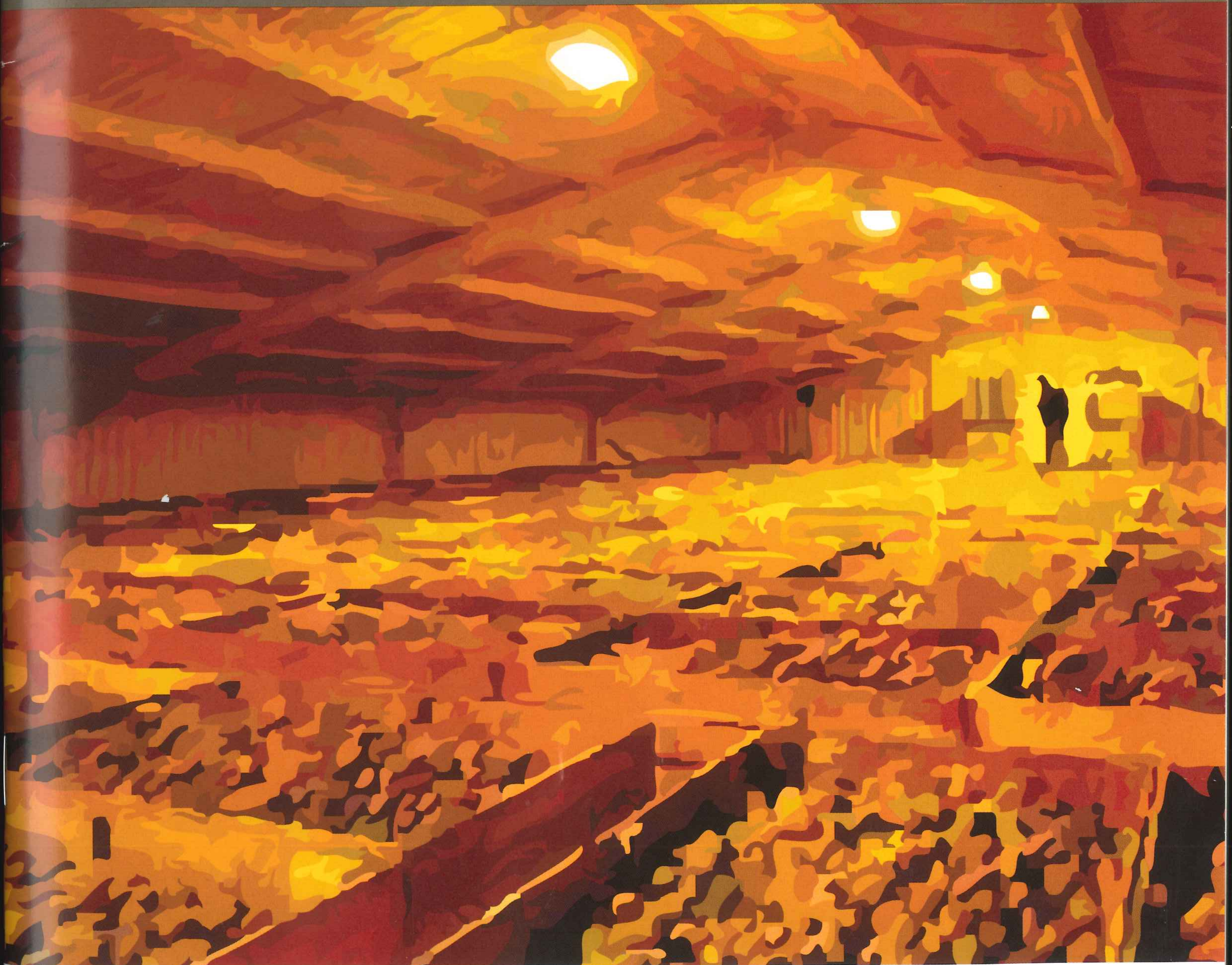
SEED POTATOES

A BEST PRACTICE HANDLING AND STORAGE GUIDE FOR GROWERS AND STORE OPERATORS



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Further Reading

A list of references and storage related internet information can be found on Pgs 48-51 of Horticulture Australia Ltd's Final Report for PT01030: Potato Seed Handling and Storage.

HAL reports are available in hard copy and cost $22 in Australia ($30 outside Australia) including postage and handling. An order form can be found on www.horticulture.com.au

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CONTENTS

INTRODUCTION

Underlying principles of managing, handling and storage of seed

Seed potatoes represent a sizeable part, about 25% of the total investment in any potato crop. It is therefore important for growers to protect this investment.

The following guide highlights the principles of how to manage the handling and storage of seed for ware, French fry and crisping potato production. However, each farm is different and growers need to consider how the information can best be used for their situation. Each end use also places different requirements on the seed management process which need to be considered.

Seed in Australia does not always perform to its potential. Growers therefore need to be vigilant in ensuring they are using the best practices and always strive to improve what they do. Many improvements can be made by the grower by simply monitoring what is happening, understanding where the problems are and taking corrective action.

The guide uses information from Australia and overseas. How the information is applied may differ between countries but the basic principles still apply. So even when something may not seem totally relevant to your situation, the aim of the proposed action and how it relates to your circumstances may still apply and should be considered.

Why is seed storage and handling so important

The starting point for producing high yielding crops and high quality produce is good seed. Good seed is certified seed of the appropriate physiological age which has quality assurances for varietal purity, damage and disease.

If growers are to reap the full value of good seed, then how they manage it from the time it is harvested until it is sown as a commercial or next generation seed crop is critical.

Poor seed ----- Good storage and handling ----- Fair result

Good seed ----- Poor storage and handling ----- Fair result

Good seed ----- Good storage and handling ----- Good result

Starting off with good seed is no guarantee of achieving high yielding crops and high quality produce. Good seed must be managed properly from harvest to sowing the commercial crop for its full potential to be realised.

Key points to remember

While going through this guide keep the following points in mind.

- Bad seed cannot be made good by good storage and handling. Start with good seed. Good seed is healthy and of the right physiological age. Know the seed you are putting into a clean store - paddock history, health and age. Only by knowing what you are buying can you act appropriately. A crop inspection of the seed crop you intend to buy may be worth considering.
- The seed grower may take great care but if the buyer or transport operator fails to adopt best practice the end result will be disappointing.
- Protect your seed from disease. Cull piles, harvested product and dirty store and equipment e.g. cutters are only some of the ways disease spreads to your seed. Understand where the risks are and manage them.
- Airflow & ventilation are very important. Seed potatoes are alive. They need fresh air to breathe and can die if they do not get it.
- Bruising is a sign that seed potatoes have been hurt due to a fall or heavy impact. Reduce the size of drops, soften the landing and eliminate damaging impacts.
- Seed potatoes need rest and sometimes treatment after wounding and from the stress of handling or cutting. Cure seed until all wounds have healed.

- The best temperatures for curing and storage differ. One temperature does not suit all situations. Gradually lower tuber temperature to storage temperature after curing.
- Constantly check that storage systems are operating correctly. A mistake or fault can be costly.
- Treat tubers that have had a difficult start with extra care.
- One of the best training grounds is the farm. We can be told what to do but often we learn far more by monitoring and learning from our own actions.

Good seed handling and storage pays – it does not cost

Growers who pay attention to improving seed handling and storage stand to significantly reduce their waste (hence costs) and improve the performance of their seed.

At the extreme, poor handling and storage can result in total loss of the seed or crop. However, much of the time, most growers fall somewhere between the worst case scenario and the ideal.

This guide details best-practice potato seed handling and storage requirements to help you move towards the ideal. Focus on the principles as application techniques are likely to differ quite a lot between farms. Australia is a big and varied place for growing potatoes and the needs and priorities of individual businesses will differ. However, the basic needs of seed potatoes do not differ.

Handling and storage – what we mean

For the purpose of this guide, seed handling and storage starts at harvest of the seed crop and ends at planting of the next generation of seed or the commercial crop. To gain a good result, all stages need to be managed carefully.

The following is a simple sequence of major activities:

- Decide who is responsible for the different activities
- Plan and prepare for harvest
- Harvest
- Hold tubers in paddock, organise transport and intake to store
- Cure
- Grade
- Store
- Cut
- Transport seed from store to commercial/seed grower and pre-plant

WHAT NEEDS TO BE DONE – MANAGING THE RISK

Who is responsible for the different activities

Activity	Further information on Page:	Operator	Person reponsible in my operation
Plan and prepare for harvest	8	Seed grower, Harvest contractor or Transport contractor	
Harvest	9		
Holding seed in paddock prior to transport	10		
Transport to seed or commercial grower for curing, grading or storage	10		
Management of seed on receipt	10	Seed grower, Commercial grower or Contracted cool store operator	
Plan and prepare for curing	11		
Curing (before or after grading)	11-13		
Prepare for grading	14-15		
Grading	15		
Waste management	14-15		
Plan and prepare for storage	16		
Holding prior to storage	15		
Chemical treatment prior to storage	15		
Ambient storage	10		
Cool storage	16-20		
Warming up ex cool store	20		
Grading after storage	14		
Seed cutting	48-49	Seed grower, Commercial grower or Seed cutting contractor	
Pre-plant seed treatment	46		
Holding of cut and treated seed (planting delay)	49		

Plan and prepare for harvest

What has to be done	What can go wrong	How to reduce the risk	Reference
Harvester, tractor fork, truck (tarps) inspection / maintenance	Harvester not ready in time.	Have equipment ready to go one week before predicted date. No drops above 15cm.	
Prediction of: 1. Harvest date 2. Number of harvest days (start and finish)	Too early harvest leads to higher respiration rates = higher CO_2 production.	Predict harvest date by physiological age, planting time, growing conditions and when skin set finished. Harvest when soil temperatures are between 12°C and 15°C and similar to tuber temperature. Ventilate potatoes in store for at least two days to avoid CO_2 damage. Monitor CO_2 levels in poorly ventilated areas of the store.	Page 50-51: Evaluation of physiological age
Vine (haulm) kill	Tubers from young or recently killed vines are susceptible to skinning and mechanical injury during harvest, causing storage decay. Such tubers tend to have relatively low starch and high sugar concentrations compared to mature tubers.	Kill vines two or preferably three weeks before harvest.	
Estimating the number of bins required 1. Per variety 2. Per day	Harvest delays waste time. Dirty bins contaminate, unsafe bins can break.	Use a rough estimate of 100-150 bins per hectare; consider truck capacity.	
Bin maintenance and cleaning	Contamination with storage pests and diseases.	Repair bins; use hot, high pressure wash and sun dry bins.	
Clear labels: Use pre-printed waterproof bin labels on both sides above tyne pockets (= 2 labels per bin) Attach labels securely to survive transport and moist conditions	Poorly or no labelling can waste time at sorting and mix up varieties. It can also lead to wrong treatment in store or transit.	20 x 20 cm label to include: Grower, Grower code/ID Location Variety and generation No Certification No Harvest date Generation Minituber size (if applicable) Other, as required Labels above both tyne pockets make handling bins easier. If one is lost, the bin is still labelled.	

