

HORT INNOVATION PROJECT PT16000

A REPORT ON THE 2018 SURVEY OF THE AUSTRALIAN POTATO INDUSTRY INVESTIGATING POTATO SEED QUALITY AND HANDLING AND ITS IMPACT ON THE AUSTRALIAN POTATO SUPPLY PIPELINE



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EXTENSION ACTIVITIES FOR THE AUSTRALIAN POTATO INDUSTRY – LITERATURE
REVIEW AND SURVEY 2016/2017 PT16000

THE IMPACT OF POTATO SEED QUALITY AND HANDLING ON POTATO SEED
PRODUCTION, PROCESSING AND FRESH MARKET PRODUCTION

**Hort
Innovation**
Strategic levy investment

**POTATO –
FRESH FUND**

**Hort
Innovation**
Strategic levy investment

**POTATO –
PROCESSING FUND**

The strategic levy investment project Extension Activities for the Australian Potato Industry – Literature Review and Survey 2016/2017 (PT16000) is part of the Hort Innovation Potato – Fresh Fund and Potato – Processing Fund.

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1. EXECUTIVE SUMMARY

Hort Innovation Project PT 16000 reviews the Australian Potato Industry Seed Handling and Seed Quality.

A literature review was completed looking at latest trends and research in Seed Quality. A survey was then completed across the Australian potato supply chain to investigate opportunities to drive sustainable, economic industry improvement.

The Australian Potato industry is geographically diverse, supplying fresh market and processing potatoes. Variety and climate impacts supply continuity and quality. Supply chain customers were surveyed to understand their key success elements that impact the supply chain. Relationships, grower economical sustainability and communication were pivotal to support consumer safety and deliver no surprise quality, with in full on time supply.

The Potato Industry Supply chain is long, 5 to 6 years. Seed quality and handling is business critical for the chain success. Certification, management of quality and physical seed management including cold storage were found to be well controlled compared to research data.

Key elements identified for driving a stronger, efficient and sustainable supply chain are:

Physiological Age Control

Improve understanding of physiological age, timely control of crop maturity, handling and storage. Adopt technology measuring, logging Physiological age (P Age) parameters, field climate, stress, storage temperature and storage environment (CO₂, O₂).

Communication

Increased cross chain communication, in season updates, long term vision to drive best estimate of demand, supply continuity, variety security. This will drive chain efficiency, reduce waste and achieve improved supply performance. Seed certification documentation to carry supplementary seed specification data on P Age factors.

Planting density, Seed Unit Density, Seed Planting Potential

Accurate seed piece size with stem potential to drive accurate stem density. Improve logistics and handling efficiencies by optimizing seed units per ton, industry sharing of a better chain profit. Optimize cut seed to reduce waste and cuts per ton. Use of Physiological age plus nutrition to drive seed tuber set.

Scalability, District Seed Brand Integrity

Identify strategies to build seed grower profitability through scalability initiatives, co-operation, contracted shared services and storage. Communication, extension, development of district grower groups seeking improvement through best practice to score card, quantifying sustainability and district performance.

The strategic levy investment project Extension Activities for the Australian Potato Industry – Literature Review and Survey 2016/2017 (PT16000) is part of the Hort Innovation Potato – Fresh Fund and Potato – Processing Fund.

2. INTRODUCTION

Project PT16000 was commissioned by Hort Innovation to complete a literature search and identify information and research on potato seed handling and quality. A report on the findings of the literature report was submitted to Hort Innovation. This report identified many key elements discussed in a wide range of papers, guidelines and research from researchers, industry leaders and particularly university research and extension groups across Europe, North America and South America.

A survey for Australian growers was developed to focus on the key elements identified in the literature review that addressed seed handling and quality. The topics that were investigated included:

- Irrigation method and time of production (Environment)
- Storage, storage infrastructure, transport and transport distance
- Management and quality control systems including generation
- Seed cutting and seed size
- Physiological Age and plant density

Face to face interviews were used applying a standard script which validated cohort comparison in the survey results. The survey method was effective with growers freely sharing their time and contributing in confidence. Surveys were also distributed personally to growers for them to complete and return in a postage paid envelope. Limited responses were achieved using this channel. Electronic grower surveying was also used to cover more fragmented industry sections.

The following paper summarizes the findings of the survey and identifies opportunities including areas of potential extension. The report is at the national level and maintains grower confidentiality.

Seed potato production is a critical link in the Potato Industry chain of supply. The Potato Industry delivers a perishable raw material to industry participants for conversion and value adding, eventually received by the consumer. The supply chain requires strong efficient linkage to enable sale and generation of value to return sustainable income and profit to the chain.

A focused survey was also completed with key potato grower's customers. This customer survey highlights core critical success platforms that will enhance the Potato supply chain (Seed to Crop) sustainability, efficiency and value to its customers.

Project PT16000 is an investment of industry research funds. This report summarizes conclusions and identifies extension opportunities. It works to establish a pathway forward to delivering improved seed quality and therefore productivity. To grow sustainable efficiency and deliver a positive return on investment for the grower investment.

Improving potato seed quality and handling is part of industry continuous improvement. Continuing investment into research and extension is essential to leverage the rapidly changing landscape of genetic development (variety), smart technology (data measuring and reporting) and satisfy the increasing complexity of consumer demand. The report must be translated into industry value through practical extension and communication.

3. METHODOLOGY

Methodology used in Project PT16000 is set in the initial project brief and submission. This section of the survey report is included to frame up this scope, industry level and the project process. This qualifies the quantified conclusions and findings of the survey report and data included in the following report.

This report reflects the status of approximately 99% of the Australian potato industry by volume in regards to seed quality and handling and its impact on the potato industry supply chain.

3.1 LITERATURE REVIEW

Project PT16000 includes a literature review report into potato seed handling and quality which established a foundation for the subsequent analysis of the Australian potato industry seed handling and quality.

A report was completed as part of Project PT16000 and is included as an Appendix to the project report (Refer Appendix 1 (Philp & O'Brien, The Impact of Potato Seed Quality and Handling on Seed Potato, Processing and Fresh Market Production, A Literature Review, 2017)).

A literature search was actioned on the subject of potato seed quality and handling looking at research and advisory reports, papers, lectures and extension notes. This search included all major world production areas of potatoes including North America/Canada, South America, Europe, Asia and Oceania (Australia). Research searched from 1940's to 2017.

This information summarized in the literature report framing up research and extension of key elements of potato seed handling and quality that influence yield, quality and crop performance. This includes seed handling, seed (physiological) age, storage and seed size, seed cutting.

A summary of the literature search report findings was reported to Hort Innovation SIAP at a meeting in January 2018. A copy of this power point presentation is included as an appendix in the PT16000 project report (refer Appendix 5 Project PT16000 Literature Review Summary a Power Point Presentation to SIAP January 2018) (Philp, 2018).

A survey script was developed to drill down on core elements identified in the literature review. The structure of the survey script aims to investigate the status of the Australian potato industry. This script design is included in Appendix 2 and also in this report (Refer Figure 4. Grower Survey Design Structure and Flow).

3.2 AUSTRALIAN POTATO SUPPLY CHAIN ANALYSIS KEY PERFORMANCE ELEMENTS

PT16000 is a project funded out of grower and industry funds. It is imperative that the project and reports focus on effective outcomes to drive industry success, sustainability and efficiency.

A supply chain model was developed from the survey work identifying general industry structure and linkage (refer Figure 1). This model helps us understand how potato seed handling and quality influences the stakeholders of the Australian potato supply pipeline.

This understanding is used to focus the project report and deliver survey results, conclusions and recommendations and therefore deliver value to the industry and subsequent return on investment.

A short electronic survey was actioned. This included seed, fresh and processing industry sectors and consisted of a sample of 15 cohorts. 6 responded in full.

This survey identified the ranking of the importance of some key supply chain elements. Results of this survey are discussed in Section 4 of the Survey Report (refer Figure 2). These survey results are not weighted by volume of the respondent.

The survey script is included in Project PT16000 report as Appendix 3 (Philp, Project PT16000 Horticulture Innovation Australia Potato Seed Handling and Quality, Understanding The Potato Growers Customers Key Success Factors, 2018).

3.3 AUSTRALIAN POTATO INDUSTRY SURVEY ON POTATO SEED HANDLING AND QUALITY

As per the Project PT16000 brief, a survey of the Australian potato industry was actioned to investigate the status of the Australian industry against the key research findings that affect potato seed quality and handling.

The survey consisted of 14 questions that quantified the industry performance by cohort in the area of seed quality and management. It also analyzed growers' attitude to key management strategy. The script structure and design is shown in Figure 4. Grower Survey Design Structure and Flow.

The survey design was proofed with 3 cohorts to review its functionality and effectiveness prior to rolling out. The script was adjusted to reflect feedback and include detail relating to potato cool storage atmosphere management. The final script version is included in the Project PT16000 final report as Appendix 2.

Survey was then rolled out as a face to face interview with potato industry businesses. Each interview took between 2 to 4 hours. The survey population included all states of Australia that grow significant volumes of potatoes.

Scalability of the survey is measured in tons. The objective was to survey at least 75% of the industry benchmark volume of 1.154 million ton as reported by the Australian Bureau of Statistics, Agricultural Commodities, Australia – 2014-2015 Ref 71210D004_201415.

The survey total volume as reported by cohorts is 1.143 million tons which achieved 99% of the benchmark volume. The survey exceeded its objective volume. This gives the survey a strong foundation for the analysis of trends and opportunities.

Analysis of survey responses is by weighted average of the survey respondents reported volume (Question 2) based on a benchmark volume of 1.154 million tons. This report reflects status of the majority of the Australian Potato Industry regards potato seed quality and handling and its impact across all major sectors of the industry (refer Figure 3).

It is important that volume is used in the results analysis, not grower number. The objective of this survey is to understand the Australian industry performance against the literature review findings. The practice of a seed grower is balanced against the impact of potato crop yielded. Each cohort responses are weighted by a factor calculated by dividing the cohort reported volume by benchmark of 1.154 million tons.

Other survey methods were also tested but are not included in the survey analysis. This data is less controlled and the total volume gathered in the survey method not significant compared to face to face sampling.

A sample of 10 growers were presented with survey documents and invited to complete the survey and mail back their responses. They were briefed on the project background. Only 1 response was received and this was not complete. Electronic survey was also tested using a simpler questionnaire format (refer Appendix 4) (Philp, 2018). A sample of 60 cohorts were sent the survey (including a follow up reminder) with a response of 7 cohorts completing the survey.

Data analysis was achieved through weighted average of the response using an excel spread sheet. All data reported in the survey report is summarized at the Australian industry level. At this level of summary, the method of weighting provides a robust analysis of survey response. Reporting at this level also protects the confidentiality of respondents.

3.4 SURVEY REPORT CONCLUSIONS AND RECOMMENDATIONS

This survey report draws analysis and conclusions from comparing project PT16000 survey responses compared to the literature review findings for the Australian potato industry. This includes using attitude rating and ranking of key management strategy to manage potato seed quality and handling.

From the data analysis and using respondent comments, conclusions and recommendations have been generated and summarized in section 7, Summary Conclusions and Suggested Recommendations of this survey report.

As part of the project reporting a Power Point Summary is also prepared for presentation to SIAP (refer Appendix 6).

This summary and project report use the data and findings from the survey report and should only be taken in the context of the project PT16000. The survey data should not be used for any other purpose.

An executive summary is included in this report as Section 1 Executive Summary.

Recommendations:

1. **Extension and communication of findings to the Australian Potato Industry**
Through media and a series of grower seminars the findings and conclusions are to be communicated to growers across key production areas. This includes Queensland, New South Wales, South Australia, Tasmania, Victoria and Western Australia. This extension is to include understanding of Physiological age, Lean Management and effective communication.
2. **Data communication through Certification Tags employing QR Codes**
Research and communicate with leading seed certification organizations to investigate the use of QR codes and integrate electronic data transmission relating to key seed certification data.
3. **Investigate and Develop Industry adoption of Seed Count Standards Project**
Research and quantify the advantages and disadvantages of using seed count as a quality parameter in the Australian seed potato industry. Adoption of improved seed size uniformity and size specification can drive significant savings but may also influence remuneration for seed.
4. **Potato Seed Physiological management and control project**
Investigate and research seed treatments that influence the growth regulator Luciferase. Luciferase influences change in Absciscic Acid and by influencing the balance of reducing sugars. This can initiate controlled potato seed dormancy break and reduction of apical dominance in potato seed.

4. POTATO SUPPLY CHAIN AND INDUSTRY CUSTOMER NEEDS AND VALUES

This project and its report is not about applied research, rather it presents the current state of practices related to seed quality and handling and points out where this differs from international Best practice.

Practical agricultural application ensures that findings can be translated into real, sustainable applied concepts and knowledge for the whole supply chain.

The report will be successful when it is used as a catalyst for sustainable development and continuous improvement by all stake holders across the potato industry.

The potato grower and potato seed grower can take the report as general information, consider it for their enterprise, and if it fits, test and develop the concepts in their situation.

A supply chain diagram (see Figure 1) frames potato seed fit in supply and demonstrates how the chain linkages can fit. As with any chain, it is the weakest link that drives risk of failure. The chain must connect with the customer's value equation. The ultimate consumer, by buying product from the supply chain, provides income inflow to the supply chain. Chain structure then feeds income and return on investment to the links (stake holders) in the supply chain.

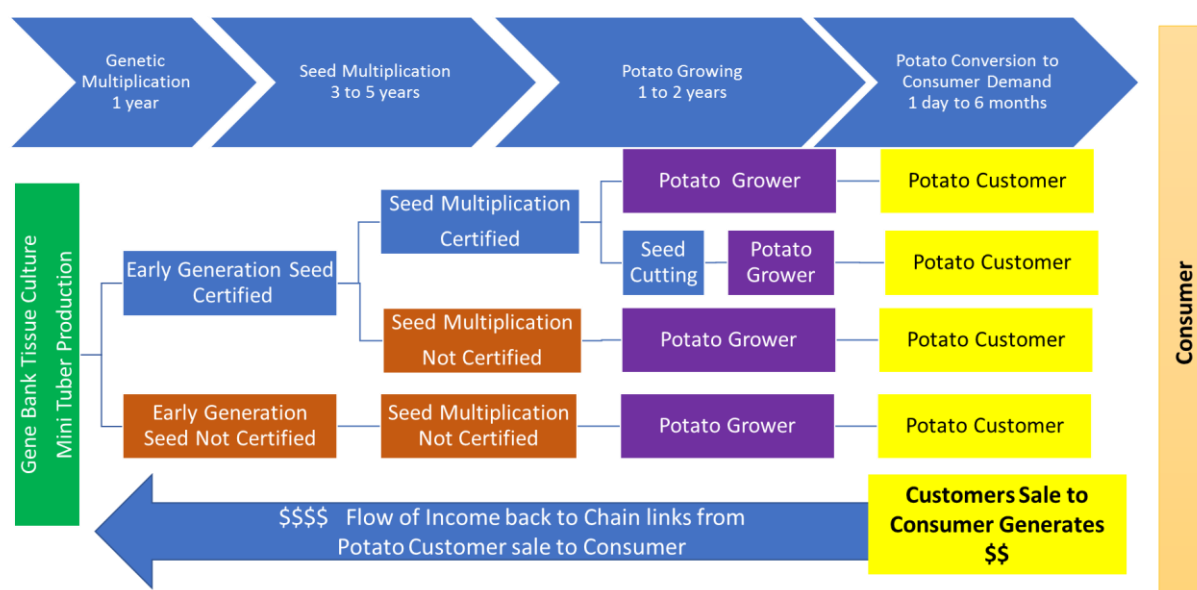


Figure 1. An example of a General Potato Supply Chain Model from Genetic Multiplication to Consumer

Seed quality and handling is a critical component that strengthens the chain.

A short survey (refer Appendix 3) with a group of leading potato growers' customers was designed to frame up some key elements that the supply chain considers important. The survey is general in nature and different sectors of the potato industry will have different needs. The potato grower should consider its customer's needs as part of their competitive advantage in delivering value to their customer.

