% down

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 4.3 Results for Time of Lifting trial 1011 LV 110 (10-DR-161)
Variety: 10-DR-161
Planted: 28 Jul 2010
Commercial Crop Lifted: 2 Feb 2011

Treatment	Lifting Date	Tops Down %	Soil Moisture at 10cm	Gross Yield/2m^2	# Weeks from ≥80% Tops Down	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
										¼	½	¾	1	>1
14d post	4/2/11	74	65	13.3	-1	5.2	2.7	2.4	5.6	0	3.3	26.3	70.4	0
7d post	27/1/11	54	48	12.2	-2	5.6	2.1	2.0	5.1	0	5.1	22.4	72.5	0
Predicted	21/1/11	14	50	11.2	-3	0.3	0	2.3	5.1	0	11.1	28.5	60.4	0
7d pre	15/1/11	1	67	10.6	-4	1.1	0	2.5	5.8	0	10.3	29.8	59.8	0
14d pre	7/1/11	1	49	9.6	-5	6.9	0	3.3	5.9	0	5.3	31.2	63.5	0
21d pre	31/12/10	1	56	8.7	-6	5.8	2.7	3.3	6.3	0	5.8	26.0	68.3	0
P				.001		NS	NS	.014	NS	-	NS	NS	NS	-
LSD 5%				1.94				0.84						

- Very firm soil by lifting; small canopy growth in trial area; canopy growth not representative of typical canopy growth for cream gold onions
- This type of "hard growth" typically produces bulbs with high skin quality and long storage life
- Yield increased significantly with later lifting
- The level of skinning 30 days post lifting was not significantly different
- The level of skinning 90 days post lifting was not significantly different
    - Note that onions that skinned at the 30 day assessment were removed from the sample and not re assessed at the 90 day assessment
- Overall, weight loss decreased as the crop approached 80% tops down
- Visible shoot development (>1) was not significantly different between lifting times

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 4.4 Results for Time of Lifting trial 1011 LV 110 (Baron)
Variety: Baron (main crop 10-DR-161)
Planted: 28 Jul 2010
Commercial Crop Lifted: 2 Feb 2011

Treatment	Lifting Date	Tops Down %	Soil Moisture at 10cm	Gross Yield/2m²	# Weeks from ≥80% Tops Down	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
										¼	½	¾	1	>1
14d post	4/2/11	79	61	12.8	-1	7.2	8.0	2.2	5.2	0	2.5	12.1	85.4	0
7d post	27/1/11	71	45	11.8	-2	0.2	2.0	1.8	5.1	0	4.9	30.6	64.3	0.2
Predicted	21/1/11	70	48	11.1	-3	0	1.6	2.2	5.0	0.2	8.5	42.2	49.0	0
7d pre	15/1/11	46	66	11.0	-4	0.3	0.5	2.7	5.8	1.1	11.4	36.2	51.3	0
14d pre	7/1/11	21	47	9.3	-5	1.9	0	3.1	5.9	0	12.7	28.0	59.2	0
21d pre	31/12/10	1	54	8.6	-6	1.5	0	3.1	6.1	0	10.1	42.0	47.9	0
P				<.001		.018	<.001	.014	.044	NS	NS	<.001	.008	NS
LSD 5%				1.18		4.20	3.39	0.78	0.84			12.60	19.87	

- Very firm soil by lifting; small canopy growth in trial area; canopy growth not representative of typical canopy growth for cream gold onions
- This type of “hard growth” typically produces bulbs with high skin quality and long storage life
- Yield increased significantly with later lifting
- The level of skinning 30 days post lifting decreased significantly when lifted <80% tops down
- The level of skinning 90 days post lifting decreased significantly when lifted <80% tops down
    - Note that onions that skinned at the 30 day assessment were removed from the sample and not re assessed at the 90 day assessment
- Overall, weight loss decreased as the crop approached 80% tops down
- Visible shoot development (>1) was not significantly different between lifting times

Results Colour Key

	Skinning >20% at either 30d post or 90d post lifting
	Skinning <20% at both 30d post and 90d post lifting

Table 4.5 Results for Time of Lifting trial 1011 LV 110 (Perez)
Variety: Perez (main crop 10-DR-161)
Planted: 28 Jul 2010
Commercial Crop Lifted: 2 Feb 2011

Treatment	Lifting Date	Tops Down %	Soil Moisture at 10cm	Gross Yield/2m^2	# Weeks from ≥80% Tops Down	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
										¼	½	¾	1	>1
14d post	4/2/11	83	61	13.5	0	10.0	35.6	1.9	5.2	0	9.5	31.2	59.3	0
7d post	27/1/11	78	47	13.5	-1	2.3	5.8	1.2	4.0	0	5.2	33.4	61.5	0
Predicted	21/1/11	78	51	11.8	-2	0.7	3.9	2.8	5.7	0	11.4	30.8	57.8	0
7d pre	15/1/11	74	67	10.8	-3	0.3	2.6	1.7	4.7	0	14.8	34.9	49.7	0.6
14d pre	7/1/11	65	50	10.3	-4	0.5	0	2.6	5.3	0.5	24.5	41.2	33.7	0
21d pre	31/12/10	35	52	10.1	-5	2.4	0	2.3	5.4	0	17.5	36.6	45.9	0
P				.013		<.001	<.001	NS	NS	NS	.007	NS	.006	NS
LSD 5%				2.28		4.14	9.55				9.32		14.26	

- Very firm soil by lifting; small canopy growth in trial area; canopy growth not representative of typical canopy growth for cream gold onions
- This type of "hard growth" typically produces bulbs with high skin quality and long storage life
- Yield increased significantly with later lifting
- The level of skinning 30 days post lifting did not change significantly when lifted <80% tops down, but increased significantly when lifted >80% tops down
- The level of skinning 90 days post lifting did not change significantly when lifted <80% tops down, but increased significantly when lifted >80% tops down
    - Note that onions that skinned at the 30 day assessment were removed from the sample and not re assessed at the 90 day assessment
- Overall, time of lifting did not have a consistent affect on weight loss
- Visible shoot development (>1) was not significantly different between lifting times

Results Colour Key

Orange	Skinning >20% at either 30d post or 90d post lifting
Green	Skinning <20% at both 30d post and 90d post lifting

Table 4.6 Results for Time of Lifting trial 1011 LV 110 (19045)
Variety: 19045 (main crop 10-DR-161)
Planted: 28 Jul 2010
Commercial Crop Lifted: 2 Feb 2011

Treatment	Lifting Date	Tops Down %	Soil Moisture at 10cm	Gross Yield/2m^2	# Weeks from ≥80% Tops Down	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
										¼	½	¾	1	>1
14d post	4/2/11	100	68	12.6	+3	8.1	17.8	2.1	5.0	0	4.0	29.0	67.0	0
7d post	27/1/11	100	67	13.7	+2	3.1	11.1	2.1	5.5	0	4.6	26.5	68.9	0
Predicted	21/1/11	96	64	12.0	+1	1.0	9.2	1.8	4.5	0	13.6	30.0	56.4	0
7d pre	15/1/11	94	92	11.1	0	2.0	5.6	1.7	4.6	0.7	7.0	34.4	57.3	0.5
14d pre	7/1/11	79	62	11.4	-1	4.8	1.0	2.7	5.6	0	17.0	37.2	45.8	0
21d pre	31/12/10	41	74	10.8	-2	0.8	2.8	2.4	5.0	0	14.2	37.6	48.1	0
P				.040		.032	.013	NS	NS	NS	NS	NS	.020	NS
LSD 5%				1.87		4.61	9.16						14.80	

- Very firm soil by lifting; small canopy growth in trial area; canopy growth not representative of typical canopy growth for cream gold onions
- This type of “hard growth” typically produces bulbs with high skin quality and long storage life
- Yield increased significantly with later lifting
- The level of skinning 30 days post lifting did not change significantly when lifted <80% tops down, nor when lifted >80% tops down
- The level of skinning 90 days post lifting did not change significantly when lifted <80% tops down, but increased significantly when lifted >80% tops down
    - Note that onions that skinned at the 30 day assessment were removed from the sample and not re assessed at the 90 day assessment
- Overall, time of lifting did not have a consistent affect on weight loss
- Visible shoot development (>1) was not significantly different between lifting times

Results Colour Key

	Skinning >20% at either 30d post or 90d post lifting
	Skinning <20% at both 30d post and 90d post lifting

Table 4.7 Results for Time of Lifting trial 1011 L 235
Variety: Canterbury
Planted: 9 Oct 2010
Commercial Crop Lifted: 5 Mar 2011

Treatment	Lifting Date	Tops Down %	Soil Moisture at 10cm	Gross Yield/2m^2	# Weeks from ≥80% Tops Down	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
										¼	½	¾	1	>1
14d post	17/3/11	100	59	18.0	+4	12.8	68.4	2.7	6.7	0	0	22.1	77.9	0
7d post	10/3/11	100	75	15.4	+3	10.0	56.9	2.1	5.8	0	0.5	25.2	73.6	0.6
Predicted	3/3/11	97	61	15.1	+2	7.7	48.1	3.2	6.5	0	1.0	25.9	72.4	0.7
7d pre	23/2/11	90	73	16.3	+1	11.8	37.1	2.5	5.4	0	1.0	32.3	66.6	0
14d pre	15/2/11	80	71	15.6	0	14.7	15.8	2.0	5.1	0	3.2	39.1	57.7	0
21d pre	9/2/11	0	54	11.4	-1	16.5	12.2	2.1	5.1	0	0	32.3	54.5	13.3
P				.019		NS	<.001	.022	.013	-	NS	NS	.003	NS
LSD 5%				3.42			9.59	0.71	1.01				11.78	

- This site was planted towards the end of the currently recognised planting window for this variety, in a season where the crop was maturing in cool conditions
    - Early growth was slower than expected
- Yield increased significantly with later lifting
- The level of skinning 30 days post lifting did not change significantly when lifted <80% tops down, nor when lifted >80% tops down
- The level of skinning 90 days post lifting did not change significantly when lifted <80% tops down, but did increase significantly when lifted >80% tops down
    - Note that onions that skinned at the 30 day assessment were removed from the sample and not re assessed at the 90 day assessment
- The time of lifting did not have any consistent affect on weight loss
- Visible shoot development (>1) was not significantly different between lifting times

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 4.8 Results for Time of Lifting trial 1011 L 223
Variety: 10-DR-161
Planted: 18 Sep 2010
Commercial Crop Lifted: 10 Mar 2011

Treatment	Lifting Date	Tops Down %	Soil Moisture at 10cm	Gross Yield/2m^2	# Weeks from ≥80% Tops Down	30d Skin %	90d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	160d Shoot %				
										¼	½	¾	1	>1
14d post	17/3/11	100	50	27.4	+4	6.4	72.3	2.8	7.7	0	0	11.3	88.7	0
7d post	10/3/11	100	66	22.3	+3	7.0	38.2	2.6	5.9	0	0.6	29.5	69.8	0
Predicted	3/3/11	98	55	23.1	+2	3.8	28.5	2.8	5.9	0	0	32.5	67.1	0.4
7d pre	23/2/11	90	74	20.1	+1	11.1	13.4	2.5	5.6	0	1.5	35.4	63.0	0
14d pre	15/2/11	81	79	22.8	0	15.1	6.3	1.5	4.8	0	0	46.1	53.6	0.3
21d pre	9/2/11	0	80	17.0	-1	10.2	6.1	2.0	5.6	0	0.7	34.4	63.6	0.1
P				<.001		<.001	<.001	NS	.001	-	NS	.005	.003	NS
LSD 5%				3.39		3.15	6.25		1.11			15.08	14.89	

- This site was planted towards the end of the currently recognised planting window for this variety, in a season where the crop was maturing in cool conditions
- Yield increased significantly with later lifting
- The level of skinning 30 days post lifting decreased significantly when lifted <80% tops down, and also decreased significantly when lifted >80% tops down
- The level of skinning 90 days post lifting did not change significantly when lifted <80% tops down, but did increase significantly when lifted >80% tops down
    - Note that onions that skinned at the 30 day assessment were removed from the sample and not re assessed at the 90 day assessment
- Overall, time of lifting did not have a consistent affect on weight loss
- Visible shoot development (>1) was not significantly different between lifting times