Harvest

What has to be done	What can go wrong	How to reduce the risk	Reference
Check soil moisture Soften soil with pre-harvest irrigation, if required	If soil is too dry at harvest, soil clods can damage tuber skin or tubers can be buried, and if soil is too wet, it will not sieve well and will stick to tubers.	Check soil moisture one or two days before harvest. Soil should be moist but not wet. Irrigate to achieve a moist soil for harvest.	Page 30: Measuring pre harvest soil moisture
Check and record soil temperatures between senescence and harvest (especially in the week before harvest)	If soil temperature is much higher than tuber temperature, tubers will be susceptible to black spot bruise. If soil temperature is colder than 5°C potatoes are susceptible to shatter bruise. Adjustments in curing/early storage settings may be necessary. Communicate variations to personnel at the storage facility.	Check soil temperature at 10cm to 20 cm below the top of the mould. Preferred soil temperature is between 12°C and 15°C and is similar to tuber temperature. If the soil temperature is above 18°C, delay harvest or irrigate. If soil temperature is below 10°C special care is required to avoid bruising and if below 5°C delay harvest until higher temperatures are received.	Page 34: Adjusting early curing environment Page 41: Temperature and hydration effects on tuber damage / weight
Harvesting performance check	Damaged tubers are a direct loss and will occur if chains go too fast or harvester adjustments are faulty. Storage rots develop on damaged tubers. Damage and stressed tubers have higher respiration, increasing heat and CO_2 production, which slows wound healing.	Separate the low, wet, or diseased areas of the paddock from other areas and harvest separately if possible. Inspect tubers for damage and adjust machinery as required. If too much soil is harvested, increase agitation on the harvester web, or put the crop over a continental web or soil extractor at the store.	

Holding tubers in paddock, transport and intake into store

What has to be done	What can go wrong	How to reduce the risk	Reference
Holding harvested tubers in paddock before transport	Tubers age faster if dehydrated and heated; they respire faster and produce more CO_2 Skinned or damaged tubers dry out quickly.	Check tuber temperatures to ensure tubers don't heat above 20°C. Move harvested bins from the paddock to the store with least delay and minimum exposure to the sun. When air temperature rises above 25°C, the delay from paddock to store should be no more than 2 hours.	
Transport from paddock to store	Damage to and loss of tubers. Damaged tubers risk breakdown during storage or poor performance in the subsequent crop if not graded out.	Cover loads to avoid sunburn, wetting and tuber loss. Monitor for condensation from sweating under tarps. Install baffles between tarps and tops of bins if required. Minimise the length of any storage under tarps on truck.	
Holding harvested tubers after transport from the paddock	Lost quality and control over the physiological ageing process if treatment of tubers changes between loads or over time. If harvest and grading speed / curing capacity do not match, quality is lost.	Monitor the pre-grading / pre-curing / storage environment to ensure fresh airflow and tuber temperatures of 10°C -15°C. If grading can't keep up with the amount harvested, limit daily harvesting hours.	Page 38: Calculating pre-grading, grading, curing and storage capacity alignment Page 58-60: Evaluating physiological age
Transport of seed over long distances	Seed breakdown, especially if uncured seed is transported from cold to warm areas or over different climates. Risk of seed breakdown is high if it gets wet from condensation. Planting dormant seed, if seed handling and storage documentation has not been communicated to the person who looks after seed on arrival.	Seed supplied to commercial growers soon after harvest is best cured before transport, then freighted under refrigeration or at the curing temperature in containers that deliver as much airflow and fresh air as possible.	Page 43-44: Ideal curing / early storage

Curing

What has to be done	What can go wrong	How to reduce the risk	Reference
Design, arrange, maintain curing facility	Loss of seed quality and performance because: • Set up doesn't allow airflow through bins. • Required temperature and humidity can't be achieved. • There are more incoming bins than the facility can handle.	The curing facility has to be big enough to keep up with incoming loads.	Page 52: Curing set up
Separate ware and seed tubers	Ware potatoes have different storage needs to seed tubers.	Separate and remove ware potatoes either at harvest or at grading prior to curing. Otherwise sacrifice the ware quality to ensure conditions are appropriate for seed.	
Store loading for curing	Excess soil stops good airflow and may stop tubers drying quickly; the curing result will be poor and disease risk high.	If there is too much soil in the bins, put it over a web, pintle rollers or soil extractor at the store. Leave minimum 30cm space for air ventilation around bins especially near walls, and for easy inspection of seed in bins.	
Curing before cool storage	Tuber respiration uses oxygen and produces carbon dioxide and heat. Early harvested tubers can have higher respiration rates. High carbon dioxide levels can stress tubers. Poorly cured seed will have unhealed wounds and be prone to seed piece breakdown. Tuber temperatures may rise through respiration if airflow is poor. Seed heals faster at 20°C-25°C, but these temperatures also promote soft rot. Low humidity will stop healing, especially if temperatures are at the lower end of, or below, the curing temperature range.	Curing should be started as soon as possible after harvesting Optimum curing is at 10°C-15°C, 95% relative humidity for a minimum of 10-14 days and up to 3 weeks, but not longer than 4 weeks. If increasing curing temperature to 15°C, increase it by 0.5°C-1°C per day if possible. If cooling to bring tubers down to 15°C, do rapidly, but with air temperature just below tuber temperature. Adjust air temperature as tubers cool. If incoming tubers are very wet, ventilate continuously with humidifier off. Return to normal curing humidity (95%) when dried. Diseased tubers can benefit from dry curing at lower humidity (85%) and temperature (10°C)until completely dry (1-2 days).	Page 43-44: Ideal curing / early storage

Curing (cont)

What has to be done	What can go wrong	How to reduce the risk	Reference
Ventilation of store or area used for curing	The higher the tuber temperature, the higher the respiration rate, and CO_2 production. High ventilation rates but no humidity control will lead to seed dehydration and weight loss. Ventilation with air at temperatures of more than 4°C above tuber temperature will cause condensation on tubers. If a curing store or system is not available, a well-ventilated open shed may suit curing if temperatures are not too high or low.	Unless tubers are diseased or wet (see below), run humidifier and fans continuously while filling a store for curing. Once the store is filled, ventilate intermittently 2-6 hrs per day, and ensure there are 2 complete air exchanges per day. Stop ventilation of dry tubers and switch to internal re-circulation if the dew point temperature of ventilating air goes higher than tuber temperature (rule of thumb is to stop when air temperature is 4°C higher than tuber temperature). If possible run the humidifier with outdoor air when ventilating, to reduce moisture and weight loss.	Page 42-43: Condensation and weight loss
Change pre-grading and curing conditions according to harvest monitoring	Poor storability and poor commercial crop performance.	Obtain and use the information on soil and tuber temperature and soil moisture at harvest to modify grading and curing.	Page 44-45: Adjusting curing environment to suit harvest conditions
Monitor curing conditions and manage curing problems	Bins with small gaps between boards may not let enough airflow through seed for good curing and storage results. Poor wound healing, disease risk, poor storability and commercial crop not reaching full potential, if curing is not complete before long term cool storage. A diseased lot may need special conditions to avoid disease spread (e.g. silver scurf).	Check bins regularly to ensure they are stacked to encourage airflow through tubers. Monitor temperature and humidity of supply air (so it is above 95 %) and return air and tuber temperature. Check tubers and the walls for condensation. Supply air temperature should be 1°C cooler than tuber pulp temperature until the tuber is cooled to desired curing temperature. Use a ventilation meter[1] to confirm curing conditions are correct in different parts of the store.	Page 42-43: Condensation and weight loss
		Lower temperature by 1°C -2°C every four to six days until the long-term storage temperature is reached, or proceed as described below. You can start this after a two-week curing period.	

[1] Hand held meters are available for measuring velocity, temperature, differential pressure, humidity, dew point, wet bulb temperature and heat flow.

What has to be done	What can go wrong	How to reduce the risk	Reference
Temperature pull down for storage	Yield potential is lower if pull down is too slow or too fast.	Start temperature pull down only after curing is complete. Monitor the temperature and humidity of supply and return air. Ensure supply air humidity is above 95%. Supply air at 1°C - 2°C colder than tuber pulp temperature, and decrease it slowly until the desired temperature is reached. As pulp temperature reaches air supply temperature, reduce it a further 1°C - 2°C, until target storage temperature is reached. If tuber temperature doesn't decrease to storage temperature in 10-12 days, improve airflow in the store. Carefully monitor tubers and walls for condensation. If condensation occurs, reduce humidity and increase airflow until tubers are dry.	

Grading

What has to be done	What can go wrong	How to reduce the risk	Reference
Grading line inspection, cleaning and maintenance Grading area cleaning Fungicide application, equipment maintenance and calibration	Sweeping spreads fungal spores through the shed, spreading them to non-contaminated tubers. Cluttered work areas lower productivity / efficiency. Potential exists for unsafe work areas. If fungicide application equipment is not calibrated and / or nozzles are worn, fungicide levels on tubers may be too high or too low or there mightn't be enough coverage if droplets are too large. Mixing of seed lines, spreading of diseases form one line to another.	Wet clean or vacuum (don't sweep) the shed at the end of the day and between varieties. Drop heights mustn't be above 15 cm. Remove sharp points, pinching and skinning conditions. Fit out hoppers and line equipment with padding or deflectors where potatoes hit. To stop tubers falling into the bottom of empty bins, roll them into tilted bins. If the grading line is not set to tilt bins, use bin inserts and/or padding in empty bins to reduce drop height and speed. Separate the intake area for paddock bins from the holding/dispatch area for graded seed. Prepare a cleaning schedule which can be posted on the shed wall and crossed off and initialled when cleaning has been completed. Ensure thorough cleaning (dirt, tubers) between seed lines.	Page 32: Assessing line damage potential Page46: Seed treatment
Plan order of grading seed lines and seed generations	Disease transfer	Grade early generation before later generation seed. Grade all healthy seed before diseased seed. Clean up between seed lines.	
Organise grading waste removal	Contaminated waste bins are used for graded seed.	Label waste _ tonne bins, and don't use them for graded tubers. Old bins can be used for waste.	
Bin maintenance and cleaning	Using dirty bins for harvesting seed can lead to contamination with storage pests and diseases.	Repair bins, wash them with hot, high pressure and sun dry). Isolate buyers' bins in separate areas of the shed or loading bay and do not bring them beyond this point. Estimate the bins required for harvest and for each variety in advance of each daily harvest.	
Organise waterproof bin labels to be used on both sides of the bin (= 2 labels per bin) above tyne pockets Organise seed certificate labels (for one side per bin)	Mixing up seed lines (varieties and planting dates) reduces the seed value, potentially to zero. No labels can lead to incorrect treatment in store or transit.	20 x 20 cm label to include: Grower, Grower code/ID Location Variety and generation No. Certification No. Harvest date Generation Mini tuber size (if applicable only) Other as required. If seed certificate labels are used on one side of the bin, labelling the other side will help identification during bin handling.	

What has to be done	What can go wrong	How to reduce the risk	Reference
Staff selection and training	Poor work performance and inadequate knowledge and understanding of seed grading quality parameters.	Select staff with experience in grading operations or with appropriate aptitude for learning work responsibilities. Train staff using handbooks and visual aids to recognise tuber defects. Train staff in all safety aspects of their job.	
Waste removal and disposal	Disease transferred from waste to clean stock.	Collate and regularly dispose of grading line waste (to be kept away from grading, storage and curing facilities).	
Electric forklift for confined areas	Diesel and gas fumes can accelerate the physiological age of potatoes. Staff can be affected by carbon monoxide (headaches, nausea).	Use electric forklift in enclosed areas or ventilate to ensure no ethylene and carbon monoxide (CO) accumulates from gas or diesel fumes.	
Grading seed potatoes after removal from cool store	Bruising and breakdown.	Ensure potato core temperature is at least 7°C before handling.	
Fungicide application	Tubers aren't adequately treated. Operators and other personnel can be inadvertently exposed to chemicals.	Ensure availability of and choose appropriate product. Read and follow label directions. Ensure protective shields and other protections are adequate. Remove waste.	
Grade seed to specified size range	Incorrectly adjusted rollers or incorrect sizing chain produces seed lots varying in size which do not meet buyer specifications.	Check buyer specifications and compare against grading results. Sub sample the grading results according to a QA procedure or at regular times during grading to ensure specifications are being met.	