The response below in Table 1, frames up themes and focus for the report relating to seed, seed handling and quality including:

- Trust
- Supplier / Customer alignment
- Reliability
- Economic quality and service (value)

Survey Participant Responses
Integration, Visibility, Trust
Linkage – Long lead time means should be connection from end user back to seed development
All involved in the Supply chain are aligned and are clear on their role to meet customers' requirements
Continued emphasis on quality and service from start to finish, economically
Reliability of supply

Table 1. Potato Grower Customer Survey Responses, Key Deliverables Needed from the Potato Supply Chain

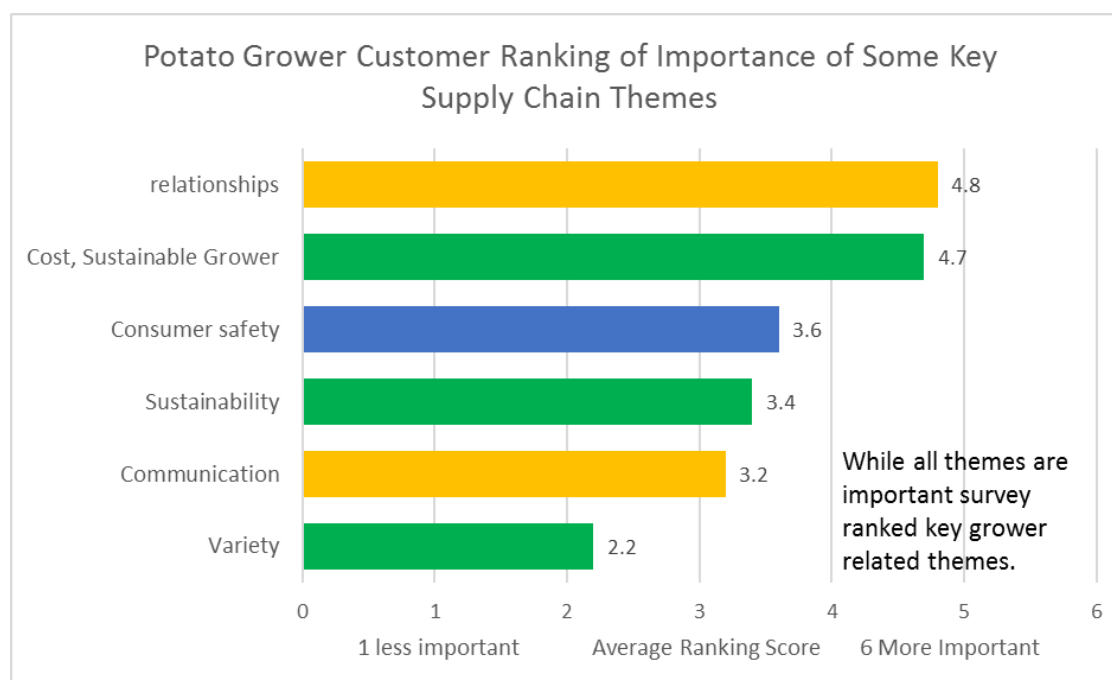


Figure 2. Potato Supply Chain Customers Ranking of Business Themes

5. VALIDATION SURVEY POTATO INDUSTRY COVERAGE AND ITS SCALABILITY

The survey was designed to investigate trends in potato seed and handling compared back to the findings of the literature survey. The project required that the survey be scalable to the industry and reflect the total industry.

Scalability and industry coverage of 99% was achieved against the survey benchmark#.

Respondents were asked to indicate an estimate of potato volume by crop use type in the survey. Total volume of 1.114 million tons was achieved (Figure 3). A benchmark of 1.155 million tons of potato production is used in the survey report (#Source Australian Bureau of Statistics, Agricultural Commodities, Australia – 2014-2015 Ref 71210D004_201415).

Crop use, processing or fresh, has variation in variety (genetics) and specifications of the product (size and solids). It was important that the survey covers this industry mix.

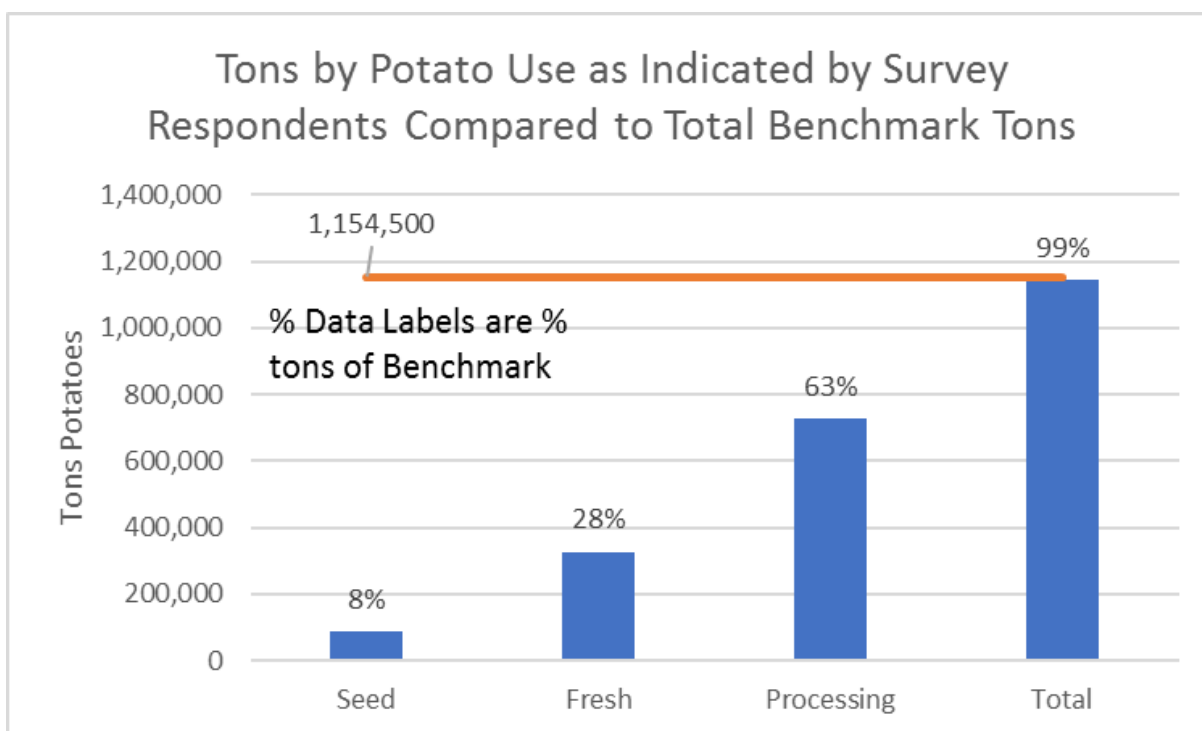


Figure 3. Tons by Potato Use as Indicated by Survey Respondents Compared to Total Benchmark Tons

This survey is not quantifying industry volume or volume of sectors. It is focused on trends in seed handling and quality. The volumes and sector splits are estimates only as indicated by survey respondents.

The survey covered New South Wales, Queensland, South Australia, Tasmania, Victoria and Western Australia being states where significant potato production is carried out. Survey activity was weighted to sector volume and volume by state applying the Pareto Principle (80:20 Rule).

6. SURVEY FINDINGS FOCUSING ON CRITICAL SEED HANDLING AND QUALITY FACTORS

This report summarizes potato and seed potato growers' responses to the survey that was structured to investigate the findings of Project PT 16000 Literature Search. Survey design development is summarized in Figure 4 below.

This document's focus also considers the importance of elements reported by the supply chain customer survey.

This delivers the key learnings for the Potato Grower and Potato Seed Grower to understand and consider as general information. Taking the learnings, the grower needs to consider their management, farm structure, dimension, location and supply chain fit.

Extension of report findings and grower group discussions will enhance the value of this report as a catalyst for:

- industry continuous improvement
- sustainability and
- profitability



Figure 4. Grower Survey Design Structure and Flow

6.1 ENVIRONMENT AND ITS IMPACT ON SEED QUALITY

6.1.1 IRRIGATION TYPE, GROUND STORAGE AND CLIMATE

6.1.1.1 IRRIGATION

Irrigation type reflected the environment (geographic location) and precipitation pattern during the crop growing cycle. Centre Pivot was the most frequent type of irrigation (68%) with gun irrigation (20%) being the second most frequent method of irrigation. Lateral irrigation (4%) was considered less reliable than Centre Pivot and was adopted where paddock shape and land value made this type of irrigation more efficient.

Centre Pivots with variable application and paddock mapping (soil type and porosity) was best developed in Tasmania.

Semi-permanent 2% (movable irrigation pipes) and permanent irrigation (1%) was less important but more widely used in seed production.

6.1.1.2 GROUND STORAGE

Survey respondents indicated 18% of total survey population used ground storage. Ground storage varied depending on soil type, climate and time of production. Ground storage is defined in the survey as where crop harvest was deferred for more than 6 weeks post haulm destruction or crop senescence. Some seed growers used ground storage to reduce harvester capacity need, processing and grading capacity. Ground storage increases potential physiological age and can increase the risk of loss of seed quality.

6.1.2 GROWING WINDOW, SEED TRANSPORT AND CLIMATE

6.1.2.1 GROWING WINDOW AND CLIMATE

Most potato crops are grown to best fit climate and environment. There are production areas that extend growing of crop to fit customer demand and maintain continuity of supply. Cold storage is also used to extend the window of supply and hold quality of the potato supply.

Crop planting timing and co-ordination of quality seed with the correct Physiological Age is critical for controlled apical dominance, crop emergence and stem density. The alignment of seed supply with a geographic location that suits the planting window is further managed with cold storage.

Generally, crop production and seed supply for crops, where storage is used, have less time pressure (for example French Fry production in Southern Australia).

Crop production for fresh market or other processing uses (for example crisps) where finished product storage is less flexible for maintaining quality. They must have continuity of supply and control quality constraints for the end crop.

Table 2. Key Learnings Growing Window and Climate

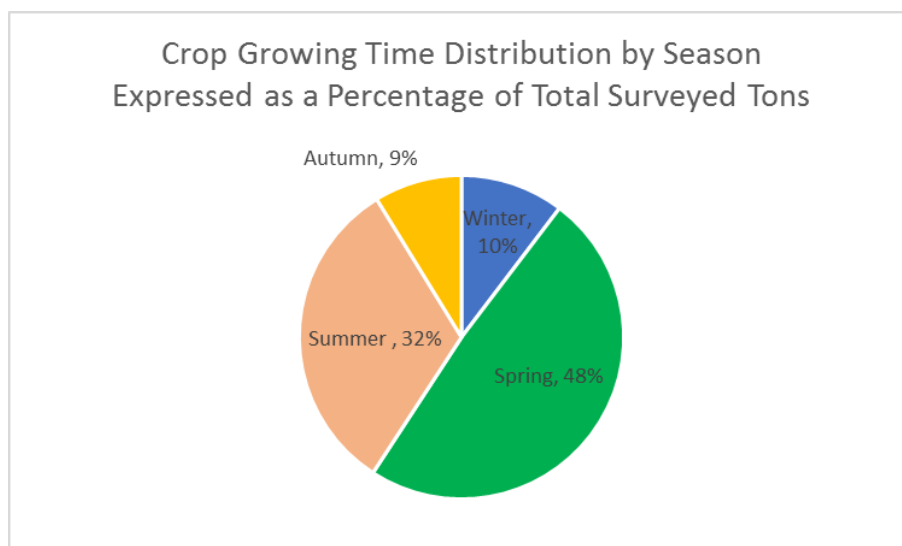


Figure 5. Survey Response Summarizing Crop Growing Season as a Percentage of Tons Harvested

6.1.2.2 SEED QUALITY, TRANSPORT DISTANCE FOR SEED, GROWING WINDOW AND CLIMATE

Transport distance and impact on seed quality is related to time of transport and ambient temperature. All seed is transported in non-refrigerated trucks either as bulk, 1 T wooden bins or 1.2 T Polypropylene Bulk Bags.

Bulk transport is used to improve efficiency of transport as 1 T bins presents a dead weight transport cost.

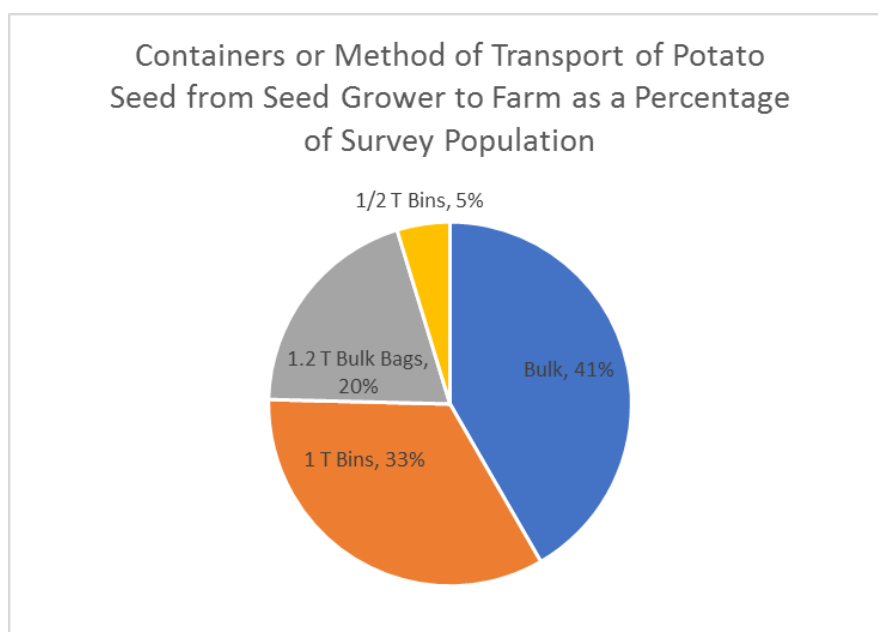


Figure 6. Seed Transport Containers used between Seed Grower and Farm

Surveyed growers preferred bulk or bins as it holds seed quality better than 1.2 T Bags. Bulk bags can cause skin abrasion (scuffing) which can drive physiological aging. Scuffing and sweating of the seed can also lead to seed break down.

Geographic location, distance from seed production to farm drives the use of 1.2 T Bulk Bags, optimizing freight cost and avoiding back loading of bins. Conversely the greater travel distance increases risk of seed breakdown and loss of quality in transit.

71% of seed is grown off farm and requires transport
 58% of seed is transported by soft-sided tautliners or flat top trucks
 41% of seed is transported as bulk either tippers or moving floor bulk trailers
 89% of seed is transported less than 500 Kilometers
 No refrigeration is used in seed transport

Table 3. Key Learnings Seed Transport

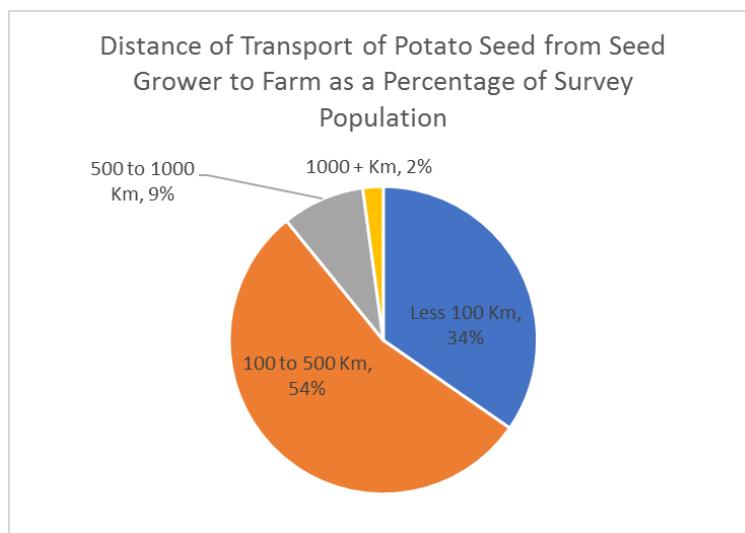


Figure 7. Distance of Transport of Potato Seed as a Percentage of Survey Population

One grower surveyed said that the transport (500 km) in a secure un-tarped truck was an advantage in helping age spring grown seed and accelerate dormancy break for autumn plant.

Risk mitigation is used to justify long haul for a percentage of seed. Geographic diversity spreads the risk but at an additional freight cost. The efficiency of the seed production location and mini tuber multiplication helps support the use of more remote seed production locations such as Kangaroo Island and southern Western Australia.

Freight cost and seed handling costs are a key consideration in seed production. Tasmania has geographic diversity in a small area through topographical structure. This allows efficient seed production while ensuring adequate segregation of production zones.

6.2 CERTIFICATION, PHYSICAL SEED QUALITY, VIRUS AND DISEASE PROFILE

Potato seed quality is a critical success factor for a strong supply chain, efficient sustainable potato production, reliable timely supply and profitability for stakeholders in the supply chain. The survey investigated how the potato industry saw quality, management of quality and the generation status of the crop.

Seed quality is measured in the certification process and is part of the condition of sale (contract) and directly influences price and demand. The certification or quality assessment can either be managed by an independent trained and accredited auditor or own management. Own management is often used to internalize seed production and reduce seed cost.