Results Colour Key

	Skinning >20% at either 30d post or 90d post lifting
	Skinning <20% at both 30d post and 90d post lifting

Table 4.9 Results for Time of Lifting trial 1112 L 101
Variety: 11-SP-211
Planted: 16 May 2011
Commercial Crop Lifted: 29 Dec 2011

Treatment	Lifting Date	Tops Down %	Soil Moisture at 10cm	Gross Yield/2m^2	# Weeks from ≥80% Tops Down	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Not Skinned Shoot >1 %	Skinned Shoot >1 %
14d post	12/1/12	100	32	11.6	+3	20.9	43.0	88.5	3.2	6.0	0	0
7d post	5/1/12	100	50	10.4	+2	18.0	43.8	76.3	2.6	6.1	0	0
Predicted	29/12/11	93	60	9.1	+1	17.1	32.9	90.0	3.4	5.1	0	1.8
7d pre	22/12/11	80	81	10.1	0	15.1	26.8	83.0	3.4	5.5	0	0
14d pre	15/12/11	61	80	9.3	-1	51.2	24.1	88.7	3.0	5.8	0	2.3
21d pre	8/12/11	3	77	7.5	-2	-	-	-	-	-	-	-
P				<.001		<.001	NS	NS	NS	NS	-	NS
LSD 5%				1.48		13.07						

- This site was not representative, due to severe herbicide burn early followed by late season fertiliser application
  - The crop's canopy grew more vigorously post bulbing than standard
- The trial area also had late season downy mildew infection, which may have impacted on skin quality
- All 4 reps, 21d pre not harvested as bulbs were too small
- Rep 2, 14d post not harvested due to onion white rot infection
- Rep 3, 7d post not harvested due to onion white rot infection
- Yield increased significantly with later lifting
- The level of skinning 30 days post lifting increased significantly when the crop was lifted <80% tops down, but did not change significantly when lifted >80% tops down
- The level of skinning 90 days post lifting did not change significantly with time of lifting
- The level of skinning 160 days post lifting did not change significantly with time of lifting
- Weight loss did not change significantly with time of lifting
- Visible shoot development (>1) was not significantly different between lifting times

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 4.10 Results for Time of Lifting trial 1112 L 102
Variety: 11-SP-211
Planted: 17 May 2011
Commercial Crop Lifted: 28 Dec 2011

Treatment	Lifting Date	Tops Down %	Soil Moisture at 10cm	Gross Yield/2m^2	# Weeks from ≥80% Tops Down	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Not Skinned Shoot >1 %	Skinned Shoot >1 %
14d post	12/1/12	100	57	17.2	+2	1.2	23.4	61.2	2.5	3.9	0	0
7d post	5/1/12	100	52	19.1	+1	3.5	4.4	59.0	2.1	3.0	0	0
Predicted	29/12/11	90	54	16.4	0	5.6	2.3	62.2	2.2	3.3	0	0
7d pre	22/12/11	55	92	16.7	-1	10.6	3.1	69.7	2.2	3.6	0	0
14d pre	15/12/11	0	59	14.6	-2	49.3	5.9	64.2	1.9	4.1	0	0
21d pre	8/12/11	0	56	9.0	-3	-	-	-	-	-	-	-
P				<.001		<.001	<.001	NS	NS	NS	-	-
LSD 5%				3.10		6.92	6.62					

- This site had late season fertiliser application
- All 4 reps, 21d pre not harvested as bulbs were too small; note that most had windows
- Yield increased significantly with later lifting
- The level of skinning 30 days post lifting increased significantly when the crop was lifted <80% tops down, but did not change significantly when lifted >80% tops down
- The level of skinning 90 days post lifting did not change significantly when the crop was lifted <80% tops down, but did increase significantly when lifted >80% tops down
- The level of skinning 160 days post lifting did not change significantly with time of lifting
- Weight loss did not change significantly with time of lifting
- Visible shoot development (>1) was not significantly different between lifting times

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 4.11 Results for Time of Lifting trial 1112 L 201
Variety: 11-SP-211
Planted: 4 May 2011
Commercial Crop Lifted: 3 Jan 2012

Treatment	Lifting Date	Tops Down %	Soil Moisture at 10cm	Gross Yield/2m^2	# Weeks from ≥80% Tops Down	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Not Skinned Shoot >1 %	Skinned Shoot >1 %
14d post	12/1/12	100	42	19.0	+2	2.3	45.2	77.5	2.7	4.1	0	0
7d post	5/1/12	100	45	18.5	+1	1.9	8.3	49.8	2.0	5.5	0	0
Predicted	29/12/11	100	64	18.6	0	2.9	2.8	57.2	2.2	3.5	0	0
7d pre	22/12/11	53	89	17.2	-1	3.9	6.2	50.9	2.0	3.8	0	0
14d pre	15/12/11	0	87	12.1	-2	24.2	8.3	67.1	2.7	3.3	0	0
21d pre	8/12/11	0	53	12.6	-3	22.2	11.3	75.4	1.6	3.5	0	0
P				<.001		<.001	<.001	<.001	NS	NS	-	-
LSD 5%				2.05		6.22	7.54	11.60				

- Yield increased significantly with later lifting
- The level of skinning 30 days post lifting increased significantly when the crop was lifted <80% tops down, but did not change significantly when lifted >80% tops down
- The level of skinning 90 days post lifting did not change significantly when the crop was lifted <80% tops down, but did increase significantly when lifted >80% tops down
- The level of skinning 160 days post lifting increased significantly when the crop was lifted <80% tops down, and increased significantly when lifted >80% tops down
- Weight loss did not change significantly with time of lifting
- Visible shoot development (>1) was not significantly different between lifting times

Results Colour Key

Orange	Skinning >20% at either 30d post or 90d post lifting
Green	Skinning <20% at both 30d post and 90d post lifting

Table 4.12 Results for Time of Lifting trial 1112 L 204
Variety: 11-SP-211
Planted: 7 May 2011
Commercial Crop Lifted: 29 Dec 2011

Treatment	Lifting Date	Tops Down %	Soil Moisture at 10cm	Gross Yield/2m^2	# Weeks from ≥80% Tops Down	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Not Skinned Shoot >1 %	Skinned Shoot >1 %
14d post	12/1/12	100	72	19.2	+3	5.7	64.1	87.3	2.1	4.3	0	2.0
7d post	5/1/12	100	43	21.8	+2	7.1	19.2	71.8	1.8	2.9	0	0
Predicted	29/12/11	95	85	19.6	+1	7.2	8.9	69.3	2.0	3.7	1.0	0
7d pre	22/12/11	80	82	18.1	0	7.1	16.9	75.7	2.2	3.8	0	0
14d pre	15/12/11	66	78	17.5	-1	56.6	9.8	88.1	2.7	4.6	0	0
21d pre	8/12/11	4	-	16.6	-2	49.4	15.9	70.1	1.7	4.2	0	0
P				<.001		<.001	<.001	.021	NS	.001	NS	NS
LSD 5%				1.65		6.55	10.23	13.53		0.67		

- Yield increased significantly with later lifting
- The level of skinning 30 days post lifting increased significantly when the crop was lifted <80% tops down, but did not change significantly when lifted >80% tops down
- The level of skinning 90 days post lifting did not change significantly when the crop was lifted <80% tops down, but did increase significantly when lifted >80% tops down
- The level of skinning 160 days post lifting did not change significantly when the crop was lifted at <80% tops down, or when lifted >80% tops down
- Weight loss did not change significantly between 30 and 90 days post lifting with time of lifting, but did increase significantly between 90 and 160 days post lifting when lifted 1 week before 80% tops down and decreased significantly when lifted 2 weeks after 80% tops down
- Visible shoot development (>1) was not significantly different between lifting times

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 4.13 Results for Time of Lifting trial 1112 L 350
Variety: 11-SP-211
Planted: 28 May 2011
Commercial Crop Lifted: 3 Jan 2012

Treatment	Lifting Date	Tops Down %	Soil Moisture at 10cm	Gross Yield/2m^2	# Weeks from ≥80% Tops Down	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Not Skinned Shoot >1 %	Skinned Shoot >1 %
14d post	17/1/12	100	72	OWR	+2	-	-	-	-	-	-	-
7d post	10/1/12	100	97	OWR	+1	-	-	-	-	-	-	-
Predicted	3/1/12	100	57	11.0	0	5.8	5.3	41.8	2.4	3.2	0	0
7d pre	27/12/11	65	80	9.7	-1	23.2	2.1	47.0	2.8	4.2	0	0
14d pre	20/12/11	5	73	9.8	-2	26.6	2.5	50.4	2.6	3.6	0	0
21d pre	12/12/11	0	60	7.9	-3	54.5	1.1	94.6	2.8	4.5	0	4.1
P				.003		<.001	NS	<.001	NS	NS	-	NS
LSD 5%				1.32		3.87		10.18				

- OWR = All 4 reps, 14d post and 7d post were not harvested due to onion white rot infection
- Rep 1, 7d pre not harvested due to onion white rot infection
- Rep 4, 21d pre not harvested due to onion white rot infection
- Yield increased significantly with later lifting
- The level of skinning 30 days post lifting increased significantly when the crop was lifted <80% tops down
- The level of skinning 90 days post lifting did not change significantly when the crop was lifted <80% tops down
- The level of skinning 160 days post lifting increased significantly when the crop was lifted <80% tops down
- Weight loss did not change significantly with time of lifting
- Visible shoot development (>1) was not significantly different between lifting times

Results Colour Key

	Skinning >20% at either 30d post or 90d post lifting
	Skinning <20% at both 30d post and 90d post lifting

Table 4.14 Results for Time of Lifting trial 1112 L 355
Variety: 11-SP-211
Planted: 30 May 2011
Commercial Crop Lifted: 16 Jan 2012

Treatment	Lifting Date	Tops Down %	Soil Moisture at 10cm	Gross Yield/2m^2	# Weeks from $\geq$80% Tops Down	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Not Skinned Shoot >1 %	Skinned Shoot >1 %
21d post	24/1/12	100	66	20.5	+3	22.8	60.5	81.1	1.8	4.9	0	0
14d post	17/1/12	100	60	21.3	+2	10.6	41.3	71.8	1.9	4.6	0	0
7d post	10/1/12	100	94	18.3	+1	10.0	18.6	69.1	1.9	3.0	0	0
Predicted	3/1/12	90	71	17.4	0	7.8	16.0	61.0	2.2	3.6	0	2.6
7d pre	27/12/11	14	66	16.4	-1	31.9	9.7	58.5	2.4	4.2	0	0
14d pre	20/12/11	6	68	12.5	-2	37.3	11.9	80.7	2.8	4.4	0	0
21d pre	12/12/11	0	66	10.7	-3	82.2	19.8	84.0	2.9	4.1	0	0
P				<.001		<.001	<.001	.021	<.001	NS	-	NS
LSD 5%				2.21		10.05	7.97	16.39	0.48			

- 21d post treatment added to this trial (labelled as Extra in the raw data)
- 35mm rain between 8-11 January delayed commercial lifting
    - Note very high soil moisture level on 10th January
    - The significant increase in skinning 90 days post lifting between lifting 7 days or 14 days post 80% tops down could due to either lifting time or the high soil moisture
- Yield increased significantly with later lifting
- The level of skinning 30 days post lifting increased significantly when the crop was lifted <80% tops down, and also increased significantly when lifted >80% tops down
- The level of skinning 90 days post lifting did not change significantly when the crop was lifted <80% tops down, but did increase significantly when lifted >80% tops down
- The level of skinning 160 days post lifting increased significantly when the crop was lifted <80% tops down, and increased significantly when lifted >80% tops down
- Weight loss increased significantly between 30 and 90 days post lifting when the crop was lifted either 2 or 3 weeks before 80% tops down, but did not change significantly between 90 and 160 days post lifting
- Visible shoot development (>1) was not significantly different between lifting times