Storage

What has to be done	What can go wrong	How to reduce the risk	Reference
Planning store capacity and logistics	Not enough oxygen and too much carbon dioxide lead to 'suffocation stress', rapid physiological ageing and poor seed performance. Unnecessary work in unloading and reloading seed lots.	Provide enough space for airflow above the bins, between walls and bins, and between rows of bins. Ensure easy access to seed lots that have to be removed first or accessed	Page 38: Calculating storage capacity alignment
Preparing, cleaning and maintenance of store, cooling and monitoring equipment.	Store is not clean, leading to carry over of infection sources for tubers and / or pest damage. Storage equipment does not work or is not working correctly, leading to faster physiological ageing of tubers (early sprouting is a sign of ageing) and disease risk. Pests (rodents and insects) carried forward as an existing population to feed on the new crop. Chemical residues such as ethylene or sprout inhibitor can affect the integrity of the potatoes as seed.	Make sure store is free of dirt and debris, is cleaned with hot wash and disinfectant. Clean and sanitise ventilation ducts. Inspect and test all systems (cooling unit, insulation, vapour barrier, fans, humidifier, duct work, doors, monitoring equipment,). Implement pest control program. Operate the entire system to humidify and pre-cool storage to 15°C a few days before potatoes are introduced. Do not store in a facility that has been used with sprout inhibitor.	
Plan store loading well in advance Consider how different varieties are to be allocated to stores • Consider disease risks and risk of cross contamination • Consider removal dates • Document the requirements for each seed lot and store user.	Cross contamination between lots belonging to different clients. Poor airflow leads to heating up of tubers and CO_2 build up in bin centres, which accelerates ageing. Conditions best for one variety may not be appropriate for another and premature ageing may result. Disease risk overlooked due to lack of documentation or knowledge	Arrange free airflow around bins and above bin stacks. Allow easy access to bins for inspection. Isolate disease affected bins or at least put them in store last, after being well cured, allowing easy access for inspections or removal. Store varieties and lots that are compatible in harvest time, sprouting behaviour, temperature requirement, and estimated removal time. Supply grading records to identify seed lots with higher risk of storage diseases.	Page 50: Evaluating physiological age
Store filling and bin location plan	Time wasted in trying to locate seed lots and unload / re-load the store. Tubers may warm up (break dormancy).	Document locations of each variety by generation and grower Record variety, generation/crop ID, grower's name, contract or job number, as required. Record bin locations on the plan.	Page 37: Store bin ID, location plan

What has to be done	What can go wrong	How to reduce the risk	Reference
	Temperatures above 6°C speed respiration and ageing. Most diseases in storage develop best in slightly higher temperatures than optimum storage temperatures. Low temperature injury can occur at temperatures just below freezing.	Optimum seed storage temperature (tuber pulp temperature) is 3°C-4°C Keep a stable tuber pulp temperature. Monitor pulp temperature daily during pull-down until tuber temperature is stable. If tuber temperature increases or decreases, change the supply air temperature. If condensation forms but tuber temperature is as required, install small circulating fans. Ensure the set temperature in older stores with poor air circulation is above 3°C, to avoid potential freezing damage.	
Monitor air temperature in different parts of the store	Chilling injury can occur if temperatures go to 2°C or less. Tissue damage, as internal browning can occur. Freezing injury occurs in tubers at temperatures just below freezing and needs only short periods of time for the injury to occur. Freezing damage can lower quality and shorten storage life, without visible signs. Storage above 4°C can lead to sprouting of the apical, dominant bud (eye) and inhibit sprouting of other buds (eyes). Storage above 4°C increases respiration and so weight loss (burning up sugars) and physiological ageing. Most pathogens favour higher temperatures. Sprouting and diseased (stressed) tubers produce more respiratory heat and CO_2 than dormant ones. They may affect store temperature and atmosphere.	The better the airflow, the more even the temperature distribution. Do not use store set temperature as a measure of store air temperature. If feasible, insert store's temperature probe inside an empty jar or tin that has been lowered into the middle of a potato bin. Take measurements with a hand held temperature probe at different points in the store to confirm even temperature distribution (not to vary more than 1°C). Place temperature probes attached to data loggers in different places in the store and inside bins to monitor temperature changes over time. An automatic warning system can alert when temperature is outside the desired range. If temperature distribution is not even, varieties can be put in different parts of the store according to temperature requirements and store performance. Adjust supply air temperature if tuber temperature goes up or down. If condensation forms but tuber temperature is as required, install small circulating fans.	Page 42-43: Condensation and weight loss

Storage (cont)

What has to be done	What can go wrong	How to reduce the risk	Reference
Store humidification	When humidity is less than 95%, tubers dehydrate, lose weight and go soft. Pressure from other tubers depresses the dehydrated tuber surfaces causing pressure bruises. Bruises persist if humidity stays below 90%. Tuber quality is lowered and affected areas become susceptible to black spot bruise when handled. Uneven humidity can exaggerate disease problems or leave some lots too dry. Problems can only be fixed, if known. When relative humidity is above 90% in poorly designed stores, condensation is likely, particularly on the roof, and free water may drip onto tubers resulting in breakdown.. If the water supply to the humidifier is not clean (no filter), plant disease and human health issues arise.	Monitor storage humidity weekly with hand held humidity probe. Monitor daily or more frequently when pulling temperature down at the beginning of storage. For normal storage, maintain supply air relative humidity (rh) at near 98% to achieve storage humidity for seed of 95% relative humidity. Poor crop condition or storage design (poor insulation and too much condensation) could require lower rh for safe storage. Humidifiers are the only way of adding enough moisture to the air. Install the humidifier immediately downstream from the fan(s). When relative humidity is more than 90%, a humidistat is inaccurate so of limited value for automatically controlling humidity in a potato storage. Design of a humidifier is critical and requires an expert in ventilation and humidification. The humidifier should be wired so it can't operate without fans running. Condensation can usually be controlled by enough ventilation and airflow unless the store is extremely poorly insulated. If tubers have some level of breakdown, maintain lower humidity to keep the decaying tissue relatively dry and reduce disease spread to other tubers.	Page 42-43: Condensation and weight loss
Prevent carbon dioxide accumulation and oxygen depletion in different parts of the store.	Very low oxygen levels cause black heart from suffocation and death of tissue. Damaged or diseased tubers have a higher respiration rate and use oxygen quicker, producing more CO_2 and heat at the same time. High CO_2 and low oxygen levels may lead to suffocation, (changing respiration from an aerobic process to an anaerobic process). Oxygen depleted seed will usually fail to germinate and break down when planted.	If CO_2 sensors are available, activate fresh air intake whenever CO_2 exceeds 2%. Alternatively, use oxygen sensors and activate fresh air exchange when oxygen falls below 19%.	

What has to be done	What can go wrong	How to reduce the risk	Reference
Ethylene eliminated from the store	Accelerated physiological ageing, loss of dormancy, and accelerated sprouting may all occur.	Ethylene levels should be below 0.1ppm Ethylene control options include: • Use only electric forklifts in the store. • Keep fruit out of the store. If the store was used for fruit, send an air sample to a laboratory with a gas chromatograph to detect residual ethylene levels. • Fresh carrots turn bitter in excess ethylene. Use them as an indicator in the seed store.	
		Odours are one of the best indicators of storage problems.	
Ventilation / air circulation through stacks of bins	Poor ventilation leads to accumulation of CO_2 in localised areas and accompanying tuber stress, uneven ageing and uneven emergence. Too much ventilation promotes dehydration of tubers and susceptibility to pressure bruise. Ventilation air temperature of more than 4°C above tuber temperature will cause condensation on tubers. Tubers on the bin surface will become colder than in the bin centre, which can cause warm air from the bin centre to rise and its humidity to condense on colder tubers on top of the bin as it cools down there. Bins containing mixed sizes from very large to very small and / or dirt may be poorly ventilated as well due to the small residual air pockets and places where can flow in a mixed size stack.	Use extra fans (eg. in headspace) and / or deflectors (on structural obstacles) to ensure uniform air movement. Make sure bins are level over the entire store. Locate bins with mixed size tubers where airflow is highest. The best systems blend air to the correct temperature, add humidity and blow it through the potato bins. Ventilation rates for seed potatoes are 3-6 [m3/min/t] when cooling down. Once long-term storage temperature is reached, ventilate intermittently for 2-6 hours per 24 hours or enough to maintain target tuber temperatures throughout the store. Choose ventilation fans to provide desired airflow at a fixed pressure of 0.30 - 0.35 [kPa] and a maximum air velocity of 5 [m/s]. A qualified person should design a suitable ventilation system. Ventilation meters are available that measure ventilation (velocity) as well as temperature, differential pressure, humidity, dew point, wet bulb temperature and heat flow.	Page 42-43: Condensation and weight loss
Condensation checks	Condensation and wet tubers will support development of diseases and rots.	Ensure no water drips from store roof and construction parts into bins	

Storage (cont)

What has to be done	What can go wrong	How to reduce the risk	Reference
Frequent tuber inspections to manage storage problems (sprouting, bruising, bacterial soft rot, weight loss)	Loss of seed quality, a percentage of tubers and / or yield potential of the following crop. Contamination of clean lots. Weight loss in storage should not be greater than 5%. There should be no untimely sprouting and no rots. If there is condensation, increase circulating fan speed. It rots are found, isolate the lot, cure and re-grade, if possible.	Before curing, bag any 20 tubers from 20 bins and put them among the top tubers in a marked box. Every week, remove and weigh them in the storage area and inspect for sprouting, rots and condensation. Odours are one of the best indicators of storage problems, Especially if soft rots are found, completely open outside air intakes and increase ventilation rate until the diseased potatoes dry up. This is best done after isolating the affected lot. An infrared gun that picks up heat generation can identify hot spots from the increased respiration of rotting tubers. Auxiliary fans may be used on hot spots.	Page 42-43: Condensation and weight loss Page 47: Field diseases causing storage problems
Preparing seed tubers for removal from the store	Moisture condensing on seed making them wet and encouraging rots.	Before moving seed, tubers should be slowly warmed to a pulp temperature of at least 7°C by increasing the delivery air temperature in increments of 0.5°C to maximum 2°C per day until the desired pulp temperature is reached.	