The following quality parameters form part of the quality matrix, fecundity and performance of seed:

- Seed size (measured in millimeters through a square ring)
- Physical quality and damage (a visual measurement expressed as percent defect)
- Disease or rots that are visual
- Viruses and Diseases not visual
- Physiological age allowing stable storage, timely breaking of dormancy to fit production plan
- Genetic purity, single variety, no contamination
- Generation status, Physical seed quality, virus and disease is currently managed through independent certification or grower own management

6.2.1 CERTIFICATION AND SELF MANAGEMENT OF POTATO SEED QUALITY

Seed pipeline management balances production cost, disease and virus levels to deliver quality assured seed fit for purpose. Certification involves the application of quality standards and compliance to production protocol that is enforced through crop inspections, sampling and assessment at grading by trained and qualified inspectors.

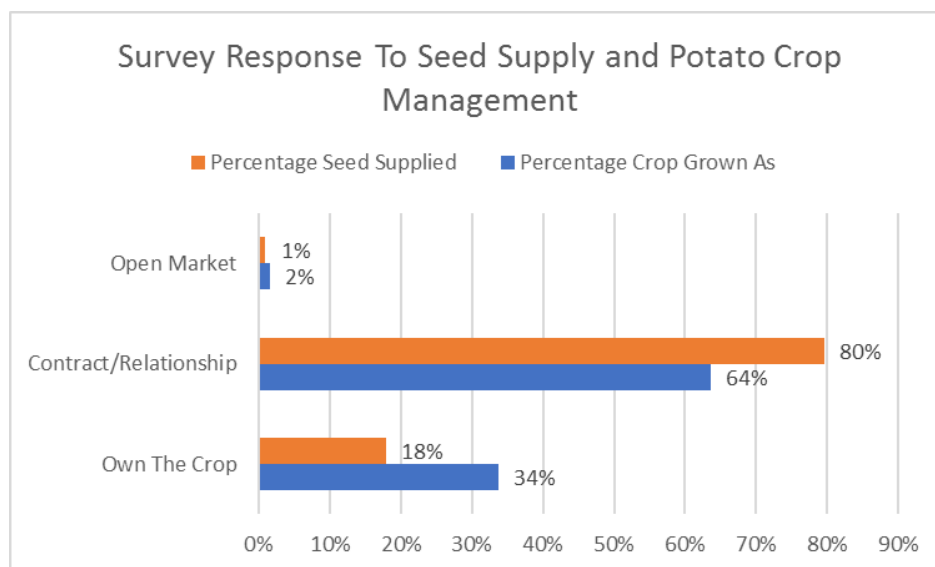


Figure 8. Survey Response Showing Relationship of Own Crop, Contract or Open Market

Overall potato seed and potato production is either directly controlled by the grower or is managed by contract or long-term relationship (verbal contract). Very little open market activity was reported.

Potato production has a significant lead time as shown in the potato supply chain diagram (refer Figure 1). Owning the pipeline, having a strong relationship through formal contract or long-term relationships (informal contract) was regarded as very important (refer Figure 8).

6.2.1.1 POTATO INDUSTRY CERTIFICATION AND INDUSTRY GENERATION PROFILE

Where potato seed passes certification, the parcel of seed receives a controlled certificate stating compliance, date of burn down, variety and generation. The certification cost is approximately \$25/T (Source VicSpa Feb 2018). Certification is often a requirement of seed sale and compliance to biosecurity regulations for transport of potatoes between States.

Some growers choose to internalize the quality assurance of potato seed and not certify seed. This is aimed to reduce cost of production. These grower's need to have sound internal quality protocols and controls to consistently deliver the quality of seed.

72% of Potato Seed planted is Certified
45% of Potato Seed planted is planted as G3 or less

Table 4. Key Learnings Australian Potato Seed Certification, Planting Generation Profile

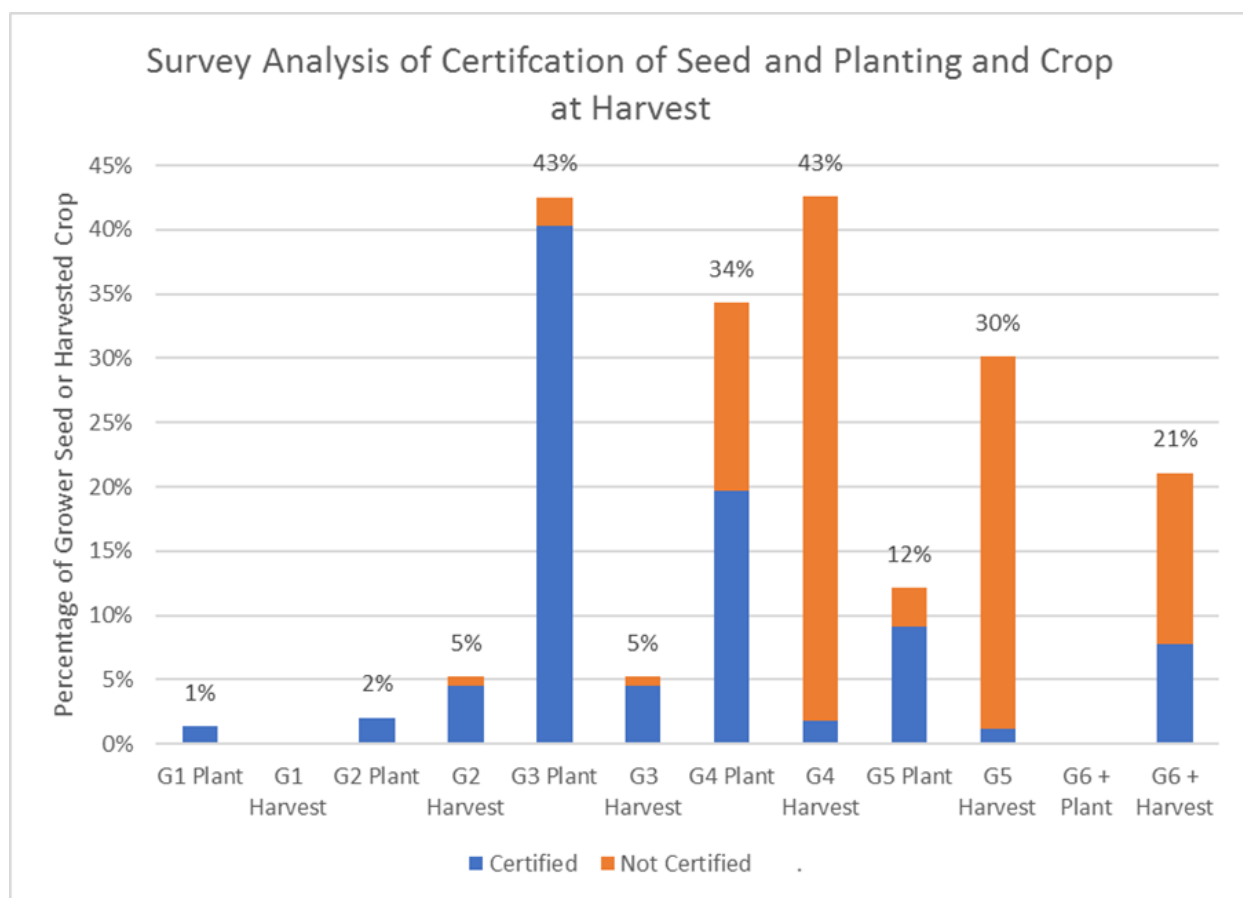


Figure 9. Graph Showing Certification Profile by Generation of Seed at Planting, Generation at Harvest

Some potato growers “bulk up seed”. Early generation seed with an elite quality standard (Black label 0.2% Virus level) is purchased. This seed is then multiplied (grown and harvested as seed) for one (1) generation, before being planted for a commercial crop. While lower generation potato seed may have a higher cost, the grower internalizes some of the cost of production and reduces freight costs.

The survey showed that over 70% of potato seed planted is certified while 20% of seed is managed internally.

6.2.1.2 POTATO SEED CROP INSPECTION AND COMMUNICATION WITH THE SEED GROWER

Seed quality and crop establishment performance was identified as a key success factor in the literature review. While still using independent certification to quantify quality, many potato growers visually inspect the seed crops during the seed crop’s growing phase or while the harvested seed is being graded to better understand seed quality.

Many potato growers have formal contracts with the seed suppliers (grower). This frames up quality, price and delivery timing. Timely delivery is important to achieve management of physiological age.

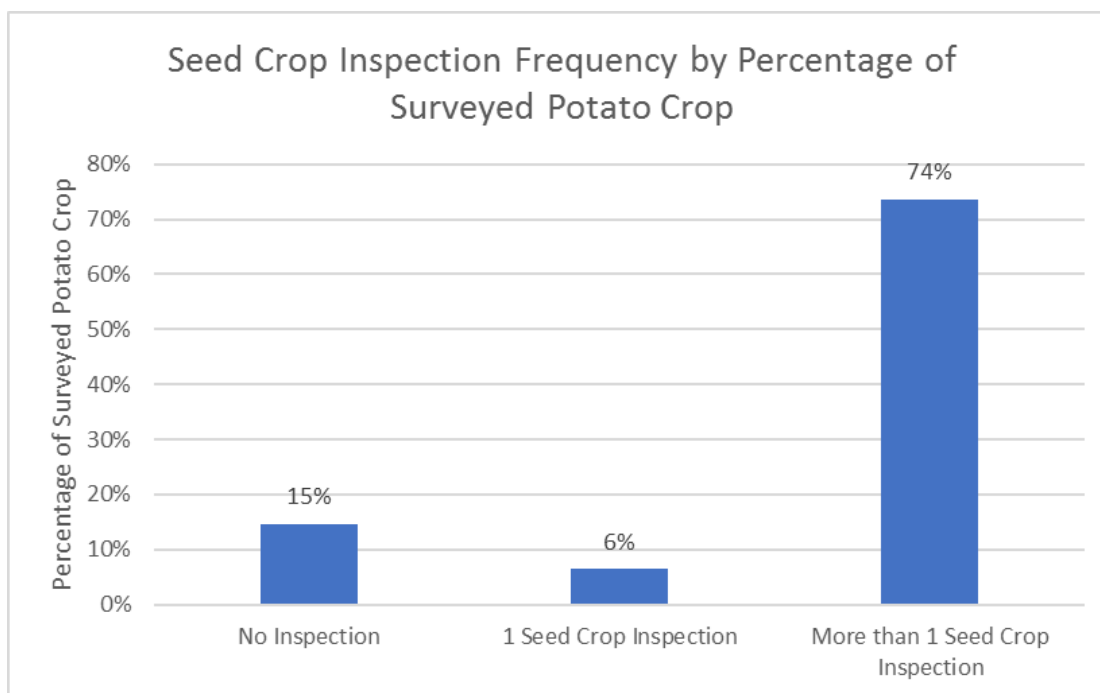


Figure 10. Frequency of Seed Crop Inspection during the Growing of the Seed Crop

Communication between the seed grower and the potato grower helps improve the understanding between the businesses in:

- production plans
- long term direction of variety demand
- feedback on quality

This allows the seed grower to better manage their enterprise to deliver their customers’ expectations and strengthen the supply chain.

80% of potato grower's (by volume) visit their Seed grower and inspect the growing seed crops for that year at least one time

Grower's commented that inspection of the seed crop (that generates seed for the next commercial crop) at least once during its growing is a **Critical Management task**

Table 5. Key Learnings Frequency of Seed Crop Inspection

6.2.2 SURVEY OF PHYSICAL SEED QUALITY, DISEASE AND VIRUS MANAGEMENT

Potato physical seed quality and freedom from virus and disease is critical for efficient sustainable potato production.

Certification of seed helps the delivery of quality seed to meet potato grower requirements. In section 6.2.1.1, it was identified that over 70% of crops planted use certified seed.

Generation is the quantification of the number of times a crop is planted and then harvested for seed. The Australian industry refers to this as Generation or G "x". The lower the generation the fewer times the crop is grown from its primary multiplication as meristem reproduction in agar. This is the "tissue culture" in a controlled environment. Controls and quality assurance in the tissue culture procedure ensures clean, disease and virus free plantlets are generated for seed production.

The fewer reproduction cycles (lower generation) or multiplications means lower generation seed has a higher cost. The improved crop performance from lower generation seed may offset seed cost. This is being assessed by potato growers with some sections of the industry using G3 planting material to drive crop efficiency and sustainability.

The generation profile, identified in the survey, is discussed in section 6.2.1.1 (refer Figure 9).

6.2.3 PROFILE OF PHYSICAL POTATO SEED CROP QUALITY AND VIRUS – ITS MANAGEMENT

Physical quality including bruise, break down and cracking impacts seed performance and risk of break down. The industry uses seed certification as a method to quantify seed quality. Using certified seed standards, the industry was surveyed to understand how the industry saw seed quality.

Red label certified seed has less than 5% physical defect and less than 2% virus. The following analysis uses this standard as a benchmark for all seed, both certified and grower managed as shown in Figure 12. Virus is often does not show a visual symptom in the seed potato. Virus can significantly affect potato crop yield and quality that can ultimately impact the supply chain customer. Virus is managed by production of seed in areas with low virus vector populations and geographic separation from main crops.

Virus loading in the crop is also managed through shortening the number of generations between meristem culture and crop harvest. In section 6.2.1.1, the weighted average of the Australian Potato industry generation profile is discussed. Survey results show crop age by generation as a percentage of certified crop by planted generation and harvested generation in Figure 9.

97% of surveyed volume report virus levels at less than 2% ... Well Controlled
72% of surveyed volume report physical damage as less than 5%

Table 6. Key Learnings **Physical Quality and Virus**

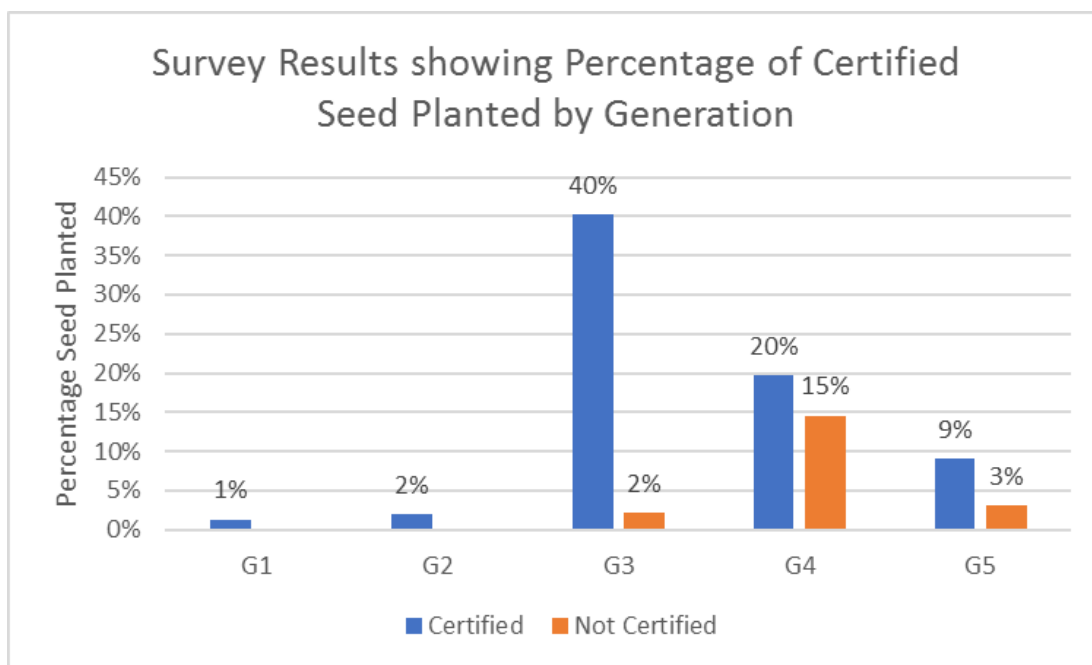


Figure 11. Survey Results showing Percentage Planted Seed by Generation Compared to Not Certified

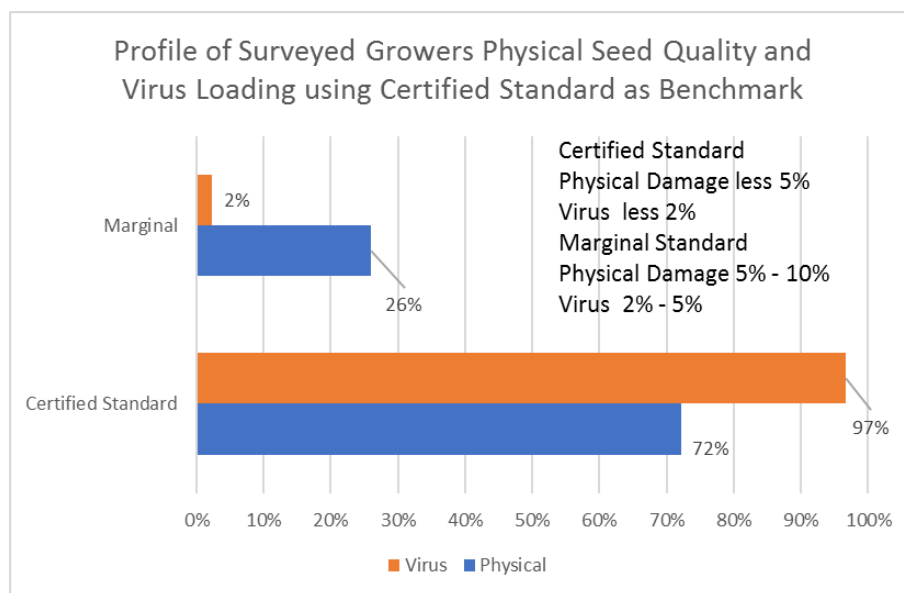


Figure 11 shows the trend of certification of early planted generations reflecting grower management of virus risk.