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 4.15 Results for Time of Lifting trial 1112 L 105
Variety: 10-DR-161
Planted: 13 Jul 2011
Commercial Crop Lifted: 25 Jan 2012

Treatment	Lifting Date	Tops Down %	Soil Moisture at 10cm	Gross Yield/2m^2	# Weeks from ≥80% Tops Down	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Not Skinned Shoot >1 %	Skinned Shoot >1 %
14d post	10/2/12	100	43	17.6	+2	4.2	30.6	64.9	2.7	3.4	0	0
7d post	3/2/12	100	43	21.3	+1	4.8	30.2	55.1	2.2	3.3	0	0
Predicted	27/1/12	95	71	18.5	0	3.4	21.4	58.2	2.7	3.2	0	0
7d pre	20/1/12	74	67	18.0	-1	7.1	19.9	64.2	2.1	3.9	0	0
14d pre	13/1/12	49	87	15.3	-2	13.7	5.2	32.0	0.2	3.0	0	3.5
21d pre	6/1/12	39	52	12.1	-3	11.2	8.1	35.9	2.1	3.0	0	3.5
P				.002		<.001	<.001	<.001	NS	NS	-	NS
LSD 5%				3.85		4.45	10.00	10.51				

- Onion white rot was present in the site, and may have reduced the yield of the latest lifting time
- Crops maturing during this period were exposed to a week of cool conditions in early January, which may have disrupted maturity and the timing of tops down
- Yield increased significantly with later lifting
- The level of skinning 30 days post lifting increased significantly when the crop was lifted <80% tops down, but did not change significantly when lifted >80% tops down
- The level of skinning 90 days post lifting decreased significantly when the crop was lifted <80% tops down, but did not change significantly when lifted >80% tops down
- The level of skinning 160 days post lifting decreased significantly when the crop was lifted <80% tops down, but did not change significantly when lifted >80% tops down
- Weight loss did not change significantly with time of lifting
- Visible shoot development (>1) was not significantly different between lifting times

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 4.16 Results for Time of Lifting trial 1112 L 106
Variety: 10-DR-161
Planted: 14 Jul 2011
Commercial Crop Lifted: 26 Jan 2012

Treatment	Lifting Date	Tops Down %	Soil Moisture at 10cm	Gross Yield/2m^2	# Weeks from $\geq$80% Tops Down	30d Skin %	90d Skin %
14d post	10/2/12	100	58	18.5	+2	9.3	65.8
7d post	3/2/12	100	55	22.6	+1	5.8	51.3
Predicted	27/1/12	88	74	20.3	0	7.1	48.1
7d pre	20/1/12	53	63	19.0	-1	6.1	36.5
14d pre	13/1/12	43	86	15.2	-2	21.5	33.4
21d pre	6/1/12	29	59	13.2	-3	24.3	21.5
P				.005		<.001	NS
LSD 5%				4.48		6.57	

- Onion white rot was present in the site, and may have reduced the yield of the latest lifting time
- There was a major loss of bulbs to disease between the 30 day and 90 day tumbling; onion white rot and high levels of Botrytis
- Yield increased significantly with later lifting
- The level of skinning 30 days post lifting increased significantly when the crop was lifted <80% tops down, but did not change significantly when lifted >80% tops down
- The level of skinning 90 days post lifting was likely influenced by the high disease level present in the bulbs

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 4.17 Results for Time of Lifting trial 1112 L 109
Variety: Baron
Planted: 17 Jul 2011
Commercial Crop Lifted: 20 Jan 2012

Treatment	Lifting Date	Tops Down %	Soil Moisture at 10cm	Gross Yield/2m^2	# Weeks from $\geq$80% Tops Down	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Not Skinned Shoot >1 %	Skinned Shoot >1 %
14d post	3/2/12	100	37	17.5	+3	3.7	18.0	43.2	3.0	3.3	0	0
7d post	27/1/12	100	60	16.8	+2	0.3	2.8	35.7	2.2	3.0	0	0
Predicted	20/1/12	100	77	17.0	+1	0	3.8	36.0	2.1	3.4	0	0
7d pre	13/1/12	94	90	15.6	0	1.2	0.3	11.5	2.2	2.9	0	0
14d pre	6/1/12	70	60	14.0	-1	3.8	0.4	8.7	2.2	2.9	0	0
21d pre	30/12/11	0	49	12.2	-2	11.3	0	6.8	2.8	2.9	0.3	6.9
P				<.001		<.001	<.001	<.001	.011	NS	NS	NS
LSD 5%				2.03		2.48	3.14	8.03	0.55			

- Yield increased significantly with later lifting
- The level of skinning 30 days post lifting increased significantly when the crop was lifted <80% tops down, and also increased significantly when lifted >80% tops down
- The level of skinning 90 days post lifting did not change significantly when the crop was lifted <80% tops down, but did increase significantly when lifted >80% tops down
- The level of skinning 160 days post lifting did not change significantly when the crop was lifted <80% tops down, but increased significantly when lifted >80% tops down
- Weight loss increased significantly between 30 and 90 days post lifting when the crop was lifted either 3 weeks after 80% tops down or 2 weeks before 80% tops down, but did change significantly between 90 and 160 days post lifting
- Visible shoot development (>1) was not significantly different between lifting times

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 4.18 Results for Time of Lifting trial 1112 L 230 (Canterbury)
Variety: Canterbury
Planted: 15 Sep 2011
Commercial Crop Lifted: 13 Feb 2012

Treatment	Lifting Date	Tops Down %	Soil Moisture at 10cm	Gross Yield/2m^2	# Weeks from ≥80% Tops Down	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Not Skinned Shoot >1 %	Skinned Shoot >1 %
14d post	5/3/12	100	98	17.3	+4	4.1	36.9	74.1	2.3	3.4	0	1.4
7d post	27/2/12	100	55	18.3	+3	1.1	30.4	70.7	2.3	3.3	0	0.9
Predicted	20/2/12	100	87	18.3	+2	6.7	18.3	62.8	2.4	3.3	0	0
7d pre	13/2/12	100	64	17.7	+1	1.2	5.3	55.3	2.0	3.0	0	0
14d pre	6/2/12	95	99	14.6	0	3.9	5.4	58.9	2.4	3.0	0	0
21d pre	30/1/12	6	93	13.7	-1	15.0	17.2	61.5	2.3	2.8	0	0
P				<.001		<.001	<.001	.025	NS	NS	-	NS
LSD 5%				2.25		3.04	6.53	11.60				

- This trial experienced severe downy mildew infection towards the end of the crop, which may have influenced the timing of tops down
- Yield increased significantly with later lifting
- The level of skinning 30 days post lifting increased significantly when the crop was lifted <80% tops down, but did not change significantly when lifted >80% tops down
- The level of skinning 90 days post lifting increased significantly when the crop was lifted <80% tops down, and also increased significantly when lifted >80% tops down
- The level of skinning 160 days post lifting did not change significantly when the crop was lifted <80% tops down, but increased significantly when lifted >80% tops down
- Weight loss did not change significantly with time of lifting
- Visible shoot development (>1) was not significantly different between lifting times

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 4.19 Results for Time of Lifting trial 1112 L 230 (161)
Variety: 161
Planted: 15 Sep 2011
Commercial Crop Lifted: 26 Feb 2012

Treatment	Lifting Date	Tops Down %	Soil Moisture at 10cm	Gross Yield/2m^2	# Weeks from ≥80% Tops Down	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Not Skinned Shoot >1 %	Skinned Shoot >1 %
19d post	10/3/12	100	56	18.8	+1wk & 5d	6.7	26.0	42.7	2.6	3.1	0	0
16d post	7/3/12	100	62	19.4	+1wk & 2d	3.3	22.2	34.8	2.8	3.1	0	0
14d post	5/3/12	100	94	18.9	+1	1.7	24.1	47.8	2.7	3.3	0	0
7d post	27/2/12	100	62	20.0	0	0	15.9	45.1	2.6	3.3	0	0
Predicted	20/2/12	56	81	18.9	-1	8.5	7.7	45.4	2.8	3.1	0	0
7d pre	13/2/12	0	72	16.6	-2	4.6	4.3	45.6	2.7	3.0	0	0
14d pre	6/2/12	0	100	16.2	-3	13.9	11.7	42.5	3.3	3.1	0	0
21d pre	30/1/12	0	94	13.1	-4	26.3	12.2	60.4	2.9	3.3	0	0
P				<.001		<.001	<.001	.005	.032	NS	-	-
LSD 5%				2.27		5.32	5.75	10.47	0.40			

- Two additional lifting times were added to measure the impact of rain after the 5th March
    - Note very high soil moisture level on 5th March
    - The high soil moisture did not result in a significant increase in skinning when lifted 2 days or 5 days later
- Yield increased significantly with later lifting
- The level of skinning 30 days post lifting increased significantly when the crop was lifted <80% tops down, and also increased significantly when lifted >80% tops down
- The level of skinning 90 days post lifting did not change significantly when the crop was lifted <80% tops down, but did increase significantly when lifted >80% tops down
- The level of skinning 160 days post lifting increased significantly when the crop was lifted <80% tops down, and did not change significantly when lifted >80% tops down
- Weight loss increased significantly between 30 and 90 days post lifting when the crop was lifted 3 weeks before 80% tops down but not when lifted 4 weeks before 80% tops down, but did not change significantly between 90 and 160 days post lifting
- Visible shoot development (>1) was not significantly different between lifting times

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 4.20 Aggregated Results Summary for the 19 Time of Lifting trials

# Weeks from ≥80% Tops Down	Proportion of trial sites with <20% skinning at 30d	Proportion of trial sites with <20% skinning at 90d	Proportion of trial sites with <20% skinning at both 30d & 90d
+3	77%	22%	22%
+2	100%	35%	28%
+1	100%	60%	53%
0	100%	76%	76%
-1	77%	88%	61%
-2	64%	85%	57%
-3	50%	90%	50%

- The proportions calculated in the table do not always include all 19 sites, as not all sites were covered by all lifting times

Results Summary Colour Key:

(green)	Proposed optimum lifting window

Table 4.21 Results of Time on Ground trials

Trial Crop #	Variety	Air 60d Skin %	Air 120d Skin %	Air 160d Skin %	Air 60-120d Weight Loss %	Air 120-160d Weight Loss %	Air Not Skinned Shoot >1%	Air Skinned Shoot >1%
101	11-SP-211	1.3	19.0	35.4	2.2	3.6	0	0
102	11-SP-211	0	8.4	56.3	2.2	3.4	0	0
201	11-SP-211	0	24.1	47.1	2.0	3.3	0	0
204	11-SP-211	4.3	29.7	64.5	2.2	3.2	0	0
355	11-SP-211	10.7	68.3	75.3	2.1	4.5	0	0
109	Baron	0	2.0	35.5	2.9	3.0	0	0
230	Canterbury	0	21.6	46.3	2.9	2.8	0	0
230 (161)	161	0	9.8	37.2	2.3	2.8	0	0
Average	All	2.0	22.8	49.7	2.3	3.3	-	-

Trial Crop #	Variety	Soil 60d Skin %	Soil 120d Skin %	Soil 160d Skin %	Soil 60-120d Weight Loss %	Soil 120-160d Weight Loss %	Soil Not Skinned Shoot >1%	Soil Skinned Shoot >1%
101	11-SP-211	7.5	45.4	83.3	2.1	3.8	0	0
102	11-SP-211	10.0	22.7	56.0	2.4	3.6	0	0
201	11-SP-211	4.8	35.9	70.7	2.5	3.4	0	0
204	11-SP-211	11.7	40.6	82.0	2.4	3.6	0	0
355	11-SP-211	32.1	70.0	91.8	2.1	5.4	0	0
109	Baron	0	18.9	50.2	2.0	4.1	0	0
230	Canterbury	3.1	27.8	50.8	2.3	2.9	0	0
230 (161)	161	5.2	24.2	48.9	2.7	3.3	0	0
Average	All	9.3	35.7	66.7	2.3	3.8	-	-