Cutting

What has to be done	What can go wrong	How to reduce the risk	Reference
Decision on timing of seed cutting	Seed is cut too early, leading to seed piece breakdown. Pre-cutting may not be successful due to poor timing and procedures. Seed is removed from store too late and does not warm up sufficiently before cutting begins.	Schedule seed for removal from storage about 3 weeks before planting date. Review continually depending on progress with planting and paddock preparation. Pre-cutting can be used to increase the flexibility of the planting operation.	Page 50-51: Evaluating physiological age
Equipment maintenance and calibration (fungicide applicators)	Poorly calibrated or worn nozzles can lead to uneven fungicide application, risking seed piece breakdown or lack of protection.	Repair, calibrate and test equipment as required in good time.	
Disinfect all equipment	Disease transmission and seed piece breakdown. Cross contamination between seed lines.	Disinfect before each seed cutting session, and between seed lines. Dip or spray; surfaces must remain wet for at least 10 minutes for the disinfectant to destroy disease organisms. Keep a pair of rubber boots soaking in disinfectant and change boots when entering the store.	Page 39: Disinfectants for store, bins, equipment
Warm seed prior to cutting	Slow, uneven emergence if seed is used straight out of cold storage. Long sprouts are tender and susceptible to mechanical damage. Cutting cold seed (less than 10°C) will tend to shatter the seed rather than slice it. This increases disease and seed piece breakdown risks.	Before cutting, (or planting after pre-cutting and re-storing) slowly warm seed to about 13°C (10°C-15°C) over about 10 days. If sprouted, warm to 10°C and cut as soon as that temperature is reached. If planting is to be delayed, use through-the-bin-ventilation with a large volume of high humidity air to help slow sprout growth. Chitting is another option for pre-spouting.	Page 50-57: Evaluating physiological age
Cutting operation	Too many pieces which are either too small or too large (leading to a poor seed uniformity, and an uneven commercial crop). Large seed pieces have a larger cut surface; more stored energy will be used on wound healing and less is left to support new plant growth. Large seed pieces do not flow well in many planters, leading to mechanical misses. Bruise problems are more severe with large cut seed pieces. Most cut seed piece bruising happens on seed edges after cutting. Excess bruising increases risk of seed decay. Blunt instruments rip and create an area for disease attack.	Seed tubers above 300 g are not suitable for use on certain seed cutters and need to be graded out first and then cut by hand. It is best to not use these large tubers at all. Seed pieces should have 2 or 3 eyes and preferably weigh around 50g-75g Collect sub-samples of 100 seed pieces and examine for number of eyes per seed piece and the number of blind sets. If more than 2 blind sets per 100, adjust seed cutter. Keep the number of cut surfaces per tuber to a minimum to reduce bruising during handling and planting. Keep cutter knives sharp and straight. Check and sharpen cutters or knives before each seed cutting session and between seed lots. Protect cut seed from dehydration and bruising.	

Cutting (cont)

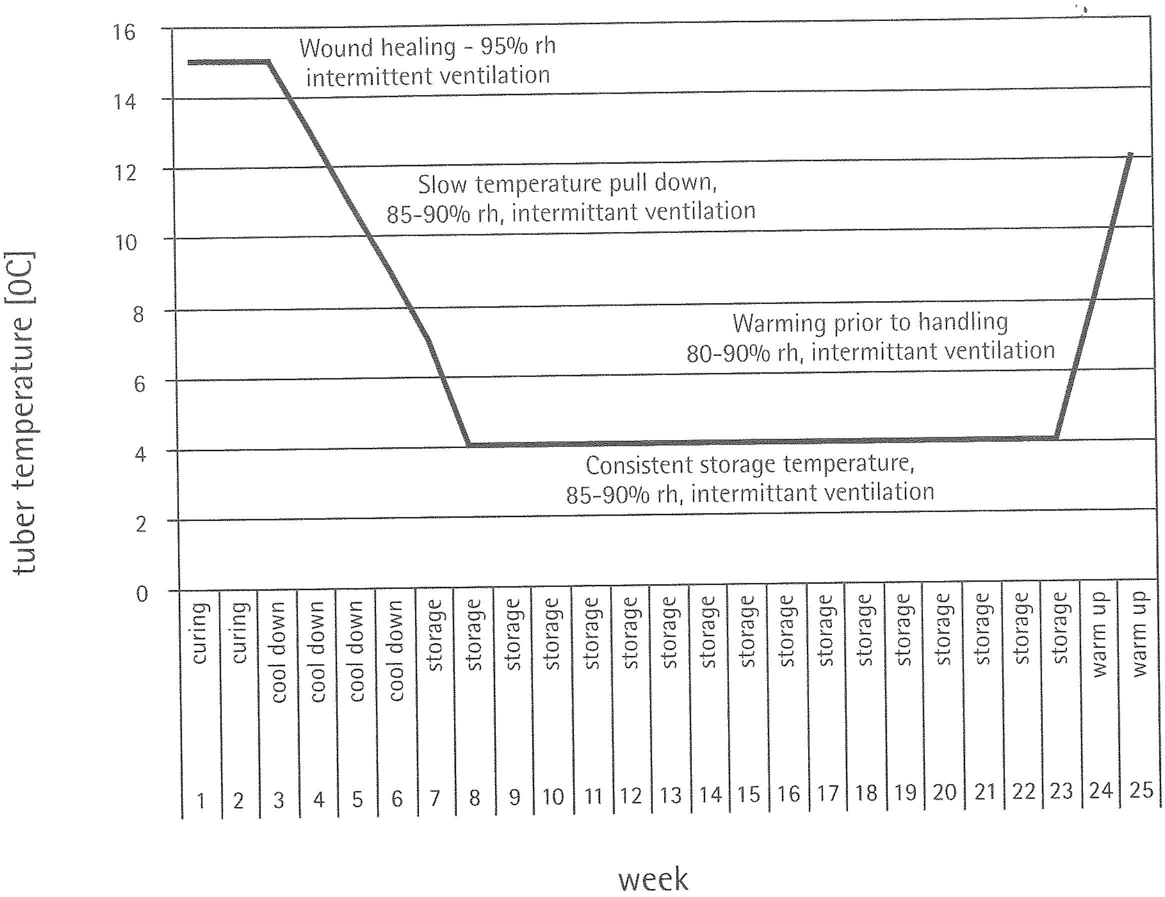
What has to be done	What can go wrong	How to reduce the risk	Reference
Pre-cutting of seed and re-storing - any time between harvest and 4 weeks before planting ('normal' cutting should occur 2 - 3 days before planting)	CO_2 can build up after cutting while the cut surface is suberising, and this can interfere with wound healing. Pre-cutting by machine can be risky due to poor disinfection of cutters, blunt cutters, little grading out of diseased or damaged tubers before cutting. Higher curing temperatures may favour disease.	Pre-cutting and storing seed can help spread the work load and reduce weather related risks at planting time. However, this practice should not be attempted on a large scale if recommended temperature, air flow, and humidity cannot be provided. After warming and cutting, cure at 13°C-16°C with humidity levels of 90%-95% and good air movement and fresh air supply for about 10-14 (an absolute minimum of 5) days. The higher the temperature, the shorter the curing time. Cool down slowly, as for seed after curing. A room may have to be set aside for warming and curing before and after pre-cutting. Hygiene is easier to maintain with hand cutting and staff can discard diseased or damaged tubers.	Page 49: Pre-cutting
Determine seed size Remove small seed pieces before planting	Poor crop performance if small seed pieces are kept. A better plant stand and more vigorous plants compensate for the extra cost associated with removing these pieces.	A seed lot with an average seed-piece with of 60 g has potential to produce high yields, provided the lot contains a high segment of single cuts. Pieces less than 40 g to be discarded.	Page 48-49: Seed cutting guide
Good air circulation and uniform temperature (curing) after cutting, before planting	Condensation on or moisture oozing from cut surfaces, poor suberisation, seed piece breakdown. Poor air circulation causing carbon dioxide build up which can damage tubers invisibly, leading to poor seed performance. Cut seed planted too early after cutting or too late is prone to seed piece breakdown.	Keep seed held after cutting and before planting in a well ventilated area or room with good air exchange, relative humidity of 90-95% and a temperature of about 13°C-16°C for 5 or more days. Seed should be held for 24 to 48hrs after cutting before planting.	Page 42-43: Condensation and weight loss
Treatment with appropriate products after cutting	Some varieties (especially the early maturing ones) are more susceptible to Fusarium and are low in forming wound-healing substances.	Consult with local suppliers about products, label rates and safe application procedures (obtain Material Safety Data Sheets - MSDS).	
Warm pre-cut seed prior to planting	Dormancy not broken prior to planting. Injury during planting, poor crop performance.	At planting, check seed is from 10°C-18°C to match soil temperature. If soil temperature is below 10°C, aim for a seed temperature of 10°C.	

Seed transport from store to commercial/seed grower and pre-planting

What has to be done	What can go wrong	How to reduce the risk	Reference
Removal from store	Transporting tubers that are close to storage temperature (4°C) can lead to shatter bruise. Cutting seed tubers that are too cold will lead to shattering.	Before moving uncut tubers from storage, increase tuber temperature in 0.5°C to 2°C increments per day to a temperature of 10°C. Then warm them to 15°C just before shipping to stimulate healing if cut, and rapid sprouting after planting.	
Preparation of transport documentation, (Con-note and seed history documentation) including warning labels for one-tonne bags	Breakdown due to lack of air and / or condensation Wrong treatment of seed on arrival.	Prepare documentation well ahead of transport. Talk to the recipient of seed and point out possible issues in regards to seed handling. Label one-tonne bags: 'empty bag on arrival'.	
Match tuber temperature with soil temperature	Planting far colder seed than the soil temperature will delay emergence. Slow emergence makes tubers and emerging shoots more prone to disease attack.	If soil temperature is below 10°C, increase tuber temperature to 10°C before planting, or match it to soil temperature (10°C-18°C). If it is not possible to warm the tubers inside the store, move them to an area that maximises airflow through the boxes until the desired temperature is reached. The area should be out of direct sunlight and protected from rain.	
Transport from store to commercial grower	Seed can become wet as a result of moisture from condensation. Seed is damaged due to handling when too cold.	Monitor the likely air temperatures during transport and seek to have the seed no more than 4°C cooler. If the weather is cool, you can let tuber temperatures increase from an initial 7°C to 15°C or the desired planting temperature while transporting, if this can be controlled. It is better, however, to transport at 15°C.	
Receipt and holding of tubers after transport, before cutting or planting	Seed can become starved of oxygen as it attempts to heal damaged areas after transport handling.	After seed is received, remove it from the truck at once and store in a clean area out of direct sunlight, designed to maximise airflow around tubers. Seed should be cut or planted as soon as possible.	

REFERENCE INFORMATION

Ideal temperatures to aim for the 'in store period'



The pros and cons of different store designs and storage containers

Custom built seed potato stores are ideal, as they have in-built technology to make it easy to meet the requirements of stored seed at each stage. However, without understanding seed requirements and appropriate store operations, even the best and most expensive technology will not lead to the desired result.

The aim with any store design is to fulfill seed requirements as best as possible.

The most important aspects are:

- Ability to maintain a set temperature
- Even air and tuber temperature distribution throughout the store and containers (bins)
- Ability to provide ventilation and good airflow throughout the store and bins

The way the store is stacked can have a major influence on how well seed quality can be maintained in any type of design

- Keep store and bins clean (separate sick from sound lots)
- Do not use gas or diesel forklifts inside the store or around seed in a confined space or close to vents. Ethylene from the exhausts will act as an aging catalyst
- Keep at least one bin space head space and 30cm clearance from walls and between stacks
- Avoid condensation on roofs and walls

If a store does not fulfil these basic requirements, address the most damaging problem first and get expert advice

- Consider extra fans in ceiling or mobile fan units for door openings
- Consider building a letterbox type system for curing and treatment of wet or infected lots
- Consider using storage bins with wide gaps between slats to allow air exchange in bins.

A lack of curing, omitting the slow temperature pull-down to reach storage temperatures or slow warming of seed before handling may have detrimental effects, even if in-store holding conditions are appropriate.

Take home messages:

Try to understand the needs of potato seed at any stage of handling and storage and fulfil them as well as possible.