The survey also asked growers to estimate the percentages of seed that meet certified standard. For simplifying discussion, the data was grouped to reflect certified quality and marginal quality (see Figure 12). Marginal quality reflected a higher acceptance of physical defect compared to virus.

Figure 12. Surveyed Seed Quality Profile of Physical Damage and Virus

6.3 POTATO SEED SIZE AND GRADING STRATEGY, CUT SEED OR WHOLE ROUND

The literature survey identified that seed size was important in driving crop performance and yield. Seed size or seed piece size demonstrated a direct relationship to yield. Variety also influenced the optimum size range as well.

The survey probed Australian grower practice regarding seed size and seed cutting strategy.

Seed cutting strategy decisions are complex and includes consideration of the following factors:

- Seed shape and size and suitability for planting
- Seed cost
- Seed physiological age
- Weather conditions and risk of seed break down

Use of whole round seed is widely used where planting conditions may present risk of seed piece break down and where varieties tend to be round or oblong round.

Seed purchase and payment is driven by weight (price is \$ per Ton). Seed size and ultimately the planting area potential of the seed parcel is a critical value driver of seed. Grading of seed allows the seed grower to add value. This ensures product delivered meets the buyer's expectation and contract conditions.

6.3.1 WHOLE ROUND SEED VERSUS CUT SEED

Cutting seed does not increase seed growing points (eyes) per ton or planting potential based on eye number.

Cutting seed does allow piece size and shape management. This can influence apical dominance or physiological age of the seed planting potential.

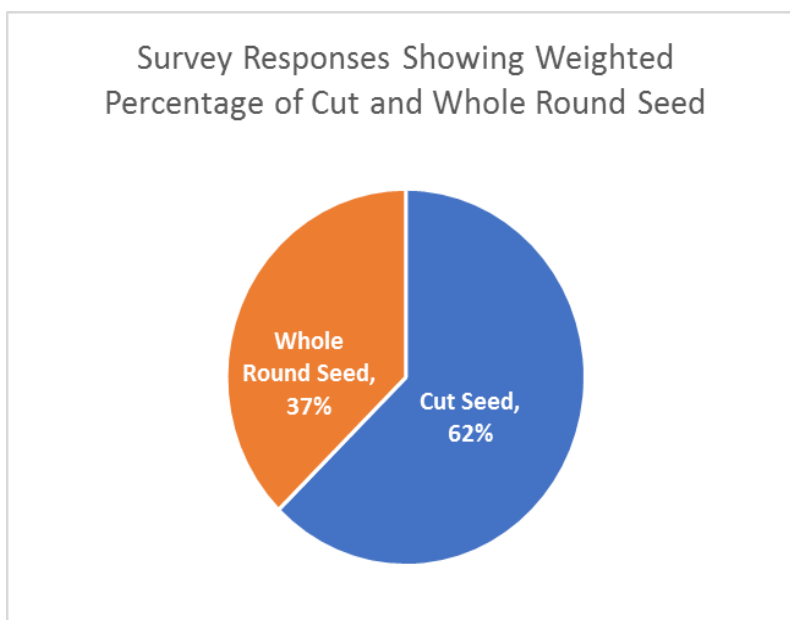


Figure 13. Survey Response Showing Percentage Whole Seed Versus Cut Seed

Cutting of seed breaks the periderm (skin) and increases risk of diseases or virus transmission. This can significantly increase infection rates in the planted crop. Adequate suberization of cut surfaces is required to reduce risk of seed piece break down. The suberization process elevates the tuber metabolic rate, temperature, oxygen demand and can impact Physiological age.

Cutting of seed is an added cost and labour sink and results in wastage. Rate of wastage is impacted by seed size, grading accuracy and cutting machine technology.

The survey indicated that average waste of cut seed was 6.4%.

Using a nominal value of \$750/T cut seed therefore costs \$48/T in waste. The seed planting units after waste therefore have a real cost of \$798/T (\$750+\$48) before labour or other cutting costs.

Variety selection and tuber shape reflects use of the potato. French fry prefers long cylindrical tubers compared to crisps using a round tuber. Seed shape reflects this genetic trait. Seed grading and cutting is used to generate seed piece shape and size to enable efficient planting.

Plant density and planter performance are considered critical elements in achieving yield and tubers that meet preferred size and weight. The Tasmanian potato industry has developed a specialized step in the supply chain to grade, cut and condition seed to meet optimum variety, crop and location needs.

Variety trait impacts the number of eyes per seed tuber and eye location. Cutting of seed and seed piece size needs to address this trait by using seed tuber size, number of cuts and the arrangement of cuts. Each cut seed piece must have an eye. Tasmania uses quality control to measure and deliver seed piece to specification to control seed piece potential. Each batch of seed's quality and size profile is documented. This enables very accurate seed placement and improved control of plant density.

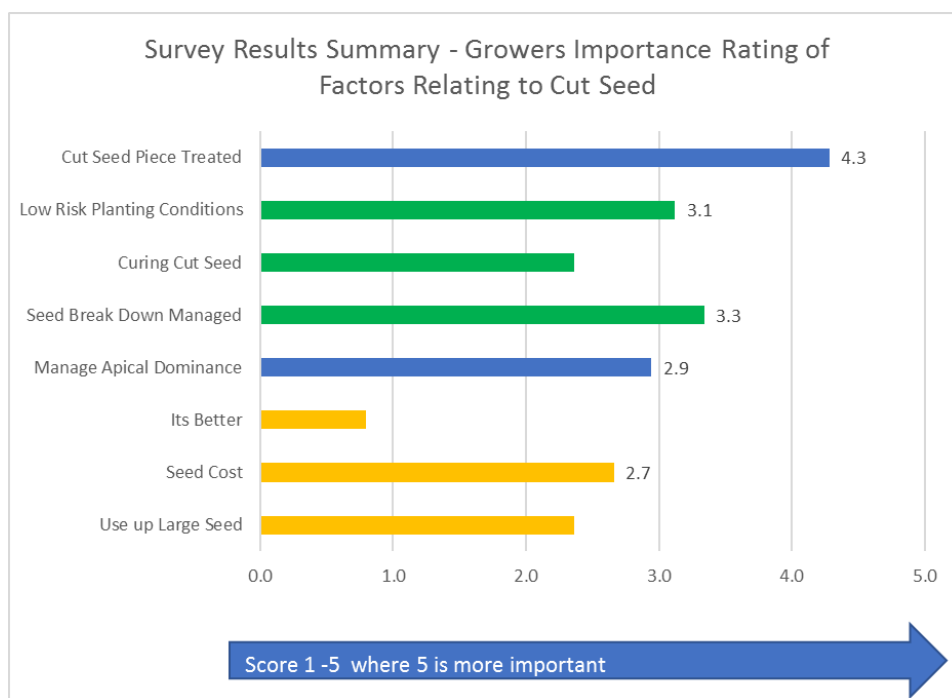
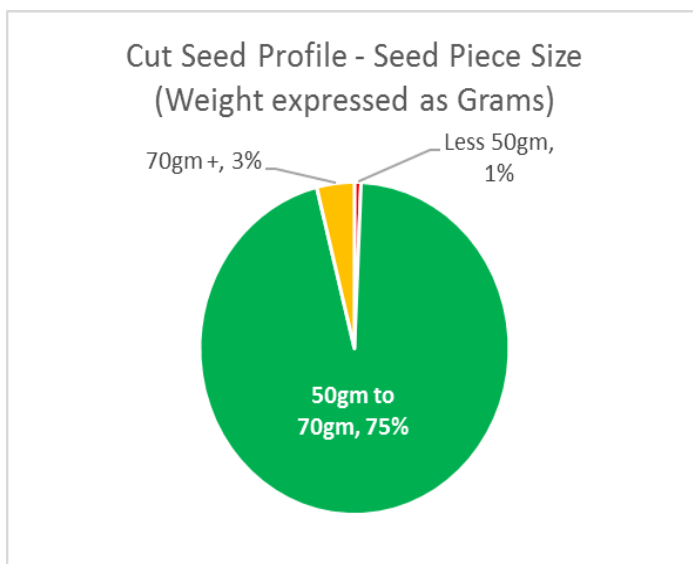


Figure 14. Grower Rating of the Importance of Factors Relating to Cut Seed

Grower use of seed treatments to aid suberization and reduce seed piece rejoining was considered important. Cut seed gives less flexibility and requires more attention to detail at planting. Management of apical dominance rated more important than seed cost reduction.

Some seed growers also commented that they cut large, unsaleable seed and planted it for their own use. This salvaged resources and reduced cost.



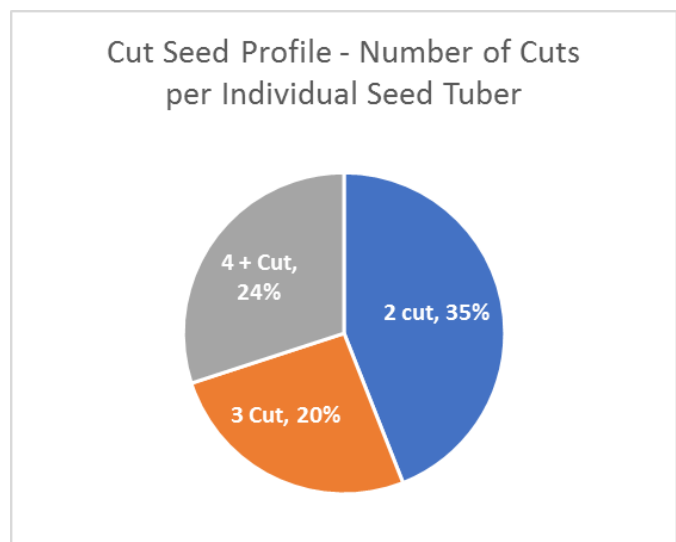
The seed cutting process management is more controlled in segments of the processing potato industry. This control reflects the tuber shape of varieties used and the need to generate a seed piece size profile that improves planter performance.

Crisping and fresh market industry segments reported less cuts per seed with less quality control on the cut piece size. They often used visual assessment going for a “blocky” shaped seed piece.

Tasmanian seed production was clearly the best practice in managing seed cutting quality and delivering graded, consistent seed piece size profile and removal of blind seed pieces.

Figure 15. Cut Seed Profile – Number of Cuts per Seed Tuber

Cut seed piece weight was identified in the literature review as critical. It impacts yield and plant performance. Optimum seed piece weight varied with variety but the suggested range was 50gm to 70gm. The majority of respondents (75% by weighted Average) identified 50gm to 70gm was the seed unit size range targeted.



Growers using mainly whole round seed have less management focus on cut seed size due to variety shape requiring less cutting.

Growers using whole round seed often only cut seed greater than 65mm. This uses the seed and reduces planter issues. Cut seed is used during the season when weather and soil conditions presented lower risk for seed piece break down. Some growers mix cut seed and whole round seed to mitigate a planting failure due to cut seed break down.

Figure 16. Cut Seed Profile - Seed Piece Weight

Growers seldom cut seed to influence physiological age. However, some processing varieties tend to be apical dominant so cutting did provide improved seed performance on early planted seed.

Scalability of cutting operations clearly gave benefits in:

- Cost (cutting rates tons per hour)
- Accuracy of cutting with pre-grading and batching
- Evenness of seed lots and segregation of seed lots
- Hygiene and sanitation as standard operating procedure
- Blade maintenance (sharpness)
- Visual inspection post cutting (volume cut per hour allows cost defrayed across seed)
- Curing and cold storage facilities
- Quantified batch reports with seed piece counts
- Management control of quality and volume (ensuring right seed, right paddock, right volume to cover planting area)

Seed piece control through average counts per weight drives accurate planting, reducing waste. Seed piece treatment and weather condition risk are critical good planting management. Aged seed should never be cut. Seed wastage, labour is offset by improved planter efficiency, planter accuracy = plant density management. Variety is main driver for using cut seed.

Table 7. Key Learnings Cut Seed V's Round Seed

6.3.2 POTATO SEED GRADING AND SEED SIZING

Fundamental agronomic rules of potato production do not meet current potato seed sales practice.

1. Potato seed is transacted and priced as \$ per ton
2. Potato seed units are planted by count per square metre
3. Potato seed set per square metre tends to be a constant, driven by variety and stem count
4. Yield is driven by average tuber weight
5. Return on investment is driven by price, by yield

(A) Seed Growers Return \$/Ha ≠ (B) Seed Customers Value \$/Planted Ha

(A) Seed growers return \$/Ha = Seed Marketable Yield T/Hectare × Price \$/Ton

(B) Seed customers Value \$/Ha = Cost per Seed Unit (Seed Price \$/T ÷ Seed Count/T) × Seed units/Ha

Equation 1. Traditional Seed Grower's Supply Chain Value Equation

The literature review identified that optimum seed size varied with variety. Seed size was critical for yield and the first 40 days of crop performance.

Planter accuracy improved where seed is graded into similar sizes. Seed shape increases the importance of seed grading. Oblong round seed does not “flow” as well as round seed and is more size sensitive.

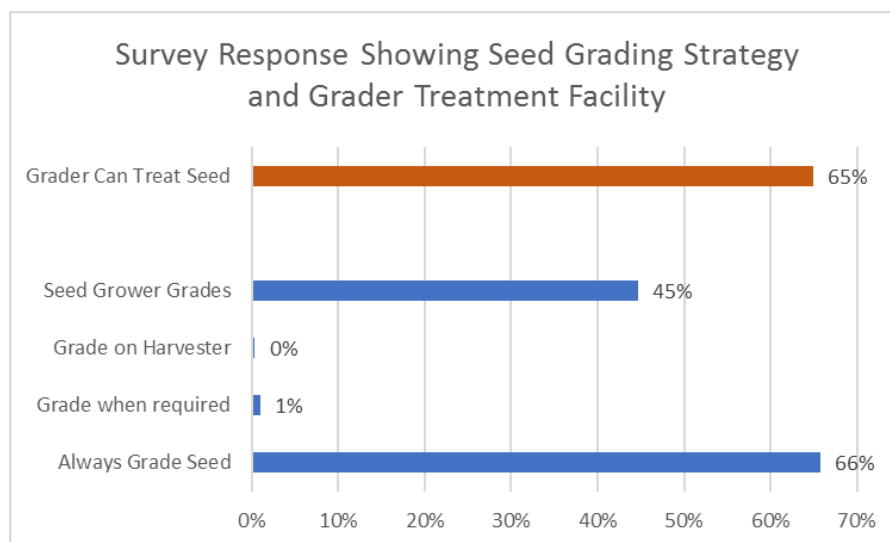


Figure 17. Survey Response Showing Percentage of Seed Graded, Seed Treatment Capability

The survey shows that most seed is graded (66%), with 45% graded by the Seed Grower. Some potato grower's grade on receipt prior to cold storage as the seed is handled at this point to decant from bulk or 1.2T bulk bags.

The application of seed treatments is only possible for 65% of seed graded.

Most seed is sold (64%) graded from 35mm to 70mm size range, while some seed is split graded, 35mm to 50mm or 50mm to 70mm. Planting equipment accuracy is often challenged by seed greater than 70mm. Seed greater than 70mm has a low sales value. While it can be cut, it often becomes waste at the seed growers cost.