- The level of skinning increased, at each tumble/assessment time, when the crop was left on soil for an extra 30 days
- Weight loss did not change up to 120 days post lifting, but did increase between 120 and 160 days post lifting, when the crop was left on soil for an extra 30 days
- Sprouting was not affected by the extra time on the ground

Results Colour Key

Orange	Skinning >20% at either 60d post or 120d post lifting
Green	Skinning <20% at both 60d post and 120d post lifting

Table 4.22 Results of Windrow Depth trials - skinning

Trial Crop #	Variety	Planted	*Density Plants/m^2	*Gross Yield t/ha	Lifted & Windrow Formed	Harvested	Days on ground
103	11-DR-211	18 May	71	77.6	27 Dec	13 Jan	17
202	11-DR-211	14 May	78	88.7	28 Dec	14 Jan	17
301	11-DR-211	20 May	74	58.5	29 Dec	17 Jan	19
306	11-DR-211	29 May		54.0	30 Dec	12 Jan	13
203	11-DR-211	15 May	61	64.0	2 Jan	16 Jan	14
207	Baron	24 Jul	77	77.4	3 Jan	20 Jan	17
307	11-SP-211	31 May		34.7	5 Jan	22 Jan	17
107	12-DR-161	19 Aug		69.1	2 Feb	22 Feb	20
256	Manuka	27 Sep	60	67.2	20 Feb	6 Mar	15
313	Manuka	12 Sep	47	75.1	25 Feb	18 Mar	22
Average							17

*Data from commercial crop – trials set up in areas representative of the commercial crop

Trial Crop #	1 Layer 30d Skin %	2 Layers 30d Skin %	3 Layers 30d Skin %	1 Layer 90d Skin %	2 Layers 90d Skin %	3 Layers 90d Skin %	1 Layer 160d Skin %	2 Layers 160d Skin %	3 Layers 160d Skin %
103	0	0	0	0	0	4.7	22.2	15.0	21.4
202	0	0	0	0	2.3	0	24.3	21.9	18.2
301	0	0	0	0	1.1	3.8	11.7	15.9	17.0
306	12.5	9.1	14.4	25.2	24.8	22.5	41.6	35.0	39.5
203	0	2.4	0	16.4	9.6	10.1	32.4	33.8	30.1
207	0	0	0	0	0	0.8	-	-	-
307	1.2	2.0	0	0	0	0	14.0	6.9	10.7
107	20.3	15.5	20.2	4.1	9.8	13.9	43.8	48.5	53.7
256	0	0	0	5.5	6.7	10.3	42.6	36.7	40.2
313	6.4	12.3	11.7	18.2	30.4	23.9	69.9	87.1	80.3
Average	4.0	4.1	4.6	7.0	8.5	9.0	33.6	33.4	34.5

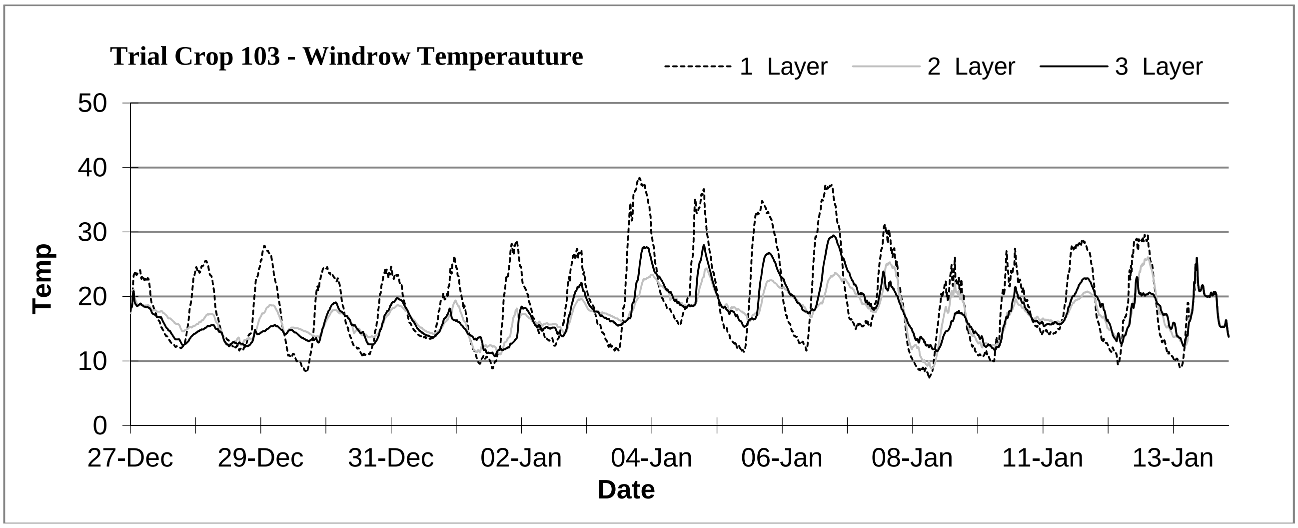
Table 4.23 Results of Windrow Depth trials – weight loss

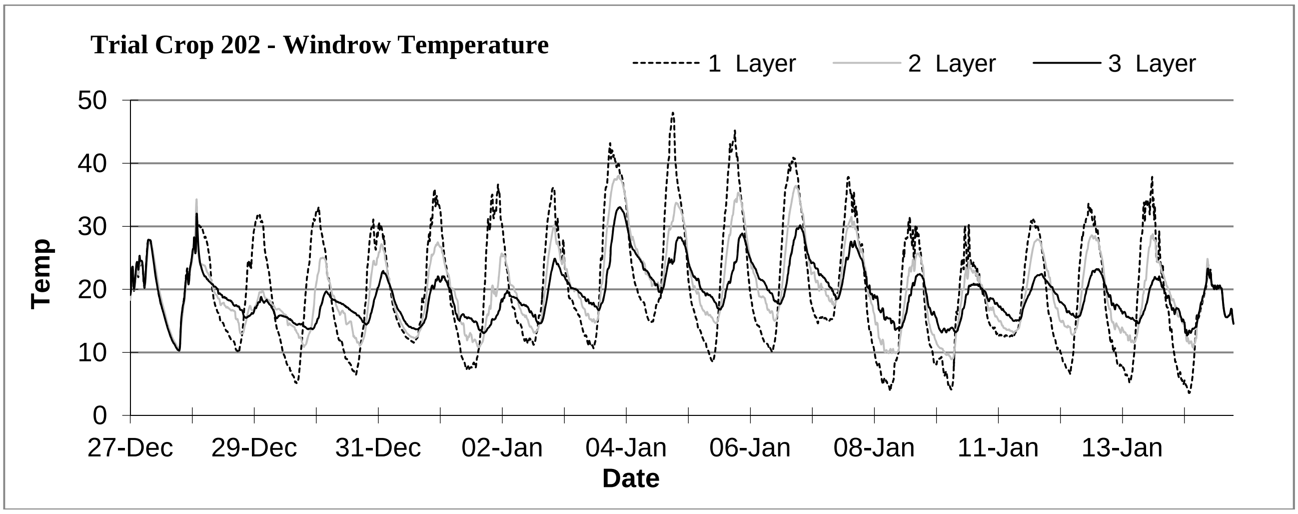
Trial Crop #	1 Layer 30-90d Weight Loss %	2 Layers 30-90d Weight Loss %	3 Layers 30-90d Weight Loss %	1 Layer 90-160d Weight Loss %	2 Layers 90-160d Weight Loss %	3 Layers 90-160d Weight Loss %
103	2.6	3.0	2.8	2.4	2.7	2.6
202	2.0	1.8	2.0	2.6	2.7	2.7
301	2.6	2.4	2.4	1.9	1.8	1.6
306	2.8	2.9	3.0	2.4	2.8	2.5
203	2.5	3.0	2.8	2.7	2.5	2.4
207	2.4	2.5	2.7	-	-	-
307	2.8	2.8	2.9	1.3	1.2	1.9
107	3.0	3.2	3.2	1.8	2.5	2.8
256	1.9	2.1	2.0	1.8	2.1	1.9
313	5.2	5.1	5.8	4.1	3.2	4.5
Average	2.7	2.8	2.9	2.3	2.3	2.5

Table 4.24 Results of Windrow Depth trials – shoot development

Trial Crop #	160d Shoot % 1 Layer					160d Shoot % 2 Layers					160d Shoot % 3 Layers				
	¼	½	¾	1	>1	¼	½	¾	1	>1	¼	½	¾	1	>1
103	0	0	38.7	61.3	0	0	0	32.4	67.6	0	0	8.3	41.1	50.6	0
202	0	0	34.1	65.9	0	0	0	45.1	54.9	0	0	3.6	24.5	71.9	0
301	0	0	6.9	93.1	0	0	0	18.6	81.4	0	0	0	29.5	70.5	0
306	0	2.0	43.0	55.0	0	0	8.6	49.8	41.5	0	0	0	55.7	44.3	0
203	0	0	21.6	78.4	0	0	1.9	16.7	81.4	0	0	0	32.6	67.4	0
107	0	0	16.0	84.0	0	0	7.6	11.9	80.5	0	0	0	10.3	89.7	0
256	0	0	14.2	85.8	0	0	5.0	19.6	75.4	0	0	0	15.0	85.0	0
313	0	0	15.8	84.2	0	0	0	5.4	94.6	0	0	0	11.7	88.3	0
Average	0	0.2	23.7	75.9	0	0	2.8	24.9	72.1	0	0	1.4	27.5	70.9	0

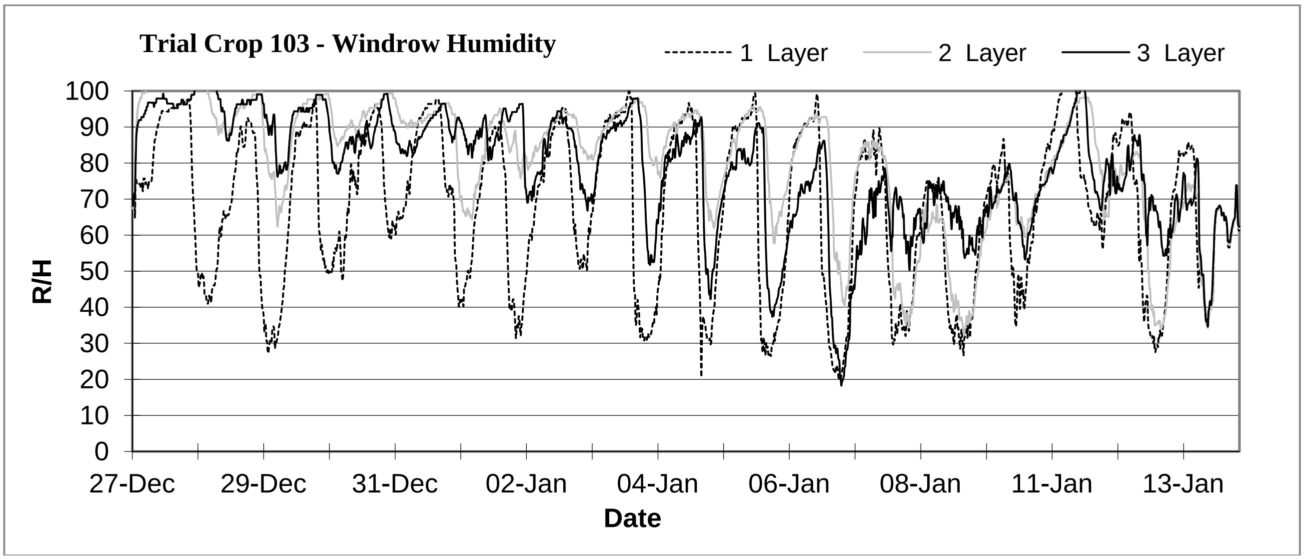
Figure 4.1 Temperature data within windrows with 1, 2 or 3 layers from coastal (103) and inland (202) location