Address problems that cause the biggest loss in quality first, prioritise others.

Address all issues that do not cost anything or little extra ASAP (planning, communication, monitoring, hygiene).

Get professional help before problems occur.

Condensation

Tubers sweat or have free water on them

Possible Cause(s)	Possible Solution(s)
• Potatoesin the bin center are warmer than on top. • Warm,moist air from recently added bins hits cold tubers. • Outsideair leaks into the store or hits cold seed after it's removed from storage. • Suddendrop in outside temperature causes headspace air to cool and condensation on cold surfaces. • Defrostwater from evaporator coils drips on produce. • Humidificationsystem droplets are too large. • Theroof is not well insulated and outside is cooler than store temperature, so water condensing on the ceiling drips on top bins.	• Keep cold seed already stored for long periods in a separate room from warm seed that is to be cooled; install more refrigeration to reduce dramatic air temperature increases. • Allow seed coming out of storage to warm up gradually; condensation is unavoidable if seed is put directly into a warm, moist atmosphere. • Drain condensation away, that is from ceiling and walls using drip trays; let it run onto the floor, if possible, to help humidify the store. • Install humidification equipment that can supply ultra-fine or atomized mist.

Walls, other structural components and/or ceiling are covered in condensation

Possible Cause(s)	Possible Solution(s)
• Interior surfaces are colder than the room air hitting them.	• Install more insulation to warm wall surfaces above the room air's dew or saturation point. • Provide better airflow (recirculation or top ventilation) in affected areas. • Heat the headspace.

Ceiling is dripping

Possible Cause(s)	Possible Solution(s)
• Poorroof room ventilation allows a build up of hot, moist air in the roof space above the store ceiling. • Insufficientroof and ceiling insulation causes condensation, which drips through cracks. • Improperinstallation or missing vapour barrier.	• Provide 1 m^2 of unrestricted air inlet / vent area into the roof space for every 600 m^2 of ceiling, and some unrestricted ventilation area in the peak (if the roof is not flat), or forced ventilate the roof area at 1 air change every 2 minutes. • Add insulation to prevent the warm, attic side of the insulation approaching the cold temperature of storage below. • Vapour barrier position depends on vapour pressure drive direction i.e. whether the water vapour would move from inside the store to the outside or the other way round. This depends on your climate (temperature, relative humidity); a vapour barrier may not be advisable depending on building use.

Floor is drying out even if floor is sprayed with water to keep up humidity

Possible Cause(s)	Possible Solution(s)
• Storagerelative humidity is too low. • Floorshave cracks for water to escape.	• Flood floors to see if water runs away, especially along concrete foundation; seal if necessary. • Install more coils so they can operate at less temperature difference between cold air leaving the coils air seed "feels"; this reduces air drying out. • Install humidification equipment that can supply ultra-fine or atomized mist.

Shriveling and weight loss, pressure bruises

Possible Cause(s)	Possible Solution(s)
• Storagerelative humidity too low. • Vapourpressure differential too high; warm, moist seed versus cold, dry air. • Woodencontainers and storage structure itself is drawing moisture out of the air and seed.	• Install more coils so they can operate at a lower temperature difference between cold air leaving the coils and air seed "feels". • Install humidification equipment that can supply ultra-fine or atomized mist. • Cool seed rapidly using the step by step approach after curing to reduce vapour pressure difference between seed and storage air, so there is less incentive for moisture to leave it, causing shrivelling. • Wet walls and floor as well if possible (this will not alleviate problems with really low humidity due to high intake of low humidity fresh air). • Reduce fresh air intake without suffocating seed.

The store environment - Troubleshooting

Inside air temperature fluctuates during storage period

Possible Cause(s)	Possible Solution(s)
• Thermostatis not in the right position and does not sense (and represent) average room temperature. • Airflowisn't uniform throughout store. • Evaporatorcoils have too large a temperature difference across them. • Poorquality or insensitive thermostats.	• Install thermostats in average room airflow, usually in the return airflow to evaporator coils; relocate thermostats away from warm/cold walls, doors, lights, cold air leaving, the coils, or warm incoming seed. • Use a smoke generator to locate dead air spots; relocate evaporator coils or increase the capacity of their fans (if possible); install air tubes and/or extra fans; rearrange storage configuration to allow more uniform airflow. • Lower the temperature difference across evaporator coils, recognising this will potentially reduce capacity to remove heat. • Use good equipment, since uniform temperature control is vital to maintain seed quality.

Inside air temperature is warmer than desired during storage period

Possible Cause(s)	Possible Solution(s)
• Poorrefrigeration. • Insufficientinsulation inside when days are hot outside. • Poorattic ventilation. • Hotsunny days with dark, roof surface. • Airflownot uniform or not enough in the store. • Poorthermostat position; not sensing the range of temperatures.	• Install more refrigeration cooling capacity. • Install enough insulation in walls, attic, roof and on foundation. • Provide 1 m^2 of unrestricted eave inlet area per 600 m^2 of ceiling, with same unrestricted peak area, or mechanically ventilate at 1 air change per 2 minutes. • Paint roof chalk-white and ensure adequate attic ventilation, since attic temperatures can reach 6°C if the roof is dark. • Use smoke generators to locate dead air spots; relocate evaporator coils or increase their fan capacity (if possible); install air tubes and/or extra fans; rearrange storage containers to allow more uniform airflow. • Install thermostats in average room airflow, usually in return airflow to evaporator coils; avoid locating thermostats on outside cold walls, near doors, or near the cold air leaving evaporator coils.

Inside air temperature is colder than desired during storage

Possible Cause(s)	Possible Solution(s)
• Thermostatpoorly located; sensing warmer temperatures.	• Install thermostats in average room airflow, usually in return airflow to evaporator coils; avoid location thermostats on outside warm walls, or near doors or lights. • Install enough insulation in walls, attic, roof and on foundation.

Inside air temperature is not uniform

Possible Cause(s)	Possible Solution(s)
• Airflownot uniform or enough in store. • Short-circuitingof air directly back to evaporator coils because of poor bin arrangement inside the store, or overfilling.	• Use smoke generators to locate dead air spots; relocate evaporator coils or increase their fan capacity (if possible); install air tubes and/or extra fans; rearrange bins to allow more uniform airflow. • Avoid bin configurations that allow air to simply by-pass bins; air will always take the easiest path and must be forced by fans to travel a meandering path to cool best; use a smoke generator to inspect for short-circuiting.

The store air smells bad or is difficult to breathe

Possible Cause(s)	Possible Solution(s)
• Concentrationsof carbon dioxide, carbon monoxide and / or ethylene can be too high as a result of rotting tubers, intense respiration or gas / diesel forklifts.	• Look for and dispose of rotting seed. • If the store is not purpose built for best ventilation, install a small exhaust fan that allows at least 2 air changes/day. • Use electric forklifts inside and near the store.

Evaporator coils are icing up and run a lot of condensate

Possible Cause(s)	Possible Solution(s)
• Coilsrunning at too low a temperature. • Defrostsystem not running properly. • Storagerelative humidity is high but air circulation poor.	• Increase coil temperature; this may require larger capacity evaporator coils. • Repair defrost system or install a more effective one. • Install a more effective defrost method, since the relative humidity should be high.

Electrical consumption is rising

Possible Cause(s)	Possible Solution(s)
• Insulationis wet or missing. • Highervolume of seed being cooled than before. • Seedis entering storage at a higher temperature than in previous seasons. • Buildingless air tight or doors open more often. • Higherfresh air intake. • Malfunctioningrefrigeration equipment.	• Correct moisture problem and re-insulate with an insulation that is more suitable for cold stores. • Install more refrigeration as heat load increases; one rarely has 'too much refrigeration capacity', but the system should be properly sized to manage costs. • Get equipment serviced by a qualified refrigeration contractor familiar with the needs of seed stores.

Measuring pre harvest soil moisture

Soil Water Status Assessment

Soil water status		Behaviur of soils subject to field test		
		Sands, Sandy loams	Loams	Clay Loams, Clays
1	D - Dry (below plant wilting point)	Will flow through fingers or fragments. Will powder.	Will not ball when squeezed in hand. Fragments will powder.	Will not ball when squeezed in hand. Fragments will break to smaller fragments or pads.
2	T - Moderately Moist (drier half of available moisture range)	Appears dry. Ball will not hold together.	Forms crumby ball on squeezing in hand.	Will ball. Will not ribbon.
3	M - Moist (wetter half of available moisture range)	Forms weak ball but will break easily.	Will ball. Will not ribbon.	Will ball. Will ribbon easily.
4	W - Wet (at or more than field capacity)	Ball leaves wet outline on hand when squeezed, or is wetter.	Ball leaves wet outline on hand when squeezed, or is wetter, sticky.	Ball leaves wet outline on hand when squeezed, or is wetter. Sticky.

Monitoring the in-store environment

Storage Facility

Store ID

Variety

Delivery Date

Storage Operator/Supervisor

Contract No

Please tick: Curing phase ☐ Storage period ☐

Date	Average tuber temperature	Humidity		Air temperature		CO_2 % in different store positions			
	Use a quality hand held temperature probe or install temperature probes with data loggers. Consult a coolstore technician about hand held or logger connected options	*If your store does not have automated monitoring of humidity and air temperature, consult a coolstore technician about handheld or logger connected options, use handheld probes once a day and record time of measurement with results*				*(e.g. select at least 4 different positions per store, including at least 2 areas where airflow may be poor)* *For CO_2 monitoring equipment, consult a coolstore technician*			
	Measure 10 tubers per box, sampling 1 box in every 20	Return air	Return air	Return air	Return air	1	2	3	4

Assessing grading line damage potential

Inspect 20 tubers after each suspected damage point. Repeat after fixing the damage points. Spray painted tubers or hard boiled eggs will show damage points easily. An electronic potato may be used for a thorough assessment of all grading and handling equipment. (Contact your local government department of agriculture for more information.)

The following table will help you assess potential damage areas over time.

Date	Number of tubers collected at damage point											
	1		2		3		4		5		6	
	Total	Dam.	Total	Dam.	Total	Dam.	Total	Dam.	Total	Dam.	Total	Dam.

Assess damage as part of an established Quality Assessment procedure

Determining cut seed size

Checking a weighed, sorted **5 kg sample** can determine any required cutter adjustments.

- At the start of cutting each different seed lot, collect a 5 kg sample of cut seed.
- Make up **six containers** for weighed seed pieces (groups 1-6 listed in the table below).
- Weigh each seed piece from the sample using a **scale**, accurately weighing in grams, and place the weighed seed piece in the appropriate container.
- Count the seed piece numbers in each group and record in table.
- To calculate the percentage of pieces in each group, add up the total number of seed pieces (5 kg sample), divide the seed piece number in each group by the total and multiply by 100.

Seed Piece Size Assessment

Cutting Supervisor

Contract/Job No

Seed Grower/Lot

Cutting Date

Variety

Contract No

Record dates or number of days

Cutting Time

Storage time

Pre-cutting warming time

Group	Weight class	Seed piece number per group	% in each group	Target %	
1	< 29 g			0	
2	30 g - 40g			0	
3	41 g - 55 g			10-30	70-75
4	56 g - 69 g			35	
5	70 g - 85 g			10-30	
6	>86 g			0	
Number of seed pieces in the 5kg sample = Total					

The ideal distribution for, e.g. Russet Burbank would be 70 - 75% or higher in groups 3-5 (41 - 85 g), with 35% in group 4 (56 - 69 g).