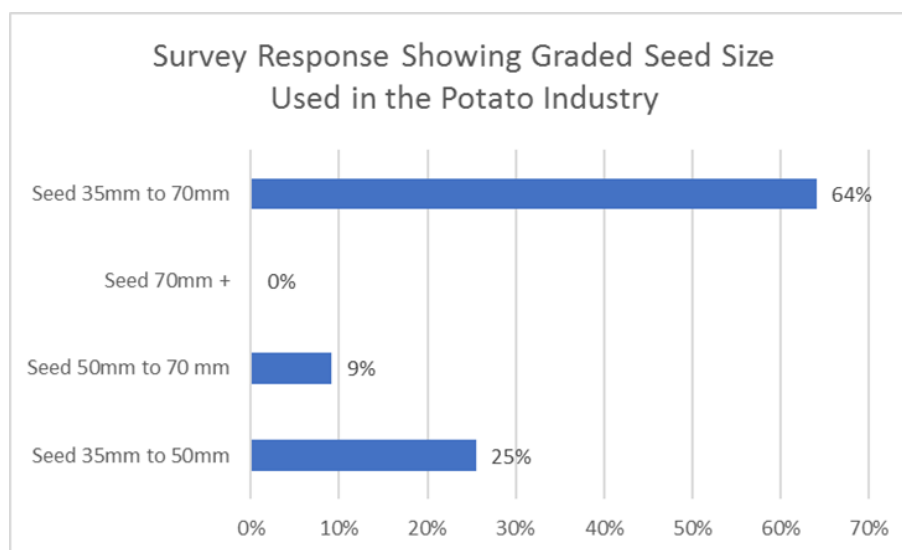


Figure 18. Survey Response showing Graded Seed Sizing by Percentage

Grower feedback highlighted variability of the planting potential of graded seed. Seed may comply to contract standard and certified standard but the seed count per 10kg can vary significantly. Seed count is the key driver to the planted area per ton of seed (refer section 6.3.3).

$$(D) \text{ Seed Coverage T/Ha} = (E) \text{ Seed Unit Count /Ha} \div (F) \text{ Seed Unit Count/Ton}$$

- (D) Seed Coverage T of Seed/Ha = Tons of seed units required per Ha at given planting density
 (E) Seed Unit Count/Ha = Number of seed units per linear row M ÷ row spacing M x 10,000
 (F) Seed Unit Count/T = Average number seed units per 10 kg x 100

Equation 2. Calculating Tons of Seed Required Per Hectare for Planned Plant Density

$$(G) \text{ Planted Seed Cost \$ /Ha} = (H) \text{ Seed Coverage T /Ha} \times (I) \text{ Graded Seed Cost \$ /Ton}$$

- (G) Planted Seed Cost \$/Ha = Average Seed Cost (after grading) per Ha at planned plant density
 (H) Seed Coverage T of Seed/Ha = Tons of seed units required per Ha at given planting density
 (I) Graded Seed Cost \$/T = Average Seed Cost \$/T x (1+% Waste)

Equation 3. Cost of Planted Seed per Hectare Using Seed Coverage to Planned Density

Planted Seed cost per Hectare is driven by seed unit cost per ton.
Seed buyers report varying “boldness” of graded seed and this can create surprises at planting.
Planting hectare coverage directly related to Seed unit count per Ton (also expressed as Count per 10kg).
Seed Grower Return is driven by seed yield per Ha not the customer planted area and seed value per Ha.

Table 8. Key Learnings Seed Value v's Seed Price

Note:

Seed planting potential is also directly influenced by seed fecundity and its physiological age (refer Section 6.5).

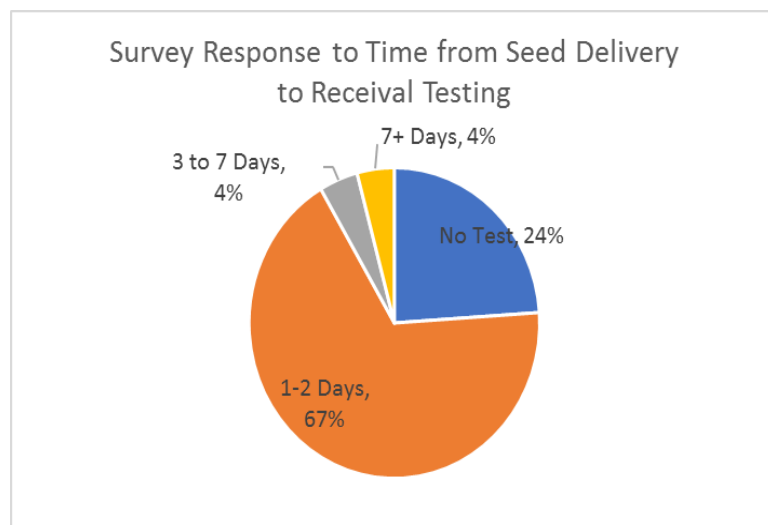
A quote from a leading Seed purchaser....“at the end of the day I buy viable eyes per Ton”

6.3.3 POTATO SEED RECEIVAL AND QUALITY ASSESSMENT CONFIRMATION

Quality assurance of seed lots meeting standards and compliance to contract terms and conditions (formal or informal), is a fundamental management tool that builds sustainable crops. This delivers customer expectations.

At transfer of ownership or management responsibility (internal transfer from seed production to commercial production) seed needs to meet the agreed quality parameters. The sooner seed quality or volume variance is identified in the chain of supply and communicated the better. Impact can be better managed.....No Surprises.

The survey probed the quality assurance process to understand the industry position when reporting variance on seed quality and volume. In section 6.2.1.2, communication and grower site visits were reported. 74% of seed buyers inspected seed more than once (refer Figure 10). Seed is a critical building block for continuity of customer supply. Attention to detail is considered important and justifies investment in frequency of inspection.



The survey reports that 24% of industry seed volume is not tested on receival and relies on the seed grower delivering seed to specification and the certification process. Inspection was completed on 67% of industry seed volume.

Some larger growers with scalability have resources allocated to inspect and test seed on delivery. Should seed not comply to specification when tested the seed load is rejected and returned to the seed grower without unloading. Figure 19 shows time between delivery and seed inspection or testing.

Figure 19. Survey Response Looking at Incoming Seed Quality Testing

In section 6.3.3.1, the importance of seed unit count per ton is discussed. The survey also investigated tuber temperature assessment discussed in section 6.3.3.2. Tuber temperature can influence physiological age and risk of tuber damage during handling.

6.3.3.1 POTATO SEED QUANTIFICATION OF SEED UNIT COUNT (TUBER COUNT)

Delivery of seed can be up to 6 months before planting. Identifying seed unit volume (T) and quality at receival and before cool storage is critical to ensure the planned planting area can be achieved at planting. In the past, potato growers would run with a surplus seed volume to cover planned plantings. However, increasing production cost, seed cost and PBR/Variety management are placing pressure on growers to manage cash flow and margin. This results in less buffer. Growers only plant crops with a firm contract or a firm market.

Seed in grade specification may be “bold” in size profile. That is, seed in the size range of 40mm to 70mm has a greater percentage of seed between 50mm to 60mm. This type of size variance can impact planted area covered per ton by 5% to 10%. A grower offered a practical example where normal planting rate moved from 3.0T/Ha to 3.7T/Ha resulting in an additional 7.0T of seed to plant a 10Ha parcel.

16% of the Survey volume did not complete any tuber count assessment or relied on graded seed sizing (refer Figure 20). 83% of volume indicates a formal quality assessment, however, some of these respondents only completed a visual inspection. This was a quick check that seed visually met the certified label conditions, size range complying to the seed specification ordered. Where the seed lot was visually ‘bold’, they would complete a quantified test.

Best Practice on Seed Receival and Assessment

- A. Agreed quality specifications, variety, volume**
- B. Prompt assessment of delivery to confirm meets A above**
- C. Immediately communicate with supplier if it does not meet A above – Quantify miss**

Table 9. Key Learnings Seed Quality Assessment and Communication

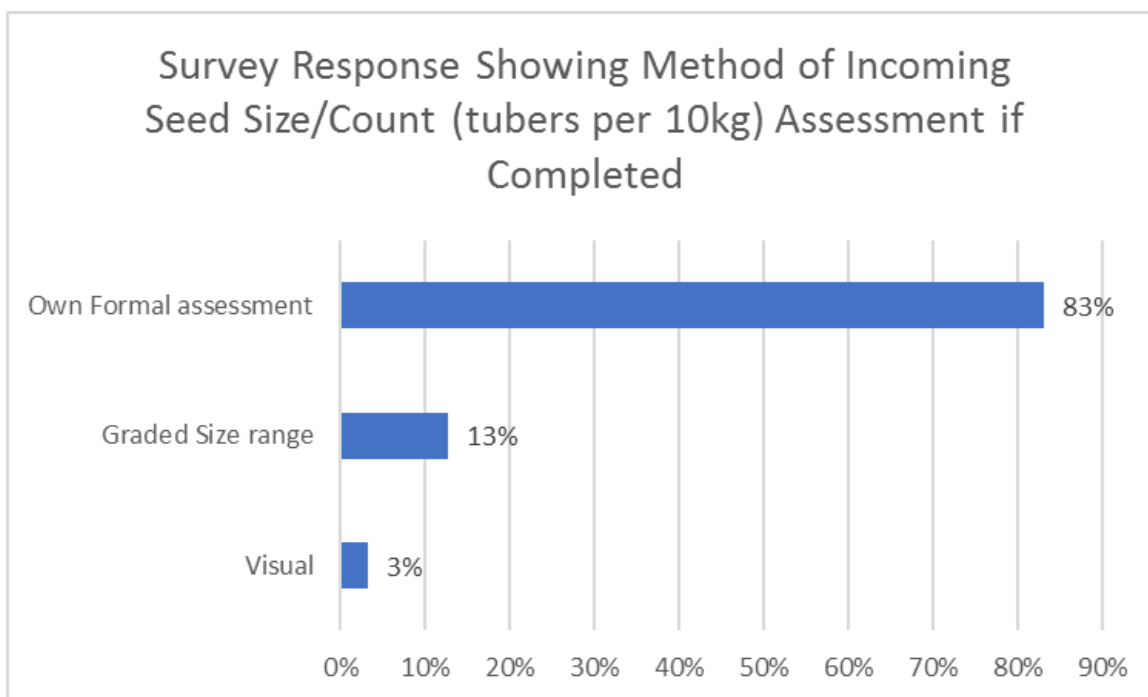
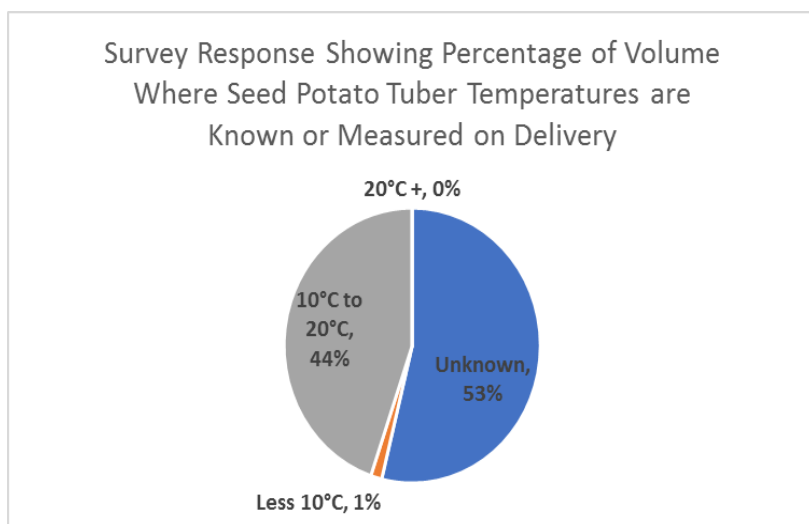


Figure 20. Survey Responses Showing Percentage of Seed with Tuber Counts per 10Kg Completed

6.3.3.2 POTATO SEED TUBER TEMPERATURE AT RECEIVAL

In Figure 21, Seed temperature at delivery is investigated. Tuber temperature can significantly impact physiological age and stable storage shelf life (refer section 6.4).

53% of growers by volume did not test tuber temperature. 44% knew tuber temperature was between 10°C to 20°C. Some of this cohort assumed temperature because seed was most likely to be at ambient temperature.



Seed is likely to be at ambient temperature because it was recently harvested, graded, or transported. It has not been placed in cool storage. Grower's commented that seed held in cool storage and graded immediately prior to transport and delivery is warmed to greater than 12°C. This is to minimize risk of potential seed physical damage and development of condensation on the seed surface. Uncontrolled condensation can promote seed rot and breakdown.

Figure 21. Percentage of Seed Volume with a known Potato Tuber Pulp Temperature on Receival

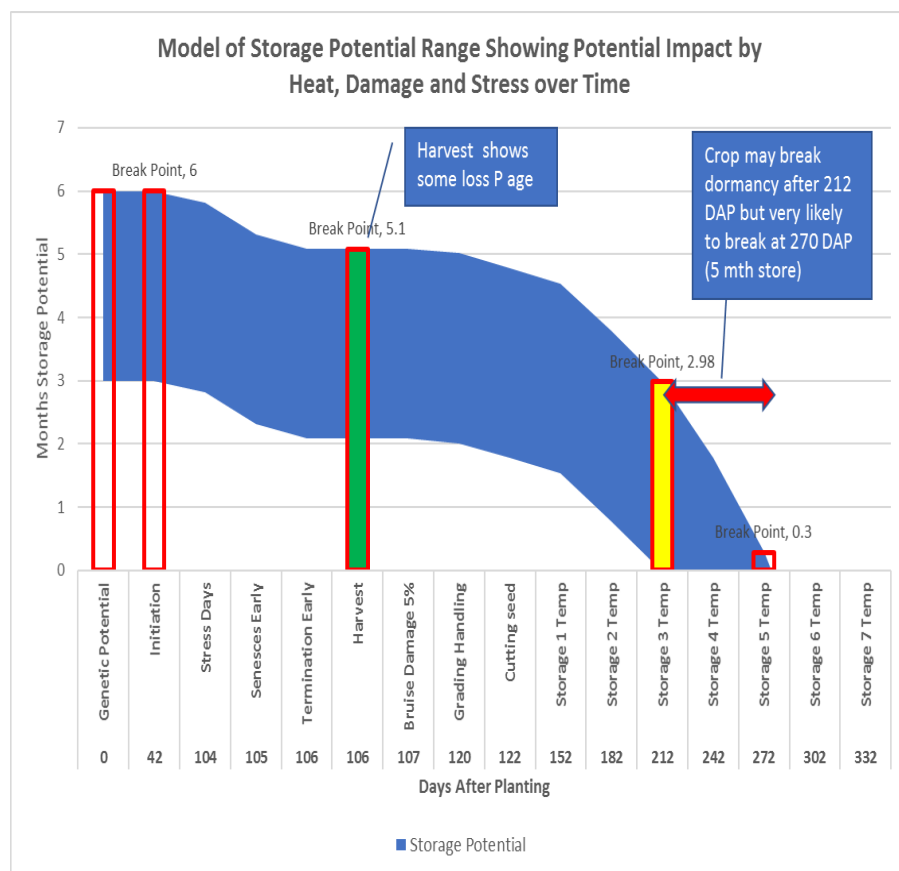
6.4 POTATO SEED PHYSIOLOGICAL AGE AND STORAGE

In the literature review, **Physiological Age (P Age)** or **Apical Dominance** was seen as the most critical element in managing crop planting density and in generating stem count and yield. Poor management of P Age will risk the grower failing to deliver their supply chain customer's expected volume. The survey prioritized focus into factors that influence P Age and respondent's attitude on P Age.

In the literature review report, Philp illustrated P Age accumulation. This reflects the cumulative influence of environment, growing management, handling, temperature and storage. P Age is a biochemical controlled trait. The rate of metabolism in the tuber can accelerate change. Predicting dormancy break is important for ensuring seed is active and not apical dominant and will emerge evenly after planting.

A model of P Age concept in Figure 22 shows the growing cycle, harvest, handling and storage. Cool storage is used to slow the biochemical process. Degree days are sometimes used to predict P Age potential. In the literature review Absciscic Acid (ABA) was reported as the main growth regulator that influenced storage and status of P Age. Below in Figure 23, a model of growth regulator change during the crop life cycle, helps to explain the biochemical process.

Tuber temperature and time from senescence (crop termination or burn down) are critical in managing P Age and stable seed storage. Seed production timing and crop planting must be synchronized to ensure seed breaks dormancy at the desired date to ensure crop maturity fits the grower's supply plan.



Main stream crop production for French Fry production fits into the optimum efficient growing window as this manufacturing process can use cold storage to extend supply. Crisp and fresh market have less opportunity to use storage and must grow crops across a geographic matrix with varying growing seasons.

Growing potatoes on the Atherton Tablelands to supply demand from October to November requires seed to be grown on the edge of seed production windows.

In the literature review variability of P Age was discussed, including across cool rooms, both laterally and vertically.