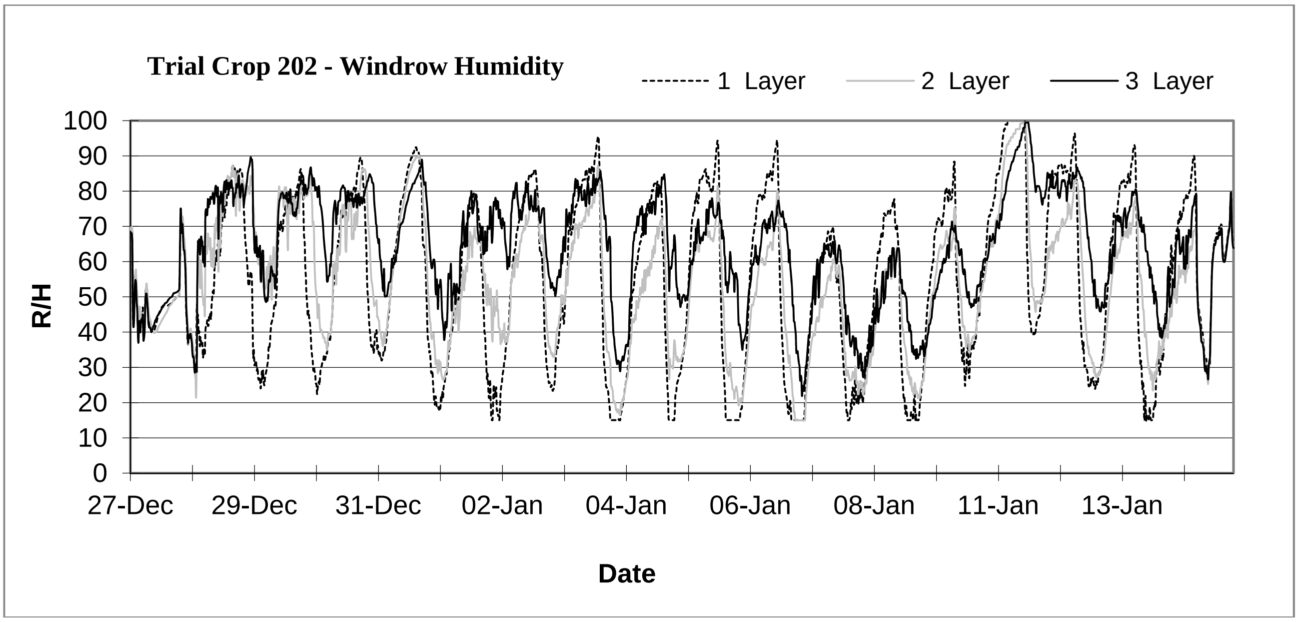




- All variety "211" May sown crops
- Trial crop 103 gross yield 77.6t/ha Devonport area
- Trial crop 202 gross yield 88.7t/ha Hagley area
- Logger located within one bulb of the top of each base layer; in a 1 layer windrow the logger was located within one bulb of the top of the windrow, in a 2 layer windrow the logger was located in the middle of the windrow and in a 3 layer windrow the logger was located a third of the way up from the base of the windrow

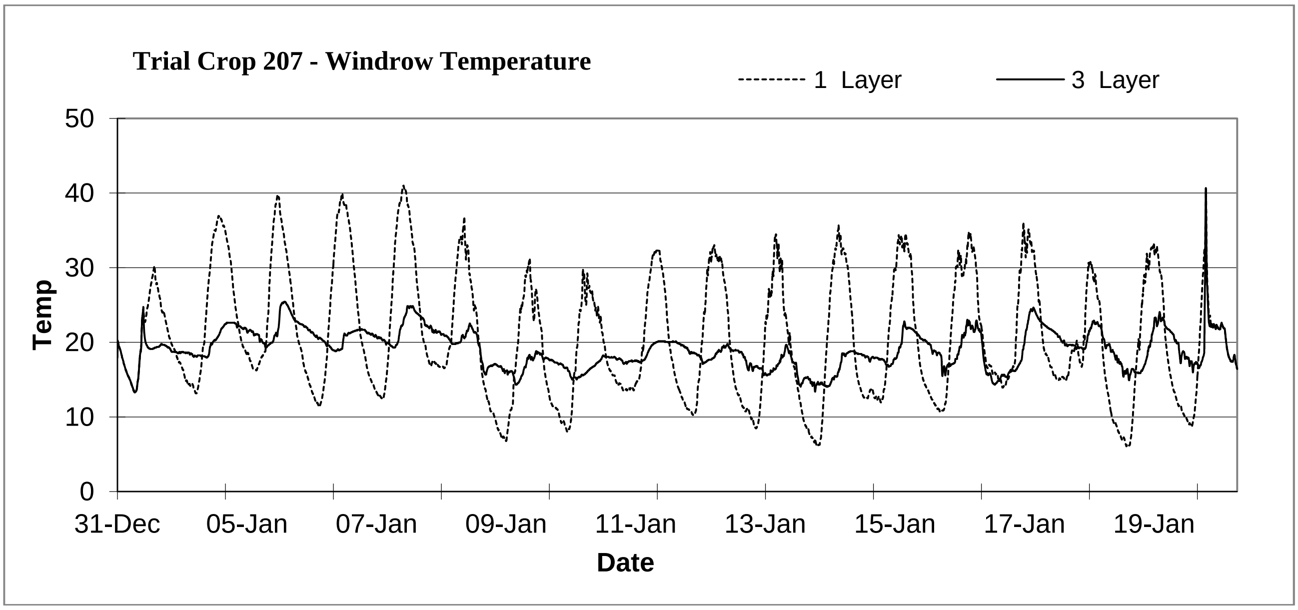
Figure 4.2 Humidity data within windrows with 1, 2 or 3 layers from coastal (103) and inland (202) location

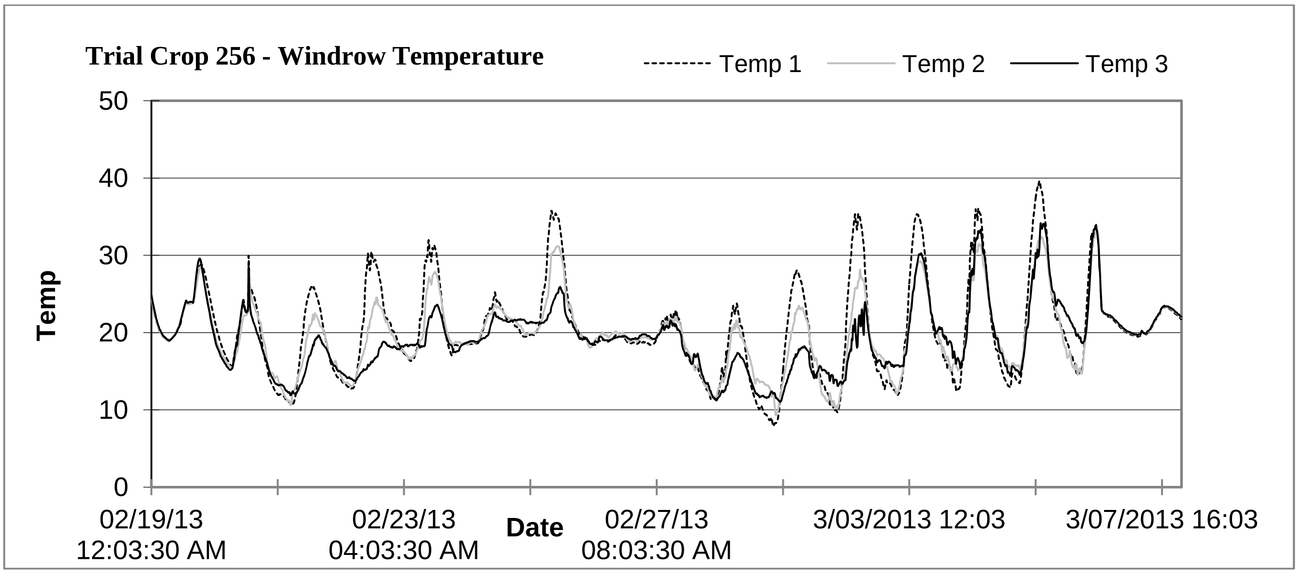




- All variety "211" May sown crops
- Trial crop 103 gross yield 77.6t/ha Devonport area
- Trial crop 202 gross yield 88.7t/ha Hagley area
- Logger located within one bulb of the top of each base layer; in a 1 layer windrow the logger was located within one bulb of the top of the windrow, in a 2 layer windrow the logger was located in the middle of the windrow and in a 3 layer windrow the logger was located a third of the way up from the base of the windrow

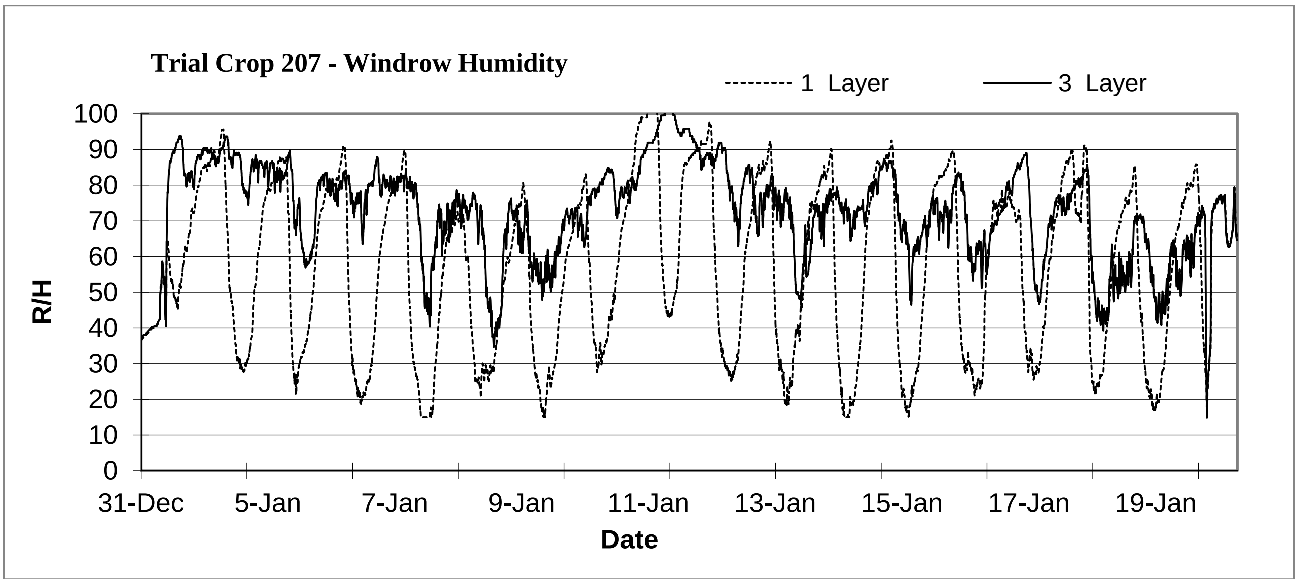
Figure 4.3 Temperature data within windrows with 1, 2 or 3 layers from July (207) and September (256) inland planting