Adjusting the early curing environment if harvest conditions are not ideal

Storage Facility

Store ID

Variety

Delivery Date

Storage Operator/Supervisor

Contract No

Soil temperature at harvest	Tuber temperature at harvest	Soil moisture at harvest

Curing approach to take: 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐

1. If soil and tuber temperature above **25°C** and soil is **dry** at harvest:
   - Run the fans and the humidifier continuously during store filling until tuber temperature is 15°C (aim for 95% rh)
   - Supply air should be 1-2°C below tuber temperature during cooling down

2. If soil and tuber temperature above **25°C** and soil is **wet** at harvest:
   - Run fans continuously with the humidifier off until all free moisture is removed from tubers
   - Supply air should be 1°C-2°C below tuber temperature until it is 15°C

3. If soil and tuber temperature is **10°C–15°C** and soil is **dry** at harvest:
   - Run fans intermittently with humidification (aim for 95% rh)
   - Supply air temperature 0.5°C-1°C lower than tuber temperature

4. If soil and tuber temperature is **10°C–15°C** and soil is **wet** at harvest:
   - Run fans continuously without any humidification until tubers are dry
   - Supply air temperature 0.5°C-1°C lower than tuber temperature

5. If soil and tuber temperature below **10°C** and soil is **dry** at harvest:
   - Run fan and humidifier intermittently (aim for 95% rh)
   - Supply air temperature 0.5°C-1°C higher than tuber temperature until tubers are at 10°C-13°C

6. If soil and tuber temperature below **10°C** and soil is **wet** at harvest:
   - Run fans continuously without humidifier until tubers are dry
   - Supply air temperature 0.5°C-1°C higher than tuber temperature until tubers are at 10°C-13°C

Once ideal curing conditions are reached, intermittent ventilation is required to provide oxygen.

Delivery notes

Delivery Note to Store -

Seed crop health management and harvest management

SEED DELIVERED IN ONE TONNE BAGS MUST BE EMPTIED ON ARRIVAL TO ALLOW SEED TO BREATHE – DO NOT STORE THE SEED IN THESE BAGS

Grower / Contract number	
Paddock ID	
Variety	
Planting date	
Harvest date	
Crop spray schedule attached	Yes ☐ No ☐ Will be faxed to number:
Disease risks *(please list)*	
Adjustment to curing conditions required *(please list)*	
Adjustment to storage conditions required *(please list)*	

Delivery Note to Store - Harvest Conditions

Soil temperature at harvest	
Soil moisture at harvest see Assessment sheet 1	
Adjustment to curing conditions required *(please list)*	
Adjustment to storage conditions required *(please list)*	

In Victoria, a pre-printed seed delivery docket book is available from Seed Potatoes Victoria. Ph (03) 5622 3025 – example below

Victorian Certified Seed Potatoes

GROWER'S NAME:

GROWER ADDRESS:

TELEPHONE: MOBILE:

FAX: ABN:

Consigned to:

Date:

Name of purchaser:

Address of purchaser:

We have this day consigned to you, via the carrier listed below, the following produce:

AGRONOMIC INFORMATION

Seed Lot Code or Paddock Number	Generation	Variety	Irrigated / Dry Grown	Planting Date	Top Removal Date or Month of Senescence	Harvest Date	Post Harvest Chemicals	Date of Packing

GRADING INFORMATION

Package Type	Number	Quantity (tonnes)	Label number (Start)	Label Number (Finish)	Size Range

PRICE $/T excl GST	$
TOTAL excl GST	$

CARRIER DETAILS

Company	Registration No
Trailer Type	Departure Time
Drivers Signature	Departure date

10 % GST	$
TOTAL incl GST	$

Special Instructions

Signed by

Example of store bin ID and location plan

Storage Facility

Store ID

Storage Operator/Supervisor

STORE PLAN (copies may be used to record store climate and atmosphere)

Mark doors, location of cooling equipment and fans and numbers rows of bins

Row No.	Date entered store	Variety, generation/ paddock ID	Grower ID	Contract No.	No. of bins	No. of stacks

Caclulating pre-grading, grading, curing and storage capacity alignment

HARVEST CAPABILITY tonnes/ha

GRADING CAPABILITY tonnes/hour

STORAGE CAPACITY tonnes

Consider airflow, headspace and gaps between bins when calculating storage capacities

Crop ID	Variety	Generation	Expected paddock yield [tonnes]	Expected1 graded yield [tonnes]	Harvest date	Capacity [tonnes] per day	Grading date	Actual graded tonnes per day	% of curing area filled	% of storage area filled

Disinfectants as sanitizers for stores, bins and equipment

The first and most important step in disinfecting shed and store surfaces (floors, grading equipment, boxes etc) is to remove all traces of soil and organic debris (remains of rotted potatoes) by washing with hot soapy water or high pressure steam. In most situations, it isn't necessary to follow up with a disinfectant, provided surfaces are thoroughly cleaned and dried. Bins can be freed of debris, cleaned with a hot pressure washer and dried in the sun for effective sanitation.

Effective sanitation requires a thorough cleaning of all surfaces before a disinfectant is applied. Avoid sweeping, – vacuum floors of sheds and stores. Soil, clay particles and organic material quickly make many classes of disinfectants ineffective.

Most disinfecting materials require that treated surfaces stay wet for up to 10 minutes (15 minutes for chlorine) to assure death of residual bacterial and fungal spores. Adding a wetting agent to the spray solution may help keep surfaces moist for the required time. When disinfecting solutions are used to dip knives, crates, picking baskets or foot dip tanks, the solution should be changed often, definitely between seed lots, to avoid it becoming ineffective.

Material	Effectiveness		Inactivation		Corrosiveness	Safety	Required concentration	Expiry Time	Shelf Life
	Wet bacterial slime	Dry bacterial slime	Organic Matter	HardWater (high calcium carbonate)					
Quarternary Ammon. Cpds.	Excellent	Excellent	Slight	No	Slight	Caution	See Label	10 min	1-2 yr
Hypochlorites, 5.25% bleach	Excellent	Excellent	Yes	No, excellent Iron	Yes	Irritant, caustic	1:50, 0.1%	10 min	3-4 months. Undiluted
Iodine Compounds.	Excellent	Excellent	Slight	No, excellent Iron	Yes	Caution	See Label	10 min	1-2 yr
Phenolics	Excellent	Excellent	Slight	No	Yes	Oral poison	See Label	10 min	1-2 yr
Copper Sulfate	Good	Good	No	Yes	Yes	Caution	0.1kg/100L	30-60 min	>10 yr as solid
Peroxygens	Excellent	Excellent	No	No	Yes (to most metals	Caution	Higher concentrations to those recommended on labels (eg 5% instead of 1%)	60min + (but it is not residual)	12 months

[1] [Adapted from: Disease Control Guidelines for Seed Potato Selection, Handling, and Planting, Extension Publication PP-877, North Dakota State University. Registrations may vary. Check with local authorities.

Comments:

Quarternary Ammonium Compounds:

Diluted solutions are relatively safe but the concentrated form is poisonous. Slightly corrosive, use stainless steel containers to make up the solution.

Hypochlorites - 5.25% bleach

Quick acting, inexpensive; caustic to skin and clothing. Use at 1:50 when mixing with water only. For maximum effectiveness, use 1 part 5.25% bleach: 200 parts water: 0.6 parts white vinegar. Very corrosive.

Iodine Compounds

Not for internal use. Becomes ineffective as yellow-brown color is lost. Tamed iodophor compounds work best.

Phenolic Compounds

Provide residual action. These compounds show "phenol" in the list of ingredients. Commonly used in hospitals.

Peroxy compounds

Mixtures of the oxidising agents peroxyacetic acid and hydrogen peroxide. These compounds are effective on hard surfaces, including equipment. Less prone to inactivation by organic matter than chlorine compounds

Copper Sulfate

Not widely used; mostly for soaking crates and bags.

Chlorine based disinfectants

They are one of the popular groups of disinfectants used in the industry. Chlorine is a surface sterilant. It is fogged into potato stores to kill fungal and bacterial spores on the potato skin, as well as on all other exposed surfaces (walls etc). The most common chlorine-based disinfectants are sodium hypochlorite, chlorine dioxide and calcium hypochlorite. Chlorine dioxide can be used as a general-purpose sanitiser. The two hypochlorite containing chlorine compounds mentioned form the spore-killing active ingredient hypochlorous acid when added to water. In this case the disinfectant activity of a chlorine solution is influenced by its pH. The pH is the measure of whether a solution is acidic or alkaline. The lower the pH (more acidic), the greater the amount of hypochlorous acid formed from the chlorine compound. This is why it is important to apply the right mix in water. Very low pH caused odour problems and corrodes equipment. Above pH 7.5 (slightly alkaline), hypochlorous acid will dissociate to form the hypochlorite ion, which is less toxic to fungi and bacteria. Therefore, for the most effective chlorine disinfectant, the pH should be maintained between 6.0 and 7.5. At this pH, damage to the equipment will also be minimal. The pH of the tank mix can be checked by using pH test paper (which changes colour at different pHs) or by using pH meters. The chlorine dioxide-based disinfectants are active at pH 2.3 to 2.5.

Other factors to consider when using chlorine disinfectants

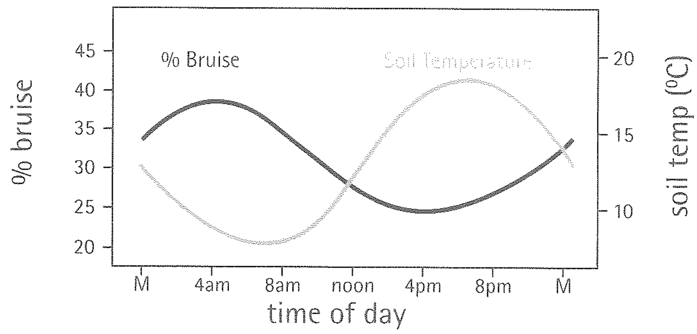
- Organic Matter: Chorine reacts with organic matter, reducing its effectiveness as a disinfectant. The more organic matter in the solution, the more chlorine is tied-up. This organic matter in the water can be a critical problem. Consequently, dip tanks used for bins and other equipments should be cleaned at regular intervals.
- Temperature: Chlorine exhibits a complex reaction to temperature. Generally, as temperature increases chlorine becomes more active as a disinfectant. However, raising the temperature increases the ability of organic matter to tie-up chlorine. In addition, raising the temperature also speeds up the loss of chlorine into the atmosphere.
- Exposure time: As exposure time to chlorine is reduced, less disinfection occurs. A minimum of 15 minutes of exposure to chlorine is needed to adequately disinfect. However, efficient disinfection depends on accurately monitoring chlorine concentration in the supply tank. Treatment is most effective when chlorine is metered continuously. It is ineffective to simply dump chlorine into a tank. For fungi, an effective concentration of 500 ppm of free chlorine is required. This is not a case of "if a little is good, more is better". If the chlorine concentration is too high or if pH of the chlorine solution too low, chlorine gas is wasted into the air. This creates an odour problem,

wastes chlorine, and corrodes equipment. It is better to meter the chlorine and control solution pH than double the chlorine in the solution. An automatic dosing system is recommended. Do not use chlorine for seed treatment, it is intended for sanitizing of equipment and surfaces that come in contact with seed tubers. Chlorine dioxide is fogged into stores as a sanitiser prior to loading.