Figure 22. Modelling Concept Demonstrating Storage Stability and Physiological Age Change

Diagrammatic representation of growth regulator influence in crop cycle

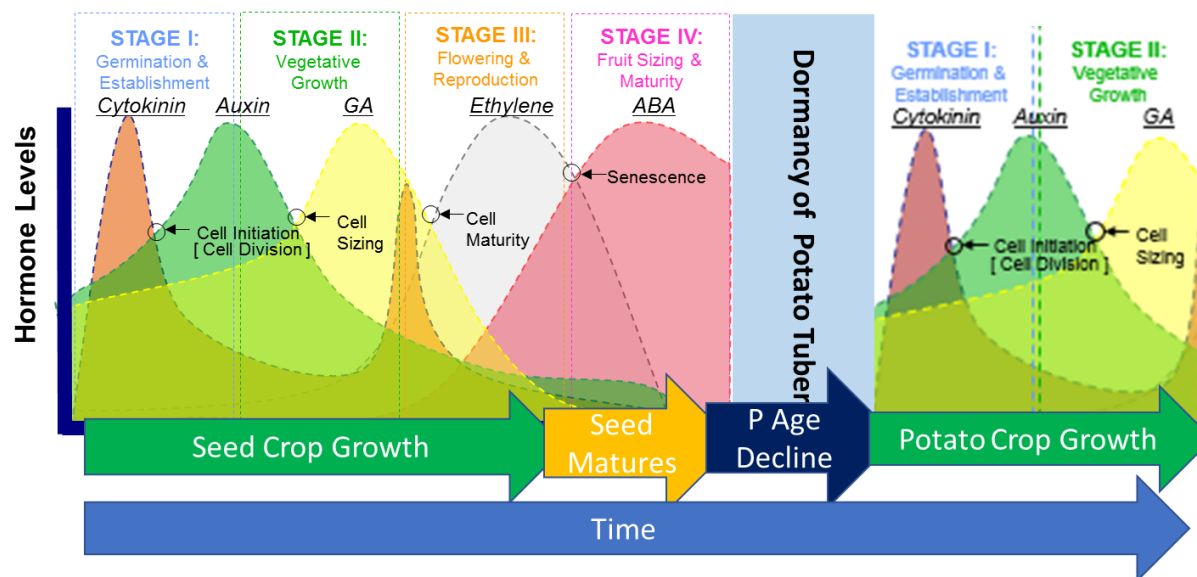
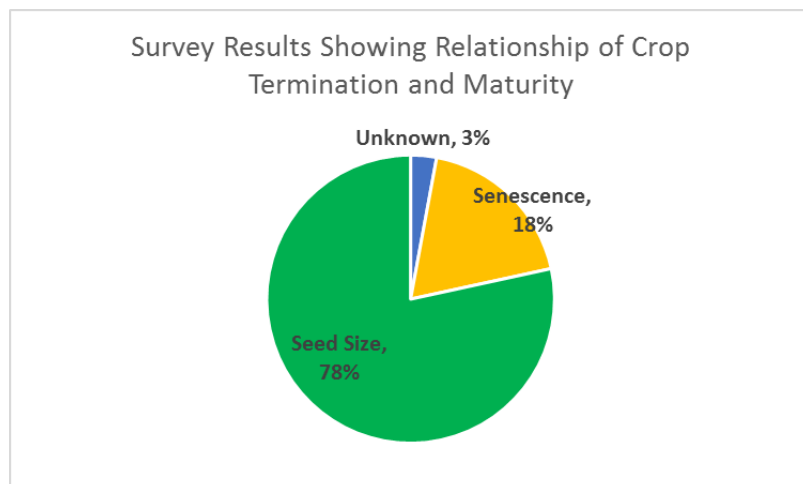


Figure 23. An Example of Growth Regulator Change Over a Crops Life Cycle (Cavallaro, 2010)

6.4.1 POTATO CROP MATURITY, DESSICATIONS AND SEED QUALITY CONTROL

Seed crop production requires seed tubers to be in a specific size range (refer Figure 18) for marketable yield. Crop spacing is the initial control for seed sizing.

Crop termination using either mechanical or desiccants is the major tool seed growers use to control crop size. Virus control and the certification process also requires crops to be desiccated immediately after certification inspection.



In the survey, crop desiccation was looked at to understand the management strategy. Respondents reported that 78% applied desiccants to control seed size while 18% allowed the crop to reach golden or naturally senesce. Of this, 80% used split application and 14% used a single application.

Split application can reduce risk of stem end browning and tuber damage.

Figure 24. Survey Response showing Crop Termination for Seed Sizing V's Senescence

This data raises the question on yield potential by tuber number versus early termination of the seed potato plant to control tuber size. For long cylindrical tuber shape size management may deliver fewer cuts, less waste and reduce risk of seed unit break down.

6.4.2 POTATO SEED STORAGE, SEED QUALITY CONTROL AND PHYSIOLOGICAL AGE

Cold storage of potato seed is widely used to manage seed physiological age and synchronize seed dormancy break to planting window. Seed storage has a significant cost in energy and capital cost. Scalability of operation drove cold storage sophistication and automation. A cold storage facility is a longer-term investment. Technology tended to be set at the time of construction.

The Tasmanian industry has an extra level in the supply chain where specialist operators prepare seed for their customers. Their size allows them to have higher capacity graders, cutting equipment and specialized conditioning rooms. Energy cost is offset by using heat exchange systems between seed cooling and seed conditioning. The result was the customer getting very accurate and consistent quality seed that is ready to plant.

Growers were surveyed on their consideration of P Age at seed receipt before storage of seed.

While there is no quantified seed dormancy test, question response showed a level of awareness to P age. Transition from dormant to seed breaking dormancy is often the focus of visual assessment by the grower.

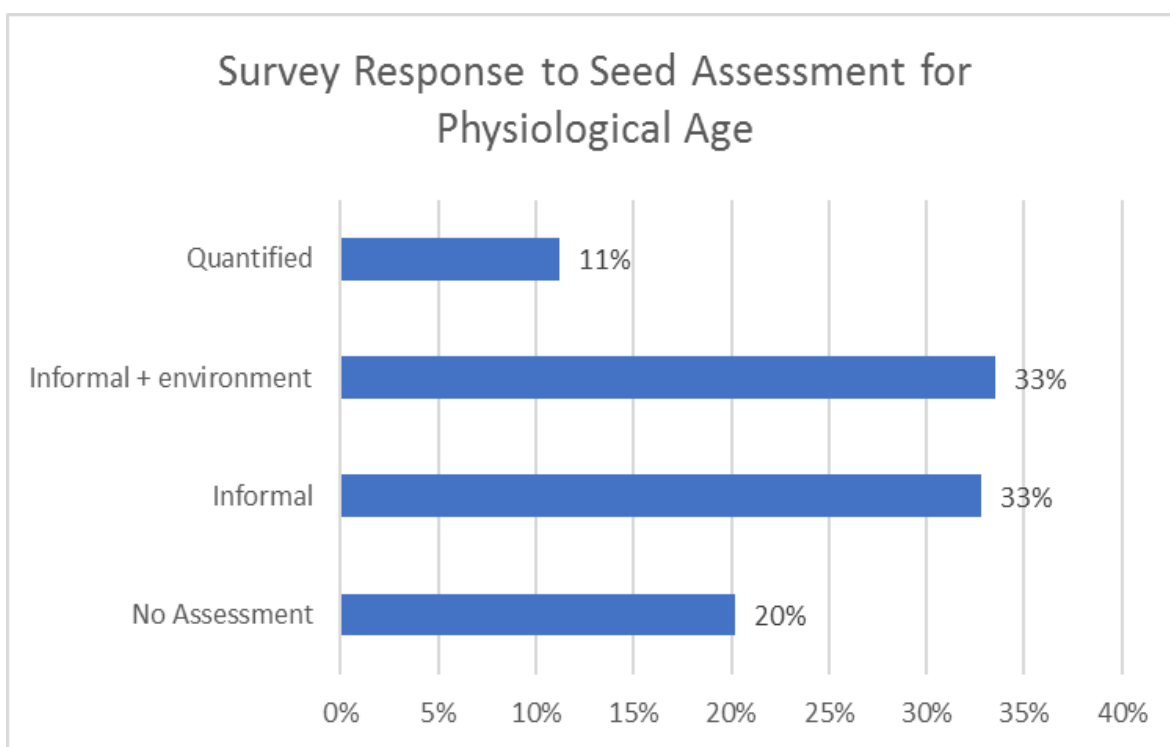


Figure 25. Survey Response to Volume of Crop Assessed for Physiological Age

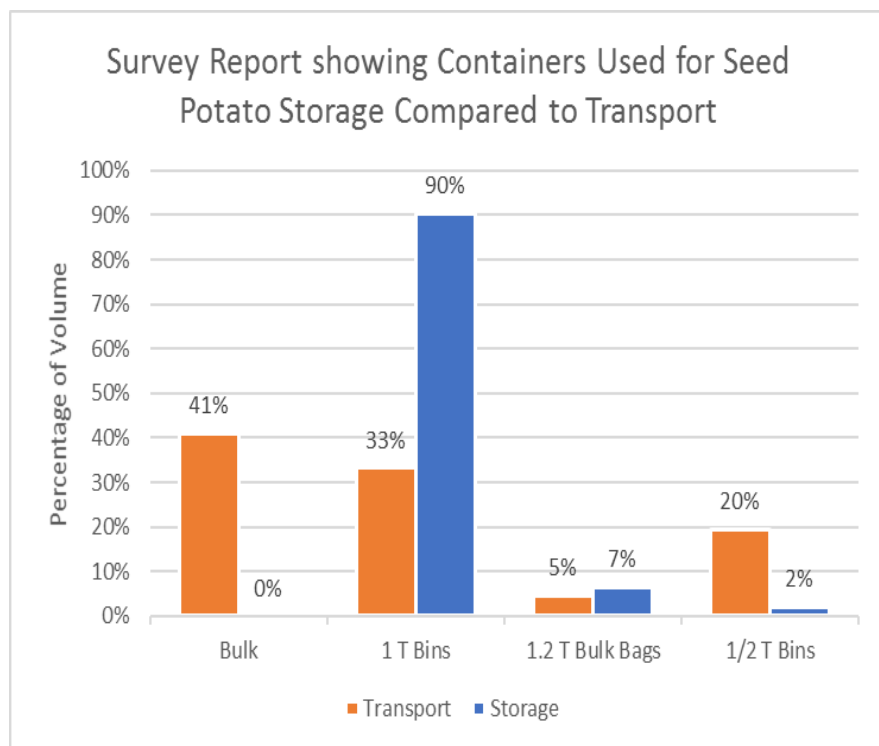
Crop termination ("Burn Down Date") and harvest date were considered essential information in assessing P Age status.

The literature review showed optimum cold storage temperature was 2°C to 5°C. 93% of volume reported that seed is to be stored in this optimum temperature range for cold storage. Some growers responded that they (6 % of volume) stored seed at ambient temperature to manage dormancy. This fitted with the seed harvest timing and fast turn around for planting.

90% of seed volume is stored in 1T wooden bins with 7% in Bulk Bags. 33% of seed volume is transported in 1T bins.

Seed is decanted into 1 ton bins from other transport containers including bulk. Bins represent a significant investment for growers and transition to alternate containers would require time.

Handling can impact seed age and the literature survey identified the importance of tuber temperature during handling to reduce damage.

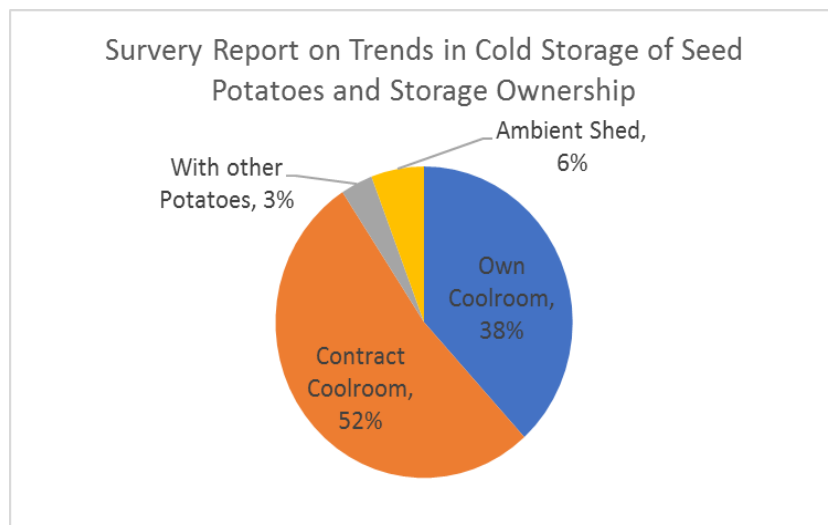


Scalability of enterprise size and its margin impacts the potential to invest in working capital items such as cool rooms. Use of contracted cool rooms reduces working capital required for seed growing enterprise.

Supply chain structure also includes specialist suppliers who provide services in storage of seed, seed grading and seed cutting.

This contracted capacity is spread across multiple seed growers and delivers scalability to the chain. In this supply chain model, the seed grower or seed customer delegates control of the seed quality to the chain resource.

Figure 26. Survey Results Showing Containers Used in Seed Storage and Transport



The efficiency, quality control and communication depend on the service provider. Commercial reality drives the efficiency balancing cost against service and value provided. Scalability enables investment in capacity and technology as the cost is spread over a greater volume of potato seed.

Communication and long-term commitment is essential to enable the storage service provider to deliver quality volume to plan. It is essential for quality seed to be placed in the store to expect quality out.

Figure 27. Cold Storage Ownership Trends

The length of storage indicates storage cost. External storage often has a higher cost than own storage. This may be offset by savings on opportunity costs or by additional services such as cutting and supply management that add value for the grower. The length of storage of seed relates to seed production and harvest to crop planting. Crop planting depends on supply timing.

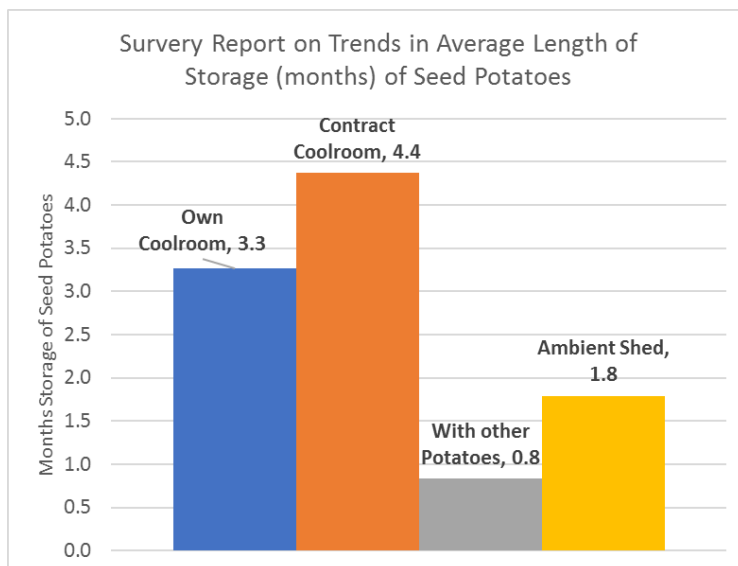


Figure 28. Average length of Potato Seed Storage

The literature review identified that cool storage performance was advantaged with the following:

- Variable Speed fans, lower running cost (power saving), better temperature control, less weight loss
- Computerized, better temperature control and air exchange management, less labour
- Humidification less weight loss, better retention of quality

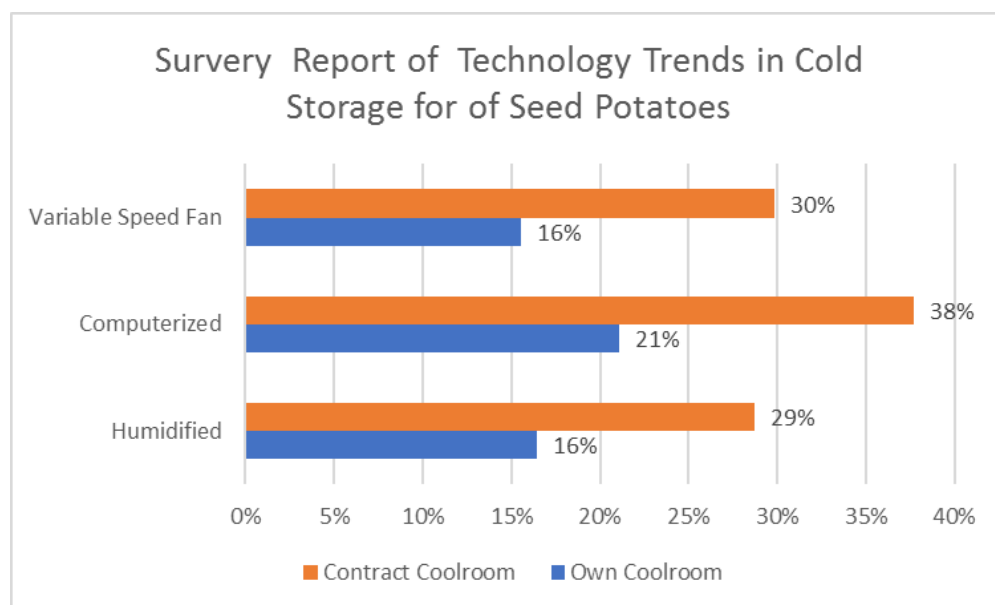


Figure 29. Contract or Owned Cool Rooms Using Variable Speed Fans, Computers, Humidification

Contract storage may have greater capital investment in stores and store systems but by storing greater volumes off set this cost over multiple growers. Owned storage has a 10 to 20 year life cycle so often technology of the store was fixed at the build date. Overall, contracted storage had better storage infrastructure including variable speed fans (power saving, better quality), computerized temperature control and humidification.