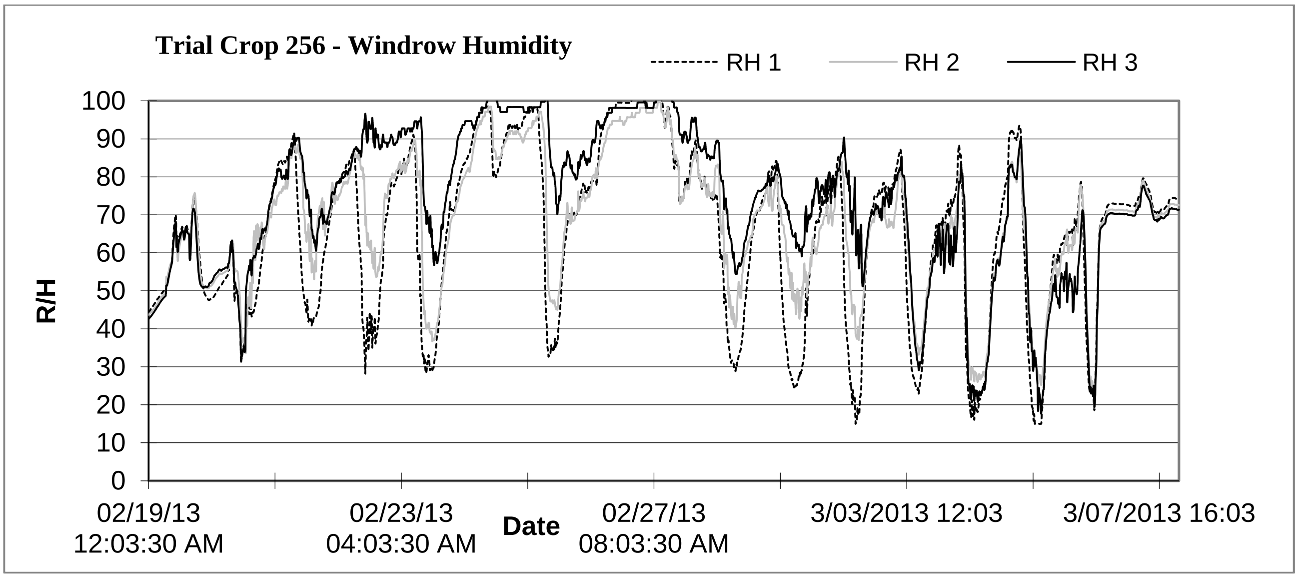




- Trial crop 207, variety Baron, gross yield 77.4t/ha, Hagley area
- Trial crop 256, variety Manuka, gross yield 67.2t/ha Longford area
- Logger located within one bulb of the top of each base layer; in a 1 layer windrow the logger was located within one bulb of the top of the windrow, in a 2 layer windrow the logger was located in the middle of the windrow and in a 3 layer windrow the logger was located a third of the way up from the base of the windrow

Figure 4.4 Humidity data within windrows with 1, 2 or 3 layers from July (207) and September (256) inland planting





- Trial crop 207, variety Baron, gross yield 77.4t/ha, Hagley area
- Trial crop 256, variety Manuka, gross yield 67.2t/ha Longford area
- Logger located within one bulb of the top of each base layer; in a 1 layer windrow the logger was located within one bulb of the top of the windrow, in a 2 layer windrow the logger was located in the middle of the windrow and in a 3 layer windrow the logger was located a third of the way up from the base of the windrow

Figure 4.5 Soil moisture data and 30day skinning data from the 17 Time of Lifting trial sites, showing data from lifting during the week 80% tops down was reached (Tables 4.1, 4.2, 4.5-4.19)

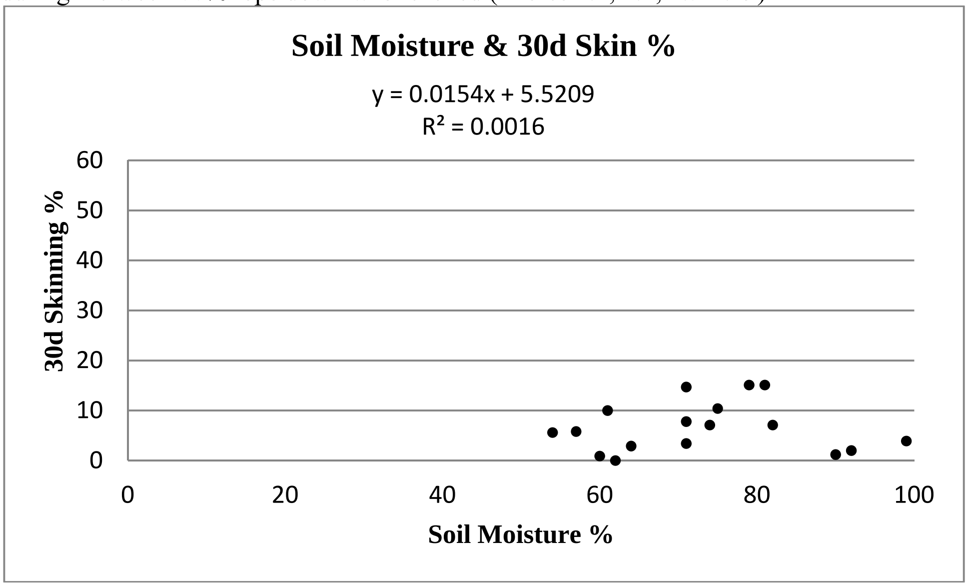


Figure 4.6 Soil moisture data and 90day skinning data from the 17 Time of Lifting trial sites, showing data from lifting during the week 80% tops down was reached (Tables 4.1, 4.2, 4.5-4.19)

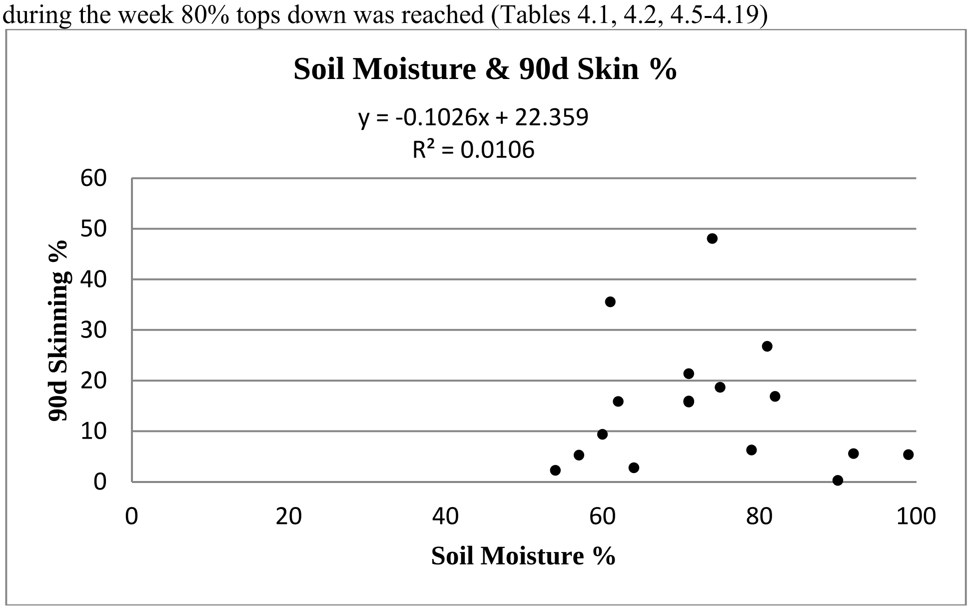


Table 4.25 Results of Soil Moisture trial 1213 SM 204
Variety: 11-DR-211
Planted: 16 May 2012
Lifted: 30 Dec 2012

Treatment	Tops Down %	Soil Moisture	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160D Weight Loss %	160d Shoot %				
								¼	½	¾	1	>1
1d post	99	80	5.2	20.4	40.1	2.5	2.4	0	2.7	32.6	64.6	0
3/4d post	96	65	4.8	19.0	41.2	2.2	2.3	0	4.8	31.7	63.1	0.3
7 d post	99	62	0.6	21.4	59.4	2.2	2.6	0	2.0	32.1	65.2	0.7
14d post	100	46	2.4	20.8	44.4	2.2	2.7	0	3.5	29.4	67.1	0
		P	.028	NS	NS	NS	NS	-	NS	NS	NS	NS
		LSD 5%	3.22									

- 14mm rain
- Trial area was ≥80% tops down for less than week when trial began
- The level of skinning 30days post lifting was significantly reduced by later lifting, however all levels of skinning were very low making results inconclusive

Table 4.26 Results of Soil Moisture trial 1213 SM 206
Variety: 11-DR-211
Planted: 18 May 2012
Lifted: 27 Dec 2012

Treatment	Tops Down %	Soil Moisture	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160D Weight Loss %	160d Shoot %				
								¼	½	¾	1	>1
1d post	100	75	0.8	0.4	10.6	2.0	2.6	0	1.2	33.2	65.5	0
3/4d post	99	73	0.5	0.4	12.5	2.2	2.5	0.1	1.0	27.5	71.3	0
7 d post	100	70	0.8	1.3	15.4	2.2	2.5	0	6.1	40.1	53.2	0.4
14d post	100	51	0.3	0	13.8	2.3	2.6	0	5.5	45.5	49.0	0
		P	NS	NS	NS	NS	NS	NS	NS	NS	.03	NS
		LSD 5%									15.59	

- 14mm rain
- Trial area was ≥80% tops down for less than week when trial began
- Tops may have been blown down by wind as lifting was earlier than expected; very high density crop and very dry site at lifting
- There were no significant differences across any of the parameters other than shoot development, which was significantly lower with later lifting

Results Colour Key

(orange)	Skinning >20% at either 30d post or 90d post lifting
(green)	Skinning <20% at both 30d post and 90d post lifting

Table 4.27 Results of Soil Moisture trial 1213 SM 101
Variety: Python
Planted: 16 May 2012
Lifted: 28 Dec 2012

Treatment	Tops Down %	Soil Moisture	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160D Weight Loss %	160d Shoot %				
								¼	½	¾	1	>1
1d post	91	76	0.8	26.0	69.0	2.3	2.4	0	4.3	28.1	67.7	0
3/4d post	96	61	0	28.1	67.8	2.2	2.3	0.9	2.3	29.1	67.7	0
7 d post	93	62	2.5	36.1	30.9	2.4	3.6	0	5.9	35.1	59.0	0
14d post	100	47	3.4	39.9	24.0	2.2	2.9	0	5.5	27.6	66.9	0
		P	.019	.001	<.001	NS	.013	NS	NS	NS	NS	-
		LSD 5%	2.21	6.30	22.26		.77					

- 12mm rain
- Trial area was ≥80% tops down for less than one week when trial began
- Poor growth throughout the season; crop lifted later than expected; not typical of historical performance of this variety
- The level of skinning 30days and 90 days post lifting was significantly increased by later lifting, and the level of skinning 160 days post lifting was significantly reduced by later lifting
    - Note that the significant differences in the level of skinning 90 days and 160 days post lifting between 3-4 days and 7 days occurred at similar soil moisture
- The level of weight loss 90-160 days post lifting increased significantly, but the increase did not follow a clear trend

Results Colour Key

Orange	Skinning >20% at either 30d post or 90d post lifting
Green	Skinning <20% at both 30d post and 90d post lifting

Table 4.28 Results of Soil Moisture trial 1213 SM 107
Variety: 12-DR-161
Planted: 19 Aug 2012
Lifted: 5 Feb 2013

Treatment	Tops Down %	Soil Moisture	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160D Weight Loss %	160d Shoot %				
								¼	½	¾	1	>1
1d post	93	81	32.1	40.5	79.1	3.0	2.6	0	0	20.8	78.1	1.0
3/4d post	100	60	34.3	44.5	90.8	2.9	2.3	0	4.2	18.3	77.5	0
7 d post	100	50	7.3	43.4	89.1	2.7	2.3	0	3.1	22.5	74.4	0
14d post	100	44	17.3	52.5	98.8	2.9	4.3	0	0	3.6	91.2	5.2
		P	<.001	NS	NS	NS	.012	-	NS	NS	NS	NS
		LSD 5%	9.23				1.23					

- 8mm rain, plus recent irrigation
- Late irrigation
- Note: trial area was ≥80% tops down for at least one week before trial began
    - First lift 1st Feb
    - 90% tops down 24th Jan
    - 60% tops down 19th Jan
    - Commercial crop lifted 5th Feb
- Tops down occurred much earlier than expected for this variety, planting time and location; top growth was very lush; site was well supplied with organic poultry waste
- Results suggest tops down did not coincide with optimum crop maturity; possibly due to excessive nitrogen uptake by the crop late in the season; top fall may have been due to excessive top weight rather than maturity
- The site was not well drained; received runoff, likely to have collected excessive nutrients
- The site was typical of a crop with a ‘soft finish’ (high water and high nutrient producing large soft bulbs)
- The level of skinning 30 days post lifting was significantly reduced by later lifting
    - Despite a drop in soil moisture between 1 day and 3-4 days, the level of skinning was not significantly different between either time
- The level of weight loss 90-160 days post lifting increased significantly