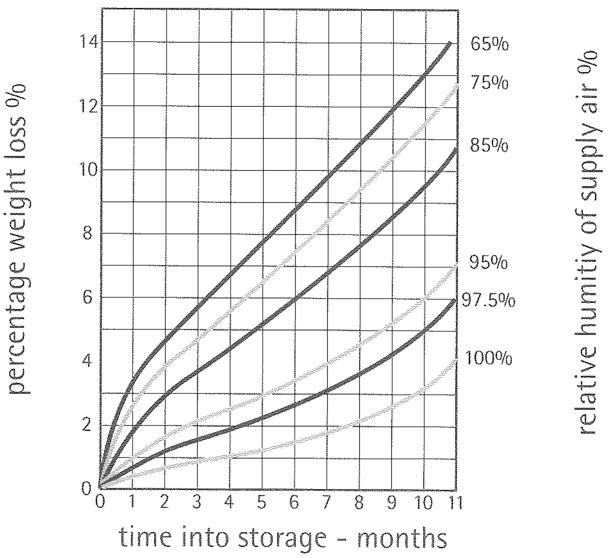
Live steam may be used to sanitise. It is effective in removing the dirt and debris but may not sanitise effectively as is difficult to consistently maintain the required temperature. The temperature of the steam contacting the surface to be disinfected must exceed 66°C. Caution: Do not confuse condensed water vapour with colourless steam. Condensed water vapour (clouds) may be at less than the required temperature. Exposure time should be five seconds for fresh, wet bacterial material, and 20 seconds for dried bacterial material. Steam must be used properly to be effective. Do not rush steam cleaning. Steam may be more useful for equipment, rather than the entire store, because of the need for high temperatures and the small surface area covered with a steam appliance. A contractor-operated technique of fogging stores with steam/air used in the fruit industry for disinfection may be suitable. Contact local experts/suppliers for more information.

Temperature and hydration effects on physical tuber damage and tuber weight

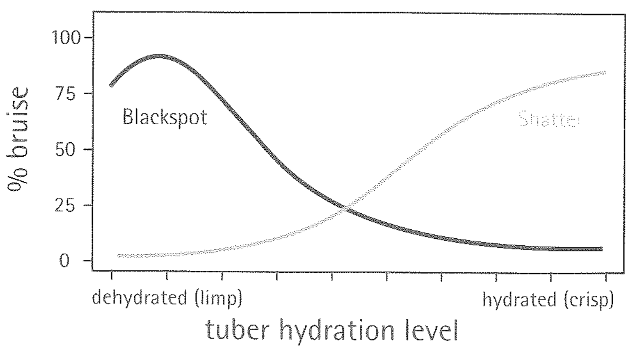
Relationship between soil temperature, tuber damage, and time of day during potato harvest



Weight loss as influenced by relative humidity and storage time

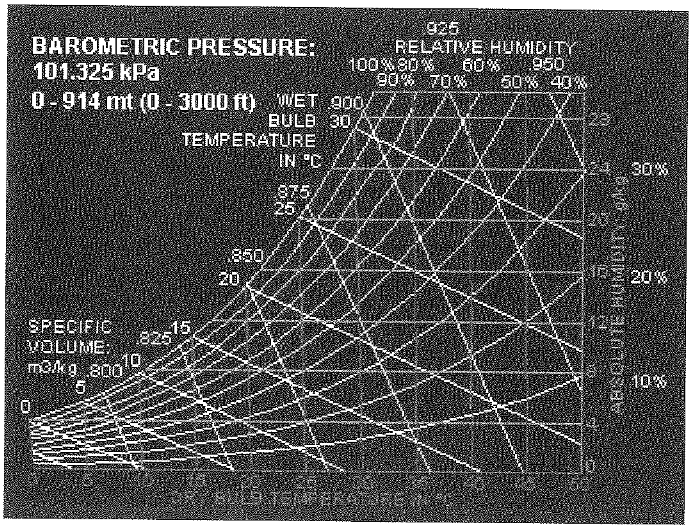


Effects of tuber hydration level on shatter and black spot bruise at 7°C-10°C



Condensation and weight loss

The following chart shows the relationship between water vapour and dry air and can help give a complete picture of humidification and condensation in a potato store.



What the psychrometric chart measures:

The chart shows the following properties of moist air:

1. Dry bulb (air) temperature (vertical lines: 0°C-50°C)

2. Absolute humidity (horizontal lines: 0-28 g/kg)

Absolute humidity is the water vapour content of air, given in grams of vapour per kilogram of air (g/kg). Air at a given temperature and pressure can support only a certain amount of moisture and no more. This is referred to as the dew point (or saturation humidity). When plotted on a graph against the dry bulb (air) temperature, it shows what is called the saturation humidity or dew point line.

3. Relative humidity (curved lines leading to right side of graph: 10%-30% and curved lines leading to top of graph: 40%-100%).

Relative humidity (rh) is a measure of the moisture content of a given atmosphere (eg. the potato store atmosphere) as a percent of the saturation humidity at the same temperature.

4. Wet bulb temperature (moderately steep diagonal lines: 0°C-30°C)

Wet bulb temperature measures the moisture carrying capacity of the air at a particular temperature and at the wet bulb temperature.

Using the psychrometric chart will help you asses the risk of condensation occurring on seed tubers in certain conditions and work out how to change one or two of the store environmental conditions to avoid condensation. Ask a coolstore technician for help on how to use the chart.

Condensation, using any two of the four properties on the chart. Once you have been shown how to use it you can also predict which humidity will occur at certain temperature and thus adjust temperatures to avoid weight loss in storage.

Example:

With regard to condensation, relatively warm, moisture saturated (outside) air supplied to several degrees cooler potatoes in the store will hit dew point (saturation humidity)and cooler potatoes will get soaking wet from condensation.

For example, tuber pulp temperatures of 16°C for incoming, freshly harvested seed requires a store supply air set point of 15°C. If a sudden weather change reduces pulp temperatures of tubers coming into the store to 10°C, the chart will show that 15°C supply air at 70% relative humidity cooled to 10°C will hit dew point (saturation humidity) and cause water to condense on the 10°C potatoes.

Also avoid placing warm tubers straight into substantially lower temperatures for storage. Pulp temperatures from 15°C-16°C are not uncommon during harvest. The chart shows what using a 10°C supply air delivery set point does when 10°C saturated (humidified) air is warmed by the warmer (15°C-16°C) potatoes. Warm air can hold more moisture than colder air, which means the relative humidity drops when the 10°C saturated air is warmed due to warm tubers being placed into the store.

Therefore, whenever the seed is quite warm relative to supply air temperature, the tubers will be subjected to undesirably low humidity and thus dehydration even if supply air is close to saturation. This situation will be much worse if relatively warm tubers are shifted straight into stores running at low temperature, without humidification. If the seed has not been cured enough, the water, and thus weight and vigour loss, of tubers will be substantial.

Take home messages:

- When placing seed into storage, the supply air temperature should be close to the tuber pulp temperature and then changed slowly (in 0.5°C-2°C increments per day) to the target temperature.
- Supply air relative humidity in the first month and a half of storage (during suberisation), and the degree of suberisation achieved, will largely determine the amount of weight loss (dehydration) over the entire in-store period.

Ideal curing / early storage conditions

Ideally, for effective suberisation (wound healing during curing), potatoes are harvested when pulp temperature is around 15°C, and initial storage temperature is set 1°C lower than harvest pulp temperatures. A slow, continuous supply of air will reduce the chances of temperature differences in different parts of the store. Relative humidity should be kept at 90%-95% unless tubers are wet or diseased. Once the store is filled to capacity, tuber temperature is best maintained at 10°C-13°C for two to three weeks to cure the potatoes (suberisation = healing of wounds). This would include the time to bring pulp temperature to 10°C-13°C. If rot problems are expected eg. silver scurf infection or soft rot, a curing temperature of 9°C-10°C and a humidity of 85%-90% may be required. Forced ventilation is essential during curing to get rid of respiratory heat and CO_2 and supply O_2 to all tubers. Once curing is complete and tubers suberised, the pulp temperature is slowly cooled to final storage conditions.

Although the above conditions are optimum for curing, there may be exceptions. For example, if bad soft-rot or Pythium infection is suspected, the best curing temperature is below 10°C, which means the actual set temperature is much lower while the store is being filled. (Source: http://www.uidaho.edu/ag/plantdisease/pstore.htm)

In some cases, the initial store temperature is set at 9°C-10°C for the entire filling period, running the fans only at night for 3 to 4 weeks. Subsequently, tuber temperatures are lowered gradually; at about 0.5°C per week; or when return air gets within 1°C of set point, set point is lowered by 0.5°C. This procedure is continued until tubers are down to storage temperature. This practice may minimise silver scurf incidence.

If the daytime weather is too warm (pulp temperatures at or above 25°C), the best time to harvest is in the morning or late evening. It is important to note that if warm weather persists, the main aim should be to remove field heat first. These potatoes should be cooled as they are put into storage using ventilating air at 10°C-13°C. This temperature, along with 90%-95 % humidity, is ideal to suberise and heal wounds.

Is there an advantage in rapid cooling of seed?

It is generally believed that lowering initial store temperatures quickly to near storage conditions can help stop storage disease problems. However, rapid cooling is not without its risks for normal or over-mature tubers. One disadvantage is that tubers at the bottom of bins can have pressure bruises and more shrinkage. The temperature of cool air around the warm potatoes goes up, reducing its vapour pressure. The air around the tubers then has a vapor pressure deficit compared to the internal water content of the potatoes. This forces the internal water to move out of tubers to compensate. The moisture loss makes the potato cells break down. The potatoes at the bottom of bins are also pressured by the weight of tubers above them, especially in 1 tonne bins. This increases the risk of pressure bruises and shrinkage loss.

A second disadvantage is, if faced with a long spell of warm weather in/after cooling down, fresh air intake has to be stopped for extended periods, which deprives seed of O_2, leading to a build-up of CO_2. Over-mature seed will be particularly sensitive. Cold temperatures and high CO_2 tend to slow the wound healing process.

Cool down to storage condition after curing

The temperature of ventilating air is reduced by 0.5°C-1°C per day until storage conditions are reached Pulp or return air temperature measurement determines the rate, pulp temperature being the more accurate. If return air temperature is within 0.5°C-1°C of the set temperature, the set temperature will need to be lowered by 0.5°C-1°C per day. The best time to measure return air is early morning, because the store would have had an extended cooling period during the night. During cool down, ventilation should always run. Once conditions inside the store have stabilised, daily ventilation should be long enough to maintain a 0.5°C-1°C difference between bins at the bottom and top, and back and front of the store. Increasingly, fans are being run in shorter cycles (at the rate of 2 to 4 hours per run and a break of at least 2 hours). The shorter cycles tend to reduce extreme temperature differences in the store. If fans are stopped for long periods, the tubers tend to warm up; so the entire load will need more time to cool down to storage temperature. Store managers are advised to check the efficiency of the air system before making any changes to ventilation.

Days to various stages of wound healing (suberisation)

Temperature [°C] Optimum humidity	Light suberisation	Complete suberisation	Start of periderm formation	Two layers of wound periderm formed
2.5 - 5	7-14	21-52	28	28-63
10	4	7-14	7-14	9-16
20	1-2	3-6	3-5	5-7

[1] Some authors claim that there will not be complete suberisation at low temperatures.

Adjusting the curing environment to suit harvest condition

Ideally, potatoes are harvested when the following conditions are met:

- Good skin set
- Availability of cool air during the night if store/curing set up is not refrigerated
- Appropriate soil moisture to move the harvester without clods
- Pulp temperatures at or around 15°C.