Oxygen and Carbon dioxide is measured in 27% of the total volume of stored potatoes. This also reflects the use of contract storage.

Fan speed and air change capacity was unknown by most respondents. In discussion with respondents on this question, they commented that it was an important specification for cool rooms, they would have it in their cool room specs but they did not know it off hand. Older cool rooms relied on regular opening of the door to manage air change.

Use of data loggers is well practiced in the export of potatoes. Growers responded well to the idea of using data loggers in their operation.

Growers drawing seed from the same seed production district expressed varying views on quality delivered by that district, delivery performance and reliability. One grower experienced bulk delivery on time with great service, another grower considered the district as being in a time warp of the 1960's.

6.5 MANAGING PLANT DENSITY, STEM DENSITY AND ACCURATE PLANTING

The literature search showed stem density was one of the keys to sustainable yield from crops and getting consistent size and quality. Stem density is driven by even **Physiological Age**, consistent bud activity across seed units and accurate planting. Sustainable and profitable potato production comes from optimum plant spacing to the crop environment, variety generating marketable yield to input cost per hectare.

Growers identified that planter accuracy and operator attention to detail was important in accurate planting. Seed cutting is used to deliver seed unit planting ability, the “blocky” seed piece. Seed unit flow and compatibility to planter metering systems is fundamental to achieving the planned stem density.

Use of GPS guidance in planting operations reduces operator work load and enables more focus on the planter. Cameras or mirrors are used to improve vision for the operator.

Calibration of planters to place seed at the desired spacing is well practiced in the industry. Often the simple tools ensure operators can check spacing during planting. Standard operating procedure needs operators to continually check spacing accuracy during planting.

Grower comment regards managing spacing accuracy

“I went down to the local hardware shop and purchased tape measures. I gave one to every manager and put one in the cab of every planting tractor. I told them to use them”

Low cost investment for accurate management of a critical crop performance factor.

Table 10. Key Learnings Simple Management Tools Help Deliver Accurate Planting Performance

90% of the surveyed volume reported that they calibrate planting equipment each spacing change in a paddock and when they changed paddocks. One grower shared the “tape measure” initiative used to focus accuracy on seed unit spacing in the field. This reflects the importance of plant density in production (refer Table 10).

Growers of 21% of the potato volume surveyed considered P Age and 17% considered stem density management at planting.

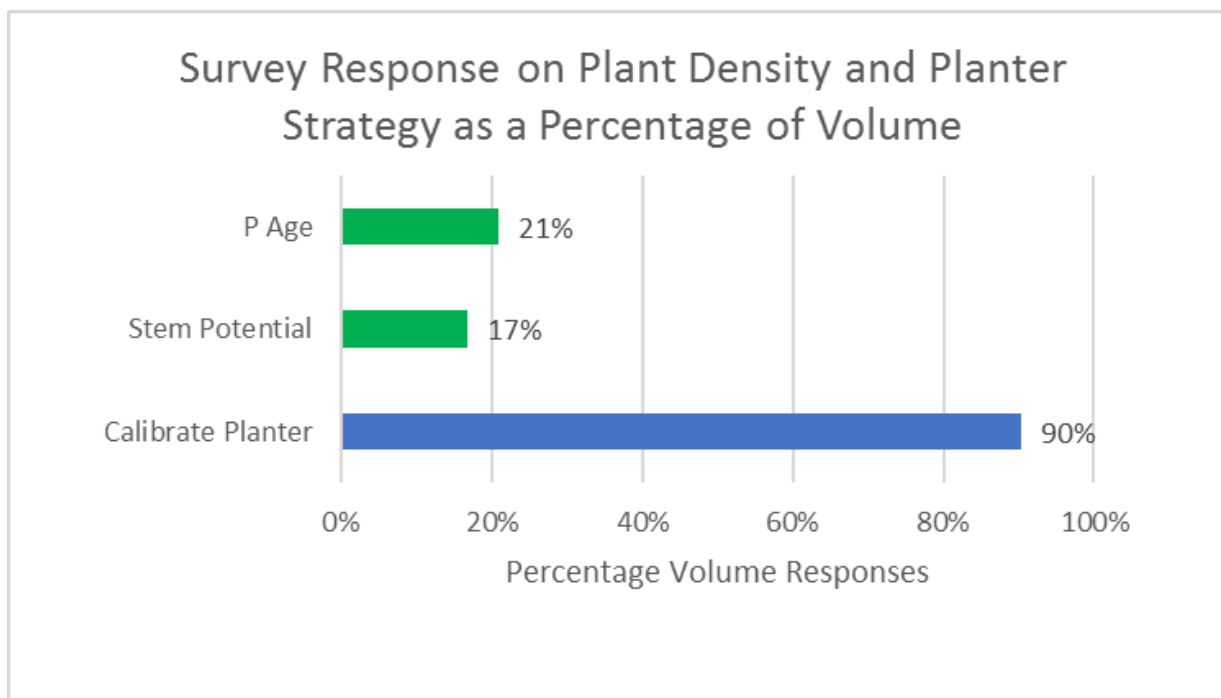


Figure 30. Survey Response on Planting Density and Calibration of Planters

Working from the literature report, clusters of seed quality and seed management elements were identified (refer Figure 4). As part of the survey process cohorts were asked to rate the importance of cluster elements from 1 (less important) to 5 (more important).

Rating identified how important growers considered or rated a seed management element and their awareness of the element. For example, research identified that the seed element, crop performance in the first 40 days, was highly correlated to yield. Cohorts rated this important, a 5, the highest rating score. The industry is aware of the seed quality element of performance in the first 40 days and its importance to the potato crop success.

Cohorts were then asked to rank the top 5 most important elements. This ranking was in order of importance, 1 being most important, 5 being less important. This shows the management thought process across the cluster of elements and the hierarchy of managing seed quality elements in the cluster.

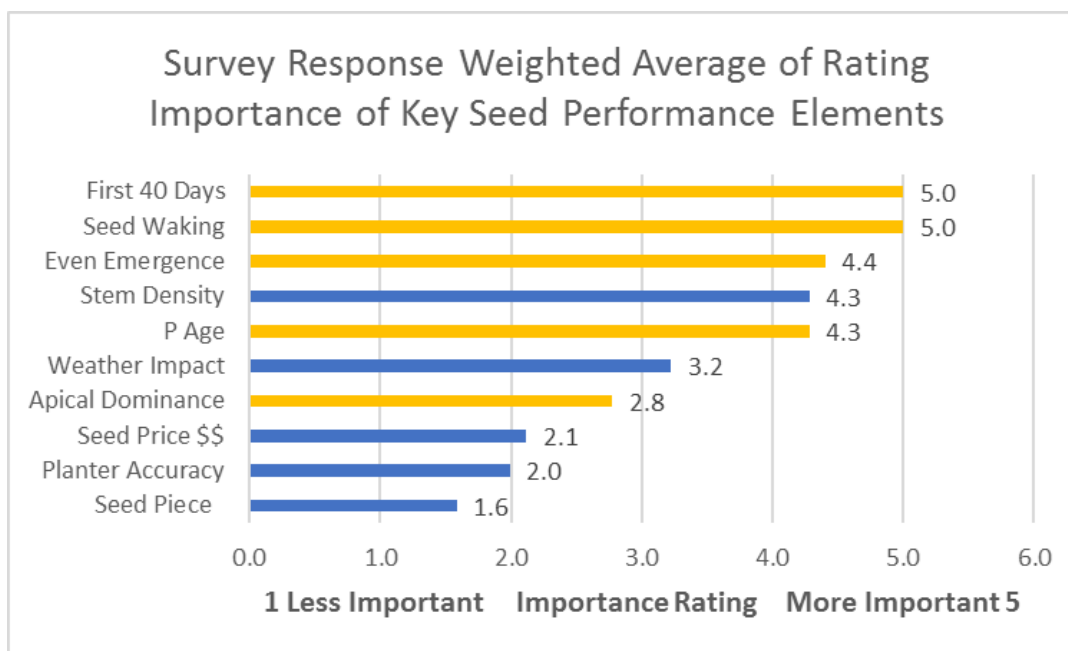


Figure 31. Weighted Average by Volume of the Rating of Importance of Seed Managment Elements

Cohort's saw stem density as the most critical element, ranking it 1. Seed Price was ranked 8th. Seed Piece break down and planter accuracy was ranked less important as they could be controlled through management.

There is a gap between P Age and Apical Dominance. Some cohorts commented on Apical Dominance management using plant density and seed management.

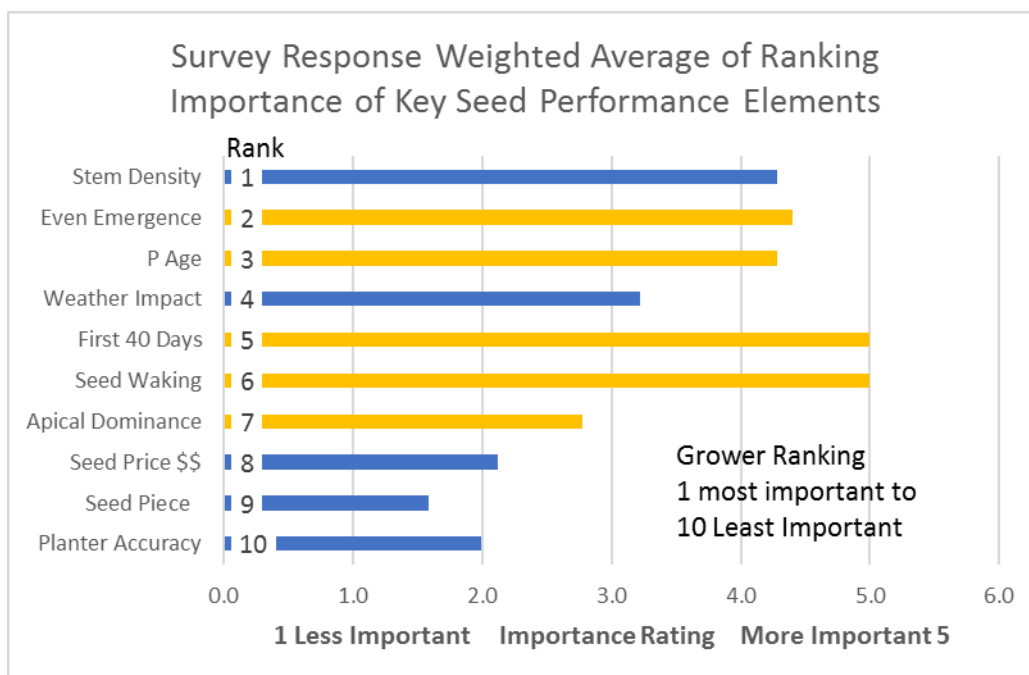


Figure 32. Survey Response showing Weighted Average Ranking of Key Seed Performance Elements

6.6 SCALABILITY, EFFICIENCY AND TIMELY PERFORMANCE

The potato industry supply chain needs are discussed in section 4. Using an electronic survey (see Appendix 3) critical seed management elements and the relationship between supply chain links were investigated. This focused on how seed handling and seed quality impacted the supply chain.

This project's output aims to lead supply chain participants to better understand opportunities for continuous improvement and sustainable cost-effective growth.

Several themes that influence seed quality and seed handling were identified during the survey work. However, they fall outside the scope of this project.

These themes relate to the financial health of businesses, scale and efficiency, investment in the business, replacement of assets and farm succession (age demographics of supply chain participants).

The researchers thank the participants for their transparency and for sharing their concerns and successes relating to the Potato Supply Chain.

1. Investment in equipment and adoption of technology.

The issue of capital investment and return is limiting the replacement of assets. Cost of specialized potato production equipment such as harvesters, grading equipment means that some regions and areas of the industry has ageing equipment. This may impact seed handling and seed quality.

Farm management economics and the balancing of capital investment, depreciation versus repairs and maintenance and unplanned down time.

2. Plant capacity to meet changing customer time lines, customer demands.

Some seed contracts require grading and delivery of seed within a specific time frame. Changing contract conditions that affect supply timing may not fit a growers processing and grading capacity. This can also affect grower's ability to manage the impact of weather on the harvesting grading process.

3. Family farm models and whole farm return, the next generation.

Family farm models rely on whole farm performance to generate income to support the business. Changes in profitability of rotational enterprises can drive exit or downsizing. Sudden change due to acquisition, for example Almonds, Avocadoes can be driven by macro agribusiness economics. The next generation of growers expectations are changing with some wanting a different lifestyle to farming and see farming as not being "attractive".

The potato supply chain financial fitness is driven by yield, marketable quality and efficiency.

Seed quality and handling has identified themes that will improve chain fitness and robustness while making better use of resources. Processors and Australian industry are driving their internal efficiency through adoption of "Lean Management". An example of Lean Management is the improved accuracy of seed size to meet the seed customer's needs. Increase tuber count per Ton in graded size range delivers suitable sized seed units but drives the supply pipeline value equation for the supply and potential seed grower return.

Seed count drives planting area per ton. Optimized planting area per ton potential reduces transport cost, more hectares per square metre of cool room and lower power costs per hectare.

6.7 DELIVERING QUALITY AND VALUE TO MEET CUSTOMER EXPECTATIONS

Relationship and communication are core platforms for a mutually successful business. Sometimes an “extra” small step actioned by the supplier can deliver big savings for the customer, for example, digging that extra load at short notice and keeping the factory running, retail store supplied.

Attitude and relationship on supply quality performance can be different from the same district for different businesses. One grower purchasing seed out of seed growing district reflected on it delivering real value. This was quality, timely supply making the grower’s business successful. This grower is acknowledged for quality and delivery performance by his customer (a processor). Another grower commented that the same seed district did not “perform” well for the business, issues with supply timing and quality, “reminds me of UK seed supply industry back in the 1960’s”.

Focus on seed quality, volume and timely supply requires a foundation of ongoing two-way communication. This communication needs formal (email) and informal (phone) with both parties listening.

The survey works to identify what is important to the supply chain customer and what drives the value equation.

As part of the survey, cohorts were asked to rate key elements impacting supply. Rating was from 1, least important, to 5, most important. The survey identified that seed grower shortfall was rated the most important seed supply element (refer Figure 33).

Survey cohorts commented that, communication was a critical element to allow management and reaction to the variance to plan.

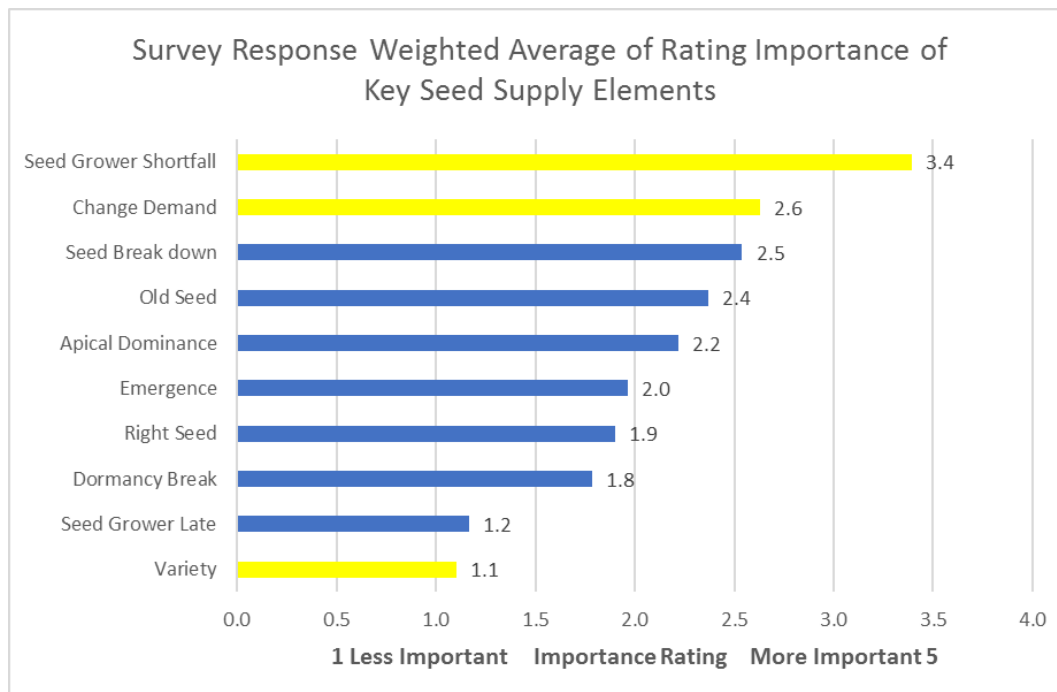


Figure 33. Rating the Importance of Seed Supply Elements that Impact the Supply Chain

The survey also asked cohorts to rank the 5 most important supply elements from 1, most important to 5, less important. Cohorts identified change of demand, to be the most important seed supply element. The earlier communication of change was shared, the better. This is critical for the seed link of the supply chain and the seed link's length.