Results Colour Key

	Skinning >20% at either 30d post or 90d post lifting
	Skinning <20% at both 30d post and 90d post lifting

Table 4.29 Results of Soil Moisture trial 1314 SM 107
Variety: 211
Planted: 8 Oct 2013
Commercial Crop Lifted: 19 Feb 2014

Treatment	Last Irrigation Date	Days from last irrigation to lifting	Number Extra Irrigations	30d Skin %	90d Skin %	160d Skin %	30-90d Weight Loss %	90-160d Weight Loss %	Not Skinned Shoot >1 %	Skinned Shoot >1 %
Control	7 Feb 2014	12	0	5.3	2.2	32.2	1.5	2.0	0	0
Early	14 Feb 2014	5	1	4.5	1.1	32.3	1.4	2.0	0	0
Late	18 Feb 2014	1	1	2.9	2.3	30.4	1.5	2.4	0	0
Twice	18 Feb 2014	1	2	4.4	2.2	28.2	1.5	1.7	0	0
P				NS	NS	NS	NS	NS	-	-
LSD 5%										

- Trial lifted 19 Feb 2014
- No yield data collected owing to bunching of windrows during lifting
- The level of skinning 30 days post lifting was not significantly different between irrigation treatments
- The level of skinning 90 days post lifting was not significantly different between irrigation treatments
- The level of skinning 160 days post lifting was not significantly different between irrigation treatments
- Weight loss was not significantly different between irrigation treatments
- Visible shoot development (>1) was not significantly different between irrigation treatments

Results Colour Key

	Skinning >20% at either 30d post or 90d post lifting
	Skinning <20% at both 30d post and 90d post lifting

Table 4.30 Results of 1213 Senescence Trials - skinning

Trial Crop #	Variety	Planted	Treatment Applied	Treatment	Days to 1st Lift	Days to 2nd Lift	1st Lift 30d Skin %	2nd Lift 30d Skin %	1st Lift 90d Skin %	2nd Lift 90d Skin %	1st Lift 160d Skin %	2nd Lift 160d Skin %
103	11-DR-211	18 May	11 Dec	Control	16	22	0	0	1.9	0	37.9	29.6
			11 Dec	Ethrel	16	22	0	3.4	6.4	6.0	35.8	40.3
			11 Dec	Herbicide	16	22	0	0	4.9	4.0	48.5	43.3
202	11-DR-211	14 May	11 Dec	Control	17	22	0	0	1.1	1.7	23.2	23.3
			11 Dec	Ethrel	17	22	3.0	3.9	12.4	9.9	28.8	32.7
			11 Dec	Herbicide	17	22	0	0	9.8	2.8	30.5	38.7
301	11-DR-211	20 May	18 Dec	Control	11	17	0	0	1.1	2.2	13.2	18.8
			18 Dec	Ethrel	11	17	11.1	10.8	12.7	20.3	20.7	28.0
			18 Dec	Herbicide	11	17	1.3	0	2.8	7.5	18.7	21.2
306	11-DR-211	29 May	18 Dec	Control	12	18	13.0	12.1	31.6	26.5	38.4	46.0
			18 Dec	Ethrel	12	18	28.8	47.5	42.8	56.8	50.3	27.6
			18 Dec	Herbicide	12	18	10.9	10.5	20.0	21.9	37.3	30.8
203	11-DR-211	15 May	11 Dec	Control	22	27	0	1.6	11.3	9.5	35.7	36.1
			11 Dec	Ethrel	22	27	2.0	0	18.4	26.6	42.7	51.6
			11 Dec	Herbicide	17	22	1.6	3.3	13.0	27.4	47.0	32.3
207	Baron	24 Jul	28 Dec	Control	6	12	0	0	0	1.3	-	-
			28 Dec	Ethrel	6	12	11.6	6.2	2.5	7.9	17.7	34.2
			28 Dec	Herbicide	6	12	0	0	0	2.4	18.3	18.0
307	11-SP-211	31 May	29 Dec	Control	7	24	1.8	0	0	0	6.3	15.8
			29 Dec	Ethrel	7	24	9.9	0	0	0	16.4	12.9
			29 Dec	Herbicide	7	-	0	-	0	-	21.3	-
107	12-DR-161	19 Aug	19 Jan	Control	14	20	22.9	8.4	23.0	12.9	57.0	37.6
			19 Jan	Ethrel	14	20	19.2	12.8	26.7	28.8	60.5	65.3
			19 Jan	Herbicide	14	20	14.4	9.2	3.2	15.4	29.0	41.7
256	Manuka	27 Sep	12 Feb	Control	8	16	0	2.7	10.1	25.1	-	-
			12 Feb	Ethrel	8	16	0	2.1	6.1	24.4	60.5	59.8
			12 Feb	Herbicide	8	16	0	1.1	17.3	27.9	45.4	45.7
313	Manuka	12 Sep	11 Feb	Control	14	21	8.4	10.1	21.9	14.4	83.5	80.8
			11 Feb	Ethrel	7	14	9.7	12.9	19.9	26.6	90.3	78.1
			11 Feb	Herbicide	7	14	10.4	9.5	14.4	16.8	77.2	66.3
			Average	Control	12.7	19.9	4.6	3.5	10.2	9.4	36.9	36.0
			Average	Ethrel	12.0	19.2	9.5	10.0	14.8	20.7	42.4	43.1
			Average	Herbicide	11.5	18.1	3.9	3.7	8.5	14.0	37.3	37.6

- Trial 307 herbicide split plot lifting treatment were both lifted on same date

Table 4.31 Results of 1213 Senescence Trials – yield and weight loss

Trial Crop #	Variety	Planted	Treatment Applied	Treatment	Days to 1st Lift	Days to 2nd Lift	1st Lift Gross Yield/2m²	2nd Lift Gross Yield/2m²	1st Lift 30-90d Weight Loss %	2nd Lift 30-90d Weight Loss %	1st Lift 90-160d Weight Loss %	2nd Lift 90-160d Weight Loss %
103	11-DR-211	18 May	11 Dec	Control	16	22	16.4	17.2	2.9	2.5	2.4	2.3
			11 Dec	Ethrel	16	22	15.8	16.6	3.2	2.6	2.7	2.5
			11 Dec	Herbicide	16	22	16.2	16.0	2.5	2.6	2.8	2.6
202	11-DR-211	14 May	11 Dec	Control	17	22	17.6	18.2	2.0	2.1	3.0	2.4
			11 Dec	Ethrel	17	22	16.4	17.4	2.1	2.2	2.8	2.5
			11 Dec	Herbicide	17	22	18.1	17.5	2.3	2.1	2.9	2.6
301	11-DR-211	20 May	18 Dec	Control	11	17	13.9	14.2	2.6	2.5	1.7	1.8
			18 Dec	Ethrel	11	17	12.4	13.2	2.6	3.4	2.4	2.0
			18 Dec	Herbicide	11	17	13.3	12.6	2.5	2.9	2.5	1.9
306	11-DR-211	29 May	18 Dec	Control	12	18	11.8	13.2	3.0	2.8	2.8	3.0
			18 Dec	Ethrel	12	18	11.8	12.1	3.2	3.0	3.5	4.4
			18 Dec	Herbicide	12	18	12.6	12.8	3.0	2.9	2.8	2.5
203	11-DR-211	15 May	11 Dec	Control	22	27	14.1	14.8	2.4	2.3	2.6	2.7
			11 Dec	Ethrel	22	27	12.8	13.4	2.3	3.8	3.1	3.0
			11 Dec	Herbicide	17	22	13.6	13.6	2.3	2.8	2.6	2.9
207	Baron	24 Jul	28 Dec	Control	6	12	15.4	16.6	3.3	2.4	-	-
			28 Dec	Ethrel	6	12	13.8	15.9	4.0	2.8	3.6	2.6
			28 Dec	Herbicide	6	12	15.2	16.8	3.3	2.6	3.8	2.3
307	11-SP-211	31 May	29 Dec	Control	7	24	-	-	2.5	2.7	1.6	2.0
			29 Dec	Ethrel	7	24	-	-	2.7	2.5	2.2	2.1
			29 Dec	Herbicide	7	-	-	-	2.5	-	1.9	-
107	12-DR-161	19 Aug	19 Jan	Control	14	20	-	-	2.9	2.3	2.0	1.9
			19 Jan	Ethrel	14	20	-	-	3.7	3.0	2.5	2.8
			19 Jan	Herbicide	14	20	-	-	3.1	2.7	2.7	1.9
256	Manuka	27 Sep	12 Feb	Control	8	16	14.5	14.7	2.2	1.9	-	-
			12 Feb	Ethrel	8	16	13.9	14.3	2.3	2.0	2.2	2.5
			12 Feb	Herbicide	8	16	14.2	13.6	2.6	2.5	2.1	2.6
313	Manuka	12 Sep	11 Feb	Control	14	21	-	-	2.7	3.8	3.3	3.3
			11 Feb	Ethrel	7	14	-	-	3.1	3.7	3.4	1.7
			11 Feb	Herbicide	7	14	-	-	4.4	4.0	4.5	5.3
			Average	Control	12.7	19.9	14.8	15.6	2.7	2.5	2.4	2.4
			Average	Ethrel	12.0	19.2	13.8	14.7	2.9	2.9	2.8	2.6
			Average	Herbicide	11.5	18.1	14.7	14.7	2.9	2.8	2.9	2.7

- Trial 307 herbicide split plot lifting treatment were both lifted on same date

Table 4.32 Results of 1213 Senescence Trials – shoot development

Trial Crop #	Variety	Planted	Treatment Applied	Treatment	Days to 1^{st} Lift	Days to 2^{nd} Lift	1^{st} Lift 160d Shoot %					2^{nd} Lift 160d Shoot %				
							¼	½	¾	1	>1	¼	½	¾	1	>1
103	11-DR-211	18 May	11 Dec	Control	16	22	0	0	20.8	79.2	0	0	8.9	44.5	46.5	0
			11 Dec	Ethrel	16	22	0	8.9	50.4	39.0	1.7	0	0	40.6	59.4	0
			11 Dec	Herbicide	16	22	0	3.2	27.9	68.9	0	0	3.1	23.6	73.3	0
202	11-DR-211	14 May	11 Dec	Control	17	22	0	0	41.5	58.5	0	0	0	25.9	74.1	0
			11 Dec	Ethrel	17	22	0	0	36.8	63.2	0	0	7.8	16.2	76.0	0
			11 Dec	Herbicide	17	22	0	3.6	18.8	77.6	0	0	4.8	36.9	58.4	0
301	11-DR-211	20 May	18 Dec	Control	11	17	0	0	8.6	91.4	0	0	0	9.3	90.7	0
			18 Dec	Ethrel	11	17	0	0	36.9	63.1	0	0	0	10.9	81.2	7.9
			18 Dec	Herbicide	11	17	0	0.9	18.9	80.2	0	0	4.1	16.2	79.7	0
306	11-DR-211	29 May	18 Dec	Control	12	18	0	4.4	35.6	60.0	0	0	5.4	59.2	35.4	0
			18 Dec	Ethrel	12	18	0	11.9	34.1	54.0	0	7.1	4.6	41.6	46.7	0
			18 Dec	Herbicide	12	18	0	0	23.8	76.2	0	0	9.1	38.0	52.8	0
203	11-DR-211	15 May	11 Dec	Control	22	27	0	0	16.1	83.9	0	0	4.0	33.6	62.4	0
			11 Dec	Ethrel	22	27	0	5.8	23.9	70.3	0	0	0	21.9	78.1	0
			11 Dec	Herbicide	17	22	0	0	37.8	62.2	0	0	3.8	26.7	69.4	0
207	Baron	24 Jul	28 Dec	Control	6	12	-	-	-	-	-	-	-	-	-	-
			28 Dec	Ethrel	6	12	0	7.9	15.4	76.6	0	0	1.3	38.5	60.2	0
			28 Dec	Herbicide	6	12	0	4.2	27.3	68.5	0		7.0	23.1	69.9	
307	11-SP-211	31 May	29 Dec	Control	7	24	-	-	-	-	-	-	-	-	-	-
			29 Dec	Ethrel	7	24	0	5.0	39.1	55.9	0	0	0	29.8	70.2	0
			29 Dec	Herbicide	7	-	0	6.9	32.0	61.1	0	-	-	-	-	-
107	12-DR-161	19 Aug	19 Jan	Control	14	20	0	0	6.4	93.6	0	0	3.2	11.2	85.6	0
			19 Jan	Ethrel	14	20	0	0	18.4	81.6	0	0	0	31.4	68.6	0
			19 Jan	Herbicide	14	20	0	0	13.8	86.2	0	0	0	20.4	79.6	0
256	Manuka	27 Sep	12 Feb	Control	8	16	-	-	-	-	-	-	-	-	-	-
			12 Feb	Ethrel	8	16	0	0	14.8	85.2	0	0	0	26.2	73.8	0
			12 Feb	Herbicide	8	16	0	2.9	32.2	64.9	0	0	4.4	24.6	71.0	0
313	Manuka	12 Sep	11 Feb	Control	14	21	0	0	6.3	93.7	0	0	6.1	35.4	58.5	0
			11 Feb	Ethrel	7	14	0	0	24.4	75.6	0	0	0	25.2	74.8	0
			11 Feb	Herbicide	7	14	0	2.9	15.2	78.4	3.5	0	0	24.6	75.4	0
			Average	Control	12.7	19.9	0	0.6	19.3	80.0	0	0	3.9	31.3	64.7	0
			Average	Ethrel	12.0	19.2	0	4.0	29.4	66.5	0.2	0.7	1.4	28.2	68.9	0.8
			Average	Herbicide	11.5	18.1	0	2.5	24.8	72.4	0.4	0	4.0	26.0	69.9	0