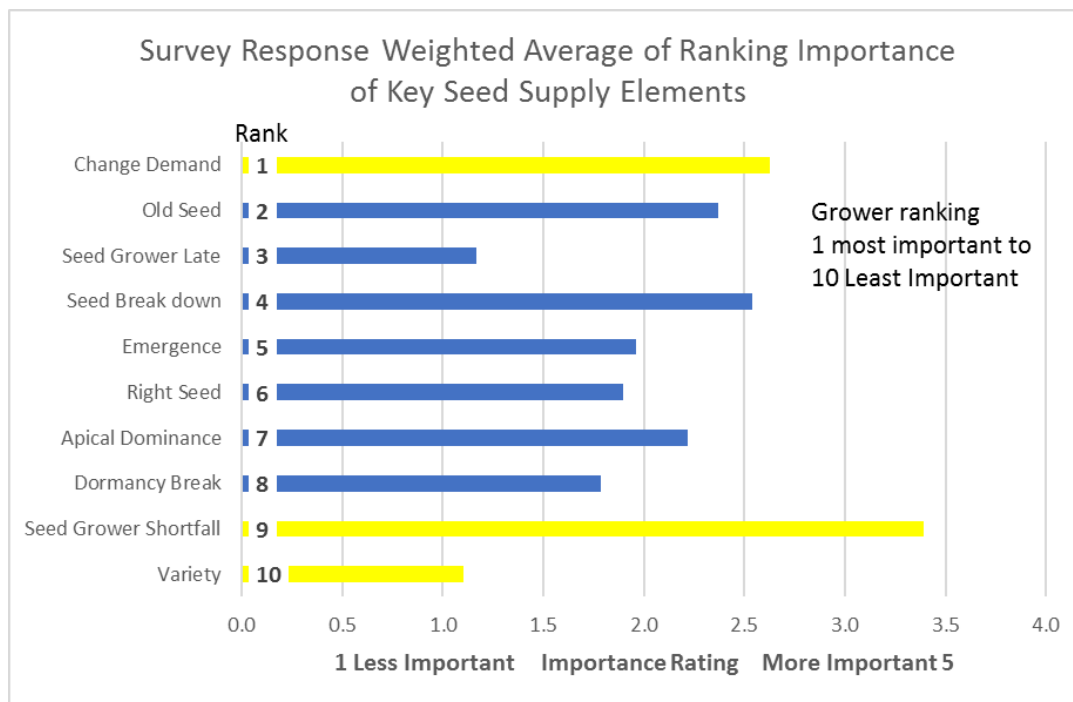


Figure 34. Survey Response showing Ranking of Importance of Key Seed Supply Elements

Lean management philosophy emphasizes the importance of early communication and communication of the exception. An example of the exception in the potato supply chain is the “short supply of seed to plan” generated by poor recovery during grading of the required seed size. Yield and size variation may be due to weather events. If the seed grower communicates exception to plan at harvest to the customer, the customer then has opportunity to solve the variance.

7. SUMMARY CONCLUSIONS AND SUGGESTED RECOMMENDATIONS

Project PT16000 identifies developments in research, best practice in potato seed quality and handling using a literature search. The findings from this search then drive a focused survey of the Australian potato industry. This explores the status of the Australian potato industry compared to the literature review findings.

This report maps the findings of the survey. It is focused on how seed quality and supply can impact the Australian potato supply chain. The report frames up a path forward to achieve improvements across the potato supply chain.

This grower survey is reported at the Australian industry level.

Communication and sharing of the finding of this report through extension to supply chain stakeholders is critical to deliver value from the investment of industry funds. The supply chain members will differ in where and how these elements of that impact their business and supply chain contribution.

To build the stronger supply chain, work must focus on strengthening the weaker links. The stronger links need to support the change process through leadership and motivation in adoption of best practice.

7.1 INDUSTRY QUALITY STANDARD, DISEASE AND VIRUS MANAGEMENT, INNOVATION

Overall, the survey shows that physical quality, disease and virus is considered reasonably well controlled by the industry. The use of certification and quantification of quality in the industry is in a strong place.

Use of seed Generation and shortening the supply chain is an opportunity. Survey shows lower generation volume is significant. Success of best practice seed models needs to be understood including the cost implications and trade off advantaged crop performance of the lower generation strategy.

A shorter supply chain will need stronger communication to manage deviation from plan due to supply demand, weather events, climate and biosecurity risk. The shorter the chain the less opportunity for management of change (to multiply tons) for planting. However, the shorter the chain the more responsive the chain can be to deliver change in plan for variety, volume and seed of the best age.

Technology is becoming available to accelerate the use of breeding (genetics) and variety traits to improve industry efficiency and performance. This allows shortening of the variety development pipeline, reducing cost and accessing advantaged traits.

Remote sensing will allow better vision of crop variance.

Tissue testing will allow quantification of virus and disease loadings in seed at a lower cost. This will enable earlier quality management of seed. The seed pipeline avoids the cost and impact of carrying poor quality seed.

7.2 COMMUNICATION AND DELIVERY TO THE CUSTOMER QUALITY EXPECTATIONS

Relationships and communication are shown to be the critical glue strengthening the links of the potato supply chain. Cohorts with better vision of plans reported better control of the seed quality. This empowered them to deliver more efficient, sustainable economic supply.

Supply plans change and climate can impact crops. Communication empowers the management and delivery of the customer's quality expectations.

The industry trend shows that by volume, most seed suppliers are visited more than 2 times by their customer. This reflects communication best practice. Grower's value this investment of time and managing the future input to their potato enterprise. It directly impacts the seed quality and volume control.

7.3 MANAGING PLANT DENSITY AND SEED PHYSIOLOGICAL AGE

Plant density and more importantly stem density is the primary element in achieving best genetic potential of crop yield, tuber size and crop timing. Physiological age is a biochemical pathway that is consistent and predictable. Understanding the levers that drive the pathway, such as stress and temperature over time will allow seed growers to deliver more P Age predictability.

Communication of P Age science and drivers will empower the seed grower's customer to better use P Age to their advantage.

Use of infield data loggers, in store data loggers and accurate records will help the seed grower's customer better manage their supply chain. Controlling P Age predictability in the supply chain will give seed growers more time to manage the seed quality and grading. This improves the economics of the supply pipeline. Less waste, sustainable management.

Predictable P Age will enable growers to improve accuracy of stem potential from seed including seed and crop early performance (first 40 days). Stem density is the single greatest driver of economic yield.

7.4 SEED UNIT SIZE CONSISTENCY AND DRIVING DOWN COST USING LEAN MANAGEMENT

The global research shows that seed unit size is a critical measurement that drives crop yield and crop performance in the first 40 days. This is reported in the literature review.

While seed is supplied per ton, graded to customers specifications (size range), the clear message from the survey is, the purchaser is buying the planted area. Physiological Age and stems per tuber is part of the multiplication potential of seed units reducing seed cost per planted area.

Tuber count per 10kg or tuber count per ton is a measure that industry needs in specifications to drive seed value. Reflecting the value of planting potential in the seed price, in specification seed count per ton, will financially reward seed growers to deliver seed unit numbers not tons. Seed value per seed unit, not tons, drives the return per area for seed growers. Using these metrics, the value equation reflects the supply chain and drives quality and sustainable efficiencies (refer Equation 3).

Optimizing productivity for the seed grower with delivery of seed units has significant potential cost efficiencies for the supply chain. More income can be generated for a similar cost per hectare input cost. Potential cost savings that flow through the chain include:

- Seed grower less lifts, storage capacity, more sales \$/Hour over grading equipment
- Logistics more planted hectares per truck unit, bulk bag, bin
- Grower less shifts, increased hectares every planter fill, better logistics less storage
- Storage more hectares per storage ton, lower storage cost per hectare (energy savings)
- Certification more hectares of future crop managed per inspector

Tuber shape and eye fecundity drives cut seed. Cut seed is aimed at presenting a "blocky" seed unit to fit planter technology. Control of seed unit size can mean less cuts per ton. Less cuts per ton will reduce waste and reduce risk of break down through a reduction of cut surface area.

Change to include seed unit number per 10kg, requires little equipment change and already is widely used in the processing industry. Change to include quantification of seed unit density per ton will require understanding of value savings, and a tradeoff analysis on change. Change in contract terms and conditions for some of the supply chain may take time. Adoption will be driven by the value of managed seed unit size.

7.5 RELATIONSHIP TIME FRAMES AND SUPPLY CHAIN LENGTH

Alignment of business cycles within the supply chain is important. Shortening the supply chain can strengthen it and build a more responsive supply chain matrix. Variety change takes time. It requires assessment for due diligence, risk assessment and qualification (fit for purpose). Fresh market also balances the competitive advantage of variety in the variety selection.

Relationships between the potato supply chain members must be timely to deliver early visibility of change. Communication must reflect positive intent and generation of value (reward) balanced against cost of production.

In section 7.1, the reduction of generation age in potato production was discussed looking at a disease and virus perspective.

Technology and change in understanding genetic mapping will accelerate variety development. This will help the understanding of the variety performance in different environments (growing locations). In short, the opportunity to drive improvement and cost effective sustainable industry change will accelerate with understanding genetic trait mapping.

7.6 SCALABILITY AND COST EFFECTIVE LEAN MANAGEMENT

Potato production in Australia often features the family farm unit. Investment in resources including land, capital assets and long-term variable assets (equipment) must consider the performance of the whole farm. Whole of farm income includes rotational crops that need to generate income but also build productivity for the potato crop.

In broad acre agriculture, various models of co-operation are available that show sharing resources, for example equipment, and working together can drive justification of investment advantaged technology or capacity. For example, investment in a high-performance boom sprayer allows more area per hour per person, use of latest controlled application technology releasing of other farm resources. By simply increasing effective boom width in potatoes reduces number of spray tracks across the crop. Spray rows generate bruising damage and loss of yield potential. Increasing yield and quality directly impacts the delivery quality to the supply chain and potential return.

Understanding proven structures, the agreements, timing and effective coverage is essential for co-operating groups to look at the potential. This can drive productivity and financial return in traditional proven potato production areas of high land value.

7.7 TOOLS QUANTIFYING QUALITY DATA AND SEED STRESS

Technology and communication is driving a revolution in remote sensing, data recording and data analysis. This makes data usable, leading to more informed decisions. Irrigation water is a limited resource, its availability and cost driven by climate and politics. Potato seed quality, performance and P Age is impacted by stress.

Technology is now available to measure and record soil moisture, total dissolved solids (salinity) and soil temperature. This data also shows growth decline and senescence of potato crops to be better predicted.

Cool room temperature, CO² and O² levels can be measured and recorded using data loggers. Non-computerized cool rooms use manual air exchange control. Data loggers will improve understanding of seed stress in storage and manage potential deviation in expected P Age and dormancy breaks. This would cover interruption of power supply or early removal from cool rooms to save power. Using technology like this helps accurate communication of critical information.

7.8 PHYSIOLOGICAL AGE MANIPULATION AND CONTROL

Research work in Australia indicates that P Age can be manipulated through various storage and handling strategies. P Age and dormancy management are a critical platform for plant and stem density performance. Currently the potato industry relies on burn down date and period of cool room storage. Growers continue to get surprises from the cool room and variation in parcels of seed dormancy.

Mapping of cool room temperature and air movement is important and will also allow for more energy efficient management of seed stock quality.

Australian research work indicates that Absciscic Acid (ABA) and dormancy break can be manipulated with seed treatments to achieve time-controlled dormancy break, reduction of apical dominance across tubers. Natural biochemical pathways show various regulators can be turned off to accelerate ABA decline. ABA influence on the degree of tuber dormancy is a complex matrix. On manipulating ABA, other growth regulators in the tuber bud zone can be influenced, resulting in 100% bud activity.

7.9 NEXT STEPS

The findings of this project need to be communicated to the industry stake holders and development of an extension program initiated. The project has identified the importance of seed and seed quality in the potato supply chain. It has identified opportunities to improve the chain, its profitability, sustainability and input cost reduction.

Extension of the learnings of this project should be actioned through a series of workshops on a grower district level communicating the following:

- Communication and quantification of seed quality and physiological age
- Understanding of longer term planning and waste reduction
- Understanding future trends in genetics and learnings in agronomic management of the supply chain
- Seed tuber size measurement and value development
- Quantification of data using data loggers, remote sensing, both in field and in cool rooms
- Principles of lean management

Further research in the development of P Age management through ABA management should also be developed.

8. THANKS AND ACKNOWLEDGEMENT

Thanks for the support from the SIAP and its team for the encouragement and input on this project. Thanks also to Anthony Kachenko and Bianca Cairns of Hort Innovation for their guidance in delivering this project and report.

Peter Philp and Peter O'Brien also wish to thank the peer group reviewers who generously gave their time, input and direction that helped ensure this project delivers value to the industry. In particular we mention Ken Morley, Ben Dowling and Terry Buckley for those late night discussions.

Thanks goes to the industry survey respondents who helped identify the important elements of supply chain performance that were used to keep this report on point.

To all the participants who freely gave their time to complete the survey, who spoke openly with truth and candor, thanks for your efforts and input.

The report talks about a Pathway into the future of the potato industry. Using a grower's analogy, that was shared during the survey work;

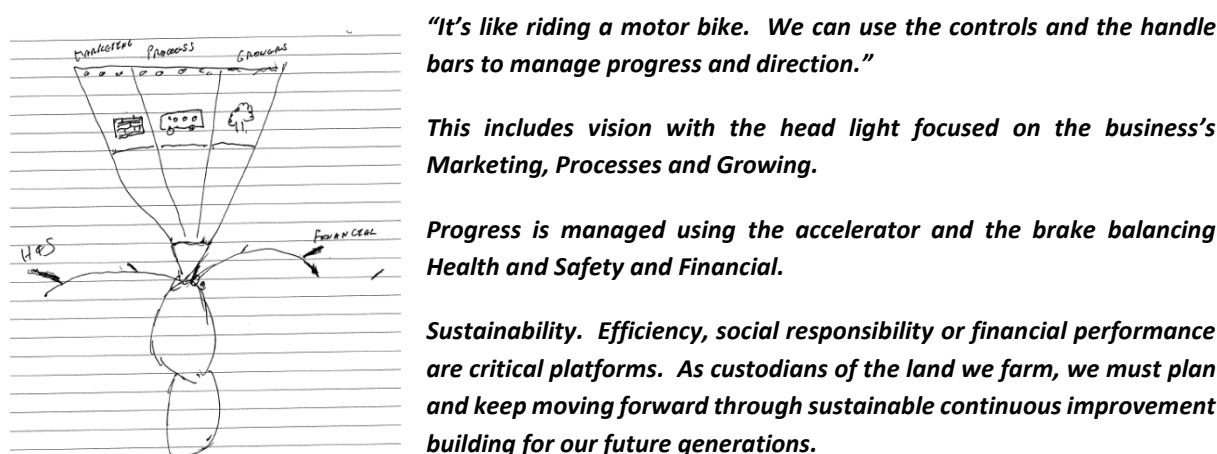


Figure 35. Grower Illustration showing a Concept of Grower Business Management (T Buckley 2017)

This report and research gives us some clear road signs that appear in the head light of the motor bike.

The next steps are:

- communicate change (extension),
- identify and prioritize delivering value (adoption process),
- setting direction then accelerate forward (adoption).

This project has been funded by Hort Innovation, using the Potato - Fresh Fund and Potato -Processing Fund research and development levy and contributions from the Australian Government. Hort Innovation is the grower owned, not-for-profit research and development corporation for Australian horticulture.

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