- Trial 307 herbicide split plot lifting treatment were both lifted on same date

Technology Transfer

In this project Field Fresh Tasmania, as well as representing most of Australia's onion exports, was also the Research Provider, resulting in exceptionally efficient flow of information from trials through to commercial adoption. Although a number of technology transfer activities were undertaken, the vast majority of adoption of trial results into commercial practice was achieved by the integration of commercial production staff into the project team from the commencement of the project. The only issue this created was that on some occasions findings were adopted literally before the ink on the annual report had time to dry. Formal technology transfer activities included:

Field Fresh Tasmania end of season Grower meetings

Reports to Board of Directors, Webster Ltd

Newsletter articles for Webster Ltd

HAL Onion Industry Annual Report 2011
HAL Onion Industry Annual Report 2012
HAL Onion Industry Annual Report 2013
HAL Onion Industry Annual Report 2014

2010/11 Field Fresh Tasmania R&D Season Report
2011/12 Field Fresh Tasmania R&D Season Report
2012/13 Field Fresh Tasmania R&D Season Report
2012/13 Field Fresh Tasmania R&D Season Report

Steering Committee meetings

- 8th June 2011
- 27th October 2011
- 21st June 2012
- 30th October 2012
- 31st October 2012
- 19th June 2013
- 29th August 2013
- 17th December 2013
- 11th March 2014

Presentation to Woolworths, December 2012

Presentation to Onion IAC, Melbourne, Feb 2013

Hosted Bill Dean from the US, 8th October 2013

Appendices

Literature Cited

Brewster, J.L. (2008) Onions and other vegetable Alliums. 2nd Edition (Crop production science in horticulture series; 15)

Dennis, J.J.C and Fawkner, D. (2005) Demonstration of new onion export opportunities. HAL project VX01028

Gracie A., Boersma, M., Smith, R., Dennis, J. And Brown, P. (2006) Investigation and manipulation of the onion skin formation process. HAL project VN03011

Hole, C.C., Drew, R.L.K. and Gray, D. (2002). Skin characteristics and quality of onion cultivars given different nitrogen and irrigation treatments. Journal of Horticultural Science and Biotechnology. 77(2) 191-199.

Compendium of Onion and Garlic Diseases and Pests. 2nd Ed, 2008

Charron, G., Furlan, V., Bernier-Cardou, M. and Doyon, G. (2001). Response of onion plants to arbuscular mycorrhizae: 2. Effects of nitrogen fertilization on biomass and bulb firmness. Mycorrhiza 11(3) 145-150.

Coolong, T. W. and Randle, W. M. (2008) The Effects of Calcium Chloride and Ammonium Sulfate on Onion Bulb Quality at Harvest and During Storage. HortScience 43 (2) 465-471.

Lambert, S., Boersma, M. and Hunt, A. (2012) Literature review of onion senescence. Tasmanian Institute of Agriculture, University of Tasmania, unpublished.

Seasonal Climate Profile – Bureau of Meteorology

Tasmania in autumn 2010: a mild season

The switch to cooler weather during May has masked what has been a very mild autumn across Tasmania. Several sites, including Hobart, had their warmest autumn on record, with daytime temperatures especially warm. Local heavy rain in the northeast at the end of May and some moderate falls in other areas meant most of the state had near-average rain for the season, but the southeast was relatively dry

- Record warm autumn, including Hobart
- Mild weather dominated until 11 May
- Dry in the southeast

Tasmania in winter 2010: Mild days, cold nights and some heavy rain

Heavy rain fell on a number of days during winter, but overall rainfall was near average over most of the state. Nights were frequently very cold, especially in the southern Midlands and Derwent Valley. Daytime temperatures were mostly warmer than usual.

- Wettest winter day on record for some sites
- Several cold nights through the season
- Cold days and snow in August, but mostly mild days
- Still a very dry year so far in the southeast

Tasmania in spring 2010: wetter than usual, temperatures near normal

Several troughs and low pressure systems ensured that it was a wetter than usual spring across Tasmania. Temperatures gradually warmed from September to November, and overall nights were generally warmer than usual while days were cooler than usual.

- Some record daily rainfall totals
- Snow to low levels on several days
- Waves to 18 metres on 16 September

Tasmania in summer 2010-11: Wet in the north, cooler than usual days

Parts of northern Tasmania had its wettest summer on record after several days of heavy rain, including extremely heavy rain around 14 January. Most other areas of the state were also wetter than usual. Daytime temperatures were cooler than usual overall, though there were a few hot days, and nights were near average after both warm and cool periods.

- 2nd-wettest summer day on record: 282 mm at Falmouth
- Several floods in the north
- A few days with mountain snow

Tasmania in autumn 2011: Dry end but still wet overall in the east

In the east, flooding rain during March and April made it a wet autumn despite a dry May. The west was drier than usual due to a lack of active cold fronts. Temperatures were cooler than usual overall, and most sites had their coolest autumn since 2006.

- Downpours in the northeast during March and April
- Tasmania's third-wettest day on record
- Coolest since 2006 in most areas
- Coldest autumn day on record for Launceston

Tasmania in winter 2011: Wet with flooding in the northeast

Two heavy flooding rain events in August meant it was a wet winter in the northeast of Tasmania.
Night time and daytime temperatures were warmer than average this winter, following a very warm August. There were however, a few very cold nights, mostly in July.

- Wet with flooding in the northeast in August
- Warm winter days and nights
- Strong winds and large waves in June and July
- A record low -11.2 °C for Liawenee

Tasmania in spring 2011: Warm with a wet finish

Spring rainfall was close to average across Tasmania in 2011. In the north, a dry September was balanced by a wet November. Maximum temperatures were up to one degree warmer than normal following a warm September and November, whilst minimum temperatures were about half a degree warmer than average.

- Warm spring days and nights overall
- Average rainfall for the season

- Hobart's warmest spring in 24 years
- A record 111 mm at Eddystone Point on 27 November

Tasmania in summer 2011-12: A hot send-off to summer

The last weekend of summer was very hot in Tasmania, with daytime temperatures reaching into the mid to high 30s, and a few sites recording their warmest summer night on record. Summer rainfall was below average for most areas, but above average on Deal and Flinders Islands.

- A hot end to summer
- Record warm summer night at Devonport, Maatsuyker Island and Geeveston
- Warm summer days and nights overall
- Below average rainfall for most areas
- A few heavy rainfall events in the north and southeast

Tasmania in autumn 2012: warm with heavy rain

Autumn rainfall was above average in most areas, but especially in the northwest and parts of the south following heavy rain in March, April and May. Autumn temperatures were warmer than average across Tasmania, by up to one degree in most areas.

- Record heavy rain in the east and northwest
- Wettest autumn on record for Cape Grim
- Warm autumn days and nights
- Warmest autumn night on record for Launceston, Dover and Maydena

Tasmania in winter 2012: Dry, except in the northwest

Winter rainfall was below average across most of Tasmania, except in the northwest which had close to average winter rainfall. There were only a few very cold days and nights, most of those in June, with temperatures close to average overall.

- Driest winter on record at Scamander
- A few cold winter days and nights in June
- Record 20 m wave off Cape Sorell

Tasmania in spring 2012: dry with warm days

Spring rainfall was generally below average following dry conditions in October and November, though a few areas received close to average spring rain. Maximum temperatures were up to one degree warmer than normal, whilst minimum temperatures were close to average.

- Below average spring rainfall for most
- Tea Tree's wettest spring day on record
- Warmest spring day on record at Strahan and Lake St Clair
- Warmest spring night on record for a few sites
- Many strong wind events

Tasmania in summer 2012-13: A warm and dry summer

Summer 2012–13 brought record high temperatures and relatively little rain to Tasmania.

- Hottest day on record at sites including Hobart
- Warmer than average overall
- Below average summer rain for most
- Driest summer in 10 years for sites in the southeast

Tasmania in autumn 2013: Hot start, cold finish, warm and dry overall

March was exceptionally warm, several sites observing their highest autumn temperature on record, but then in May Launceston and Devonport observed their coldest autumn day on record. Local heavy rain events in the north and in the southeast saw some sites break autumn daily rainfall records, but most areas had below average autumn rainfall overall.

- Both record warm and record cold temperatures
- Launceston's warmest autumn days on record
- Isolated, record heavy rain in the north and southeast
- Below average autumn rain for most areas

Tasmania in winter 2013: Wetter and warmer than usual

Winter was wetter than average across Tasmania due to a wet July and August, despite a dry June. Both maximum and minimum temperatures were warmer than average.

- Wetter than average

- Flooding in the north in August
- Warmer-than-average days and nights
- Launceston's warmest winter days on record
- A record low −12.2 °C at Liawenee in July

Tasmania in spring 2013: wet and windy, with cool days and mild nights

Spring brought a variety of weather to Tasmania, but overall it was wet with cool days and relatively mild nights.

- A wet spring for most of Tasmania
- Mostly cool days
- Some low temperatures, but mild by night overall
- Damaging westerly winds

Tasmania in summer 2013-14: a warm, dry and windy season

After a relatively cool start to summer, Tasmania had some hot days through January and February, and was warm overall. Rainfall was below average in most parts of the state. There were several days with strong and damaging winds

- A relatively dry summer in most parts
- Warmer than average days, after a cool start
- Warmer than average nights
- Several windy days

Tasmania in autumn 2014: a warm season

Tasmania experienced a warmer than average autumn. March was a generally warm month overall, although not exceptionally so, and this warmth continued into early April with several sites (including Hobart) experiencing their highest April temperature on record on the 1st. Despite a cooler period during late April and early May, the middle of May saw temperatures again increase as a high pressure system settled over the Tasman Sea, directing a warm northwesterly flow across the State. In particular, 15 May was especially warm about the southeast, with several sites (including Hobart) experiencing their highest late-season maximum temperatures on record. Campania reached a maximum temperature of 24.1 °C which is the highest maximum temperature on record so late in the season for any Tasmanian site. This prolonged autumn warm spell affected much of Australia (as detailed in *Special Climate Statement 49*).

Autumn rainfall was near average overall, although slightly below average about the southeast coast. A relatively dry start to the year continued in the southeast during March, while the north of the State experienced some moderate rainfalls during the second half of the month. Both April and May rainfall totals were near average in most parts of the state, although below average falls were recorded about the northeast during May.

- Record warm start to April, especially hot on the 1st
- Record late-season warmth during May
- A warm season overall
- Near-average rainfall