In some cases, soil and pulp temperatures may be far from ideal, and adjustments in initial storage settings may be needed.

Some general guidelines to correct extremes are as follows:

For extremely warm and dry soil harvest condition

1. Run fans and the humidifier continuously while filling the storage and for the first day or two.
2. Adjust incoming air temperature to no less than 1°C of pulp temperatures. If possible, take advantage of existing high air capacity using the outside cool night air, and reduce daytime ventilation if warm temperatures persist. Refrigerated storages can use the refrigeration to remove field heat; but tuber temperature needs close monitoring because gradual cool down is better than rapid cooling.
3. Once pulp temperatures reach 10°C-13°C (10°C is better if *Phythium* leak or soft rot is suspected), normal suberising conditions can be set.

For extremely warm weather with wet soil harvest condition

1. Run fans continuously (with the humidifier off, if installed) until all free moisture on potato surfaces is removed.
2. Modulate incoming air to about 1°C less than pulp temperature.
3. Once pulp temperatures reach 10°C-13°C, regular suberising conditions can be set.

Cool weather (10°C-15°C) with dry soil harvest condition

1. Potato pulp temperatures are already at or around curing temperature. In this case, run fans intermittently so that the pulp temperature equilibrates, and this will also help to provide the required oxygen for curing.
2. If possible, use a fresh air intake temperature close to the existing pulp temperature.
3. If daytime temperatures increase drastically, fresh intake may be reduced or closed and store air re-circulated to maintain tuber temperature.
4. Potatoes brought into storage under these circumstances need 2 to 3 weeks to complete wound healing at 10°C-13°C and with 95% relative humidity.

Cool weather (10°C-15°C) with wet harvest condition

1. It may be possible to windrow potatoes that are being dug wet. This will help dry tuber surfaces.
2. Wet tuber surfaces will encourage diseases and block air exchange through the lenticels. If pulp temperatures are near curing condition, fans need to operate continuously without any humidification. This will dry tuber surfaces.
3. Air entering the store should be slightly (0.5°C-1°C) lower than pulp temperatures.
4. Once the potatoes are dry, start normal curing conditions of 10°C-13°C again, with 95% relative humidity. These potatoes need a 2 to 3 week curing period because they came in cool.

Cold weather (5°C-10°C) with dry soil harvest condition

1. Under these conditions, potatoes are very susceptible to bruises and need to be handled carefully. Preferably crop should not be harvested below 7°C.
2. There is no need to remove field heat in these potatoes, but instead they may need to be warmed to 10°C-13°C. To achieve this, fans can be run intermittently for a short time, and this will help the potatoes increase temperature on their own by respiring and giving off heat.
3. Humidification is needed and can be timed with the fans.
4. If this weather persists while filling the storage, keep operating the intermittent fan with humidity until the storage is filled and closed. On the other hand, if the weather warms up then the set points need to be adjusted accordingly. Pay extra attention to the potatoes brought in last.

Cold weather (5°C-10°C) with wet soil harvest condition

1. As soon as the potatoes are brought into storage, dry the potato surfaces; therefore, continuously running the fans, without any added humidity, could be needed.
2. The cold wet condition may slow drying; so extra heat could warm the tubers slightly.
3. When potatoes are dry, intermittent ventilation will provide the required oxygen and spread a little of the heat of respiration to warm the stack.
4. Once the potatoes reach curing temperatures of 10°C-13°C, potatoes can be cured for 2 to 3 weeks, with 95% relative humidity.

Seed treatment – fungicides and active ingredients

Properly suberised and treated seed provides a better, more uniform stand of plants. Tubers can be protected from disease with correct application of the appropriate fungicide,. Too much chemical can be phytotoxic, especially if accumulated in tuber eyes. Sweating and condensation on tuber surfaces can lead to phytotoxicity. Poor coverage may not totally protect seed pieces.

Dust formulations are preferable for cut seed. Some seed treatments are now formulated with bark as a carrier, or should be used in combination with bark seed dressing, for improved healing of cut surfaces.

Australia

Registered trade name	Active ingredient	Diseases controlled
Fungaflor	imazalil	Fusarium; Silver scurf, Gangrene (Phoma)
Maxim	fludioxinil	Rhizoctonia, Silver scurf, Black dot
Monceren	pencycuron	Rhizoctonia
Rizolex	tolclofos-methyl	Rhizoctonia
Rovral	iprodione	Rhizoctonia
Shirlan	fluazinam	Powdery scab
Tecto BZ	thiabendazole	Fusarium, Phoma, Gangrene

(Source: South Australian Research and Development Institute)

CAUTION:

Always refer to label instructions and Material Safety Data Sheets when using fungicides.

Train your staff in responsible handling of chemicals.

Do not use unregistered products.

Dip treatments are not recommended, as they can spread pathogens to seed pieces that were previously not affected.

Do not use treated seed for food, feed or fodder.

Summary of field diseases causing storage problems

Disease & relevance to storage	Symptoms	Favourable conditions	Store prevention & management
Soft Rot *(Erwinia carotovora pv carotovora)* Wet rot of tubers	An unpleasant odour in storage: degeneration of tubers into a rancid pool of slime.	Thrives in warm, moist conditions. Needs wounds to infect. Bacteria are widespread. However, the disease does not become serious if tubers are healthy, mechanical damage is minimised, and sanitation is good. The disease can be spread with seed.	A total disease management program to maintain good tuber resistance. Good storage practices prevent spread of rot organisms (See P16-20.)
Fusarim Dry Rot *(Fusarium spp.)* Dry rot starting at the skin and progressing into the tuber flesh	Potato flesh turns dry, brown or grey to black and grainy, large hollow cavities develop inside tuber. Tuber surfaces are sunken or wrinkled, and white or pink mould is sometimes visible. A moist rot may occur if secondary infections with soft-rot bacteria also are involved (see above).	Thrives in warm, moist conditions. Most infections occur as the fungus enters tubers through harvest/ grading wounds. The disease does not become serious if tubers are healthy, mechanical damage is minimised, and sanitation is good. The diseases can be spread with seed.	A total disease management program to maintain good tuber resistance. The fungus is dormant at low storage temperatures, and will resume growth when tubers are warmed. Good storage practices prevent spread of rot organisms (See P16-20).
Phoma dry rot (Gangrene)	Small dark depressions in the tuber skin forming "thumb marks" or larger irregular shaped sharp-edged lesions with underlying internal dry rot and cavities.	Associated with damage at harvest or during grading when tubers are kept at low temperatures without a skin curing period. High risk in some cool-climate production areas.	Careful harvesting and handling of tubers, especially during dry and cold conditions. Ensure tubers get a curing period before after harvesting or grading before they go into the cool store. Treat tubers with a registered post-harvest fungicide where there is a high risk of rot developing.
Pink Rot *(Phytophthora erythroseptica)* Breakdown in storage	Brown spots develop on potato skins; the flesh becomes soft and mushy and turns pink when cut. A clear line can be drawn between healthy and diseased areas of infected tubers.	A soil borne disease that develops in very wet areas subject to poor drainage, heavy precipitation or irrigation.	Plant seed tubers in soils with good drainage. Spray with a combination contact/systemic product. Avoid excessive irrigation late in growing season. Minimise mechanical damage during harvest.
Pythium Leak *(Pythium ultimum)* Breakdown of tubers in storage	Potato skin looks bruised, tubers become soft and the skin moist. After infection, skin ruptures and tuber exudes liquid with slight pressure. A clear line can be drawn between healthy and diseased areas of infected tubers.	Infection usually occurs at harvest as tubers come into contact with spores in the soil. Spores are released into films of soil water when soil temperatures exceed 18°C.	Spray with a combination contact/systemic registered or permit holding product. Delay harvesting until tuber skins are mature. Avoid mechanical injury. Increase ventilation if rot occurs in storage area.

Managing sprouting, shrinkage and bruising

Sprouting

- Keep tuber temperature below 5°C
- Keep store and tuber temperature steady

Shrinkage and Softening

- Minimise handling damage
- Control sprouting
- Store mature crops with good skins
- Cure adequately
- Store at coolest temperature acceptable
- Ventilate intermittently, as required, for temperature control
- Maintain high humidity, particularly when outside air is used for cooling

Pressure Bruising

- Store mature crop, vine-kill if required for timely skin set
- Cure adequately
- Minimise shrinkage (high humidity)
- Pressure damage is related to time in storage

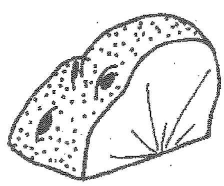
Bruising

- Minimise handling damage
- Mature the crop
- Use a fungicide when filling storage
- Manage crop nitrogen; do not overfeed

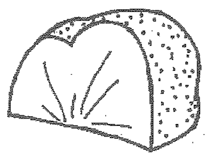
Seed cutting guide

Depending on variety and the type of crop you are growing, use a cutting technique to optimize stems per square metre planted.

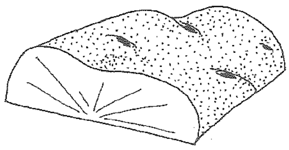
Good cutting result - seed piece with several eyes and correct size

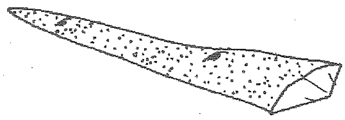


Bad cutting result - blind, no eyes, due to the use of oversized tubers

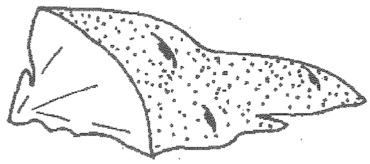


Bad cutting result - undersized - slab or sliver





Bad cutting result - ripped due to blunt cutting equipment



Pre-cutting

Pre-cutting seed potatoes involves warming tubers, cutting them to size and cooling seed pieces down to a holding/ storage temperature. Not all seed potatoes should be pre-cut.

Only seed of young or medium physiological age should be pre-cut, since pre-cutting ages seed. Young seed can be pre-cut one month or more before planting. If seed has previously sprouted, it should be cut only two weeks ahead.

Middle-aged seed can be pre-cut up to two weeks ahead of planting only if it has not sprouted. Middle-aged seed that has sprouted and been de-sprouted is old seed.

Seed that is physiologically old should not be pre-cut. Old seed should be cut as close to planting as possible; not more than a few days ahead. Cutting any earlier may cause tuber senility (Potato No Top).

The temperatures to warm the seed to, and hold cut seed at, vary for seed of different ages. The younger the seed, the higher cutting and storage temperatures should be. Young seed can be cut and held at about 10°C. Older seed should not be warmed or held above 7°C. Since sprouting ages tubers, temperatures should be lower for seed that has already sprouted. Pre-cutting offers several advantages that help seed overcome adverse soil conditions at planting and avoid dormancy issues with some varieties.

Pre-cutting allows the cutting operation to begin earlier and even out the workload before planting starts. Pre-cut seed may have a better opportunity to cure under controlled storage conditions. Properly cured cut seed, if held for at least three or four weeks, will overcome dormancy and give more uniform sprouting. Pre-cut seed will provide earlier emergence, vigorous early growth and higher plant and stem populations. Varieties with slow seed curing ability such as Atlantic and Kennebec are good candidates for pre-cutting.

Delayed emergence, slow uneven establishment and reduced plant stands are symptoms of planting seed in soil that may have been either too cold, too wet or too dry. Freshly cut seed planted under these unfavorable conditions often fails to heal properly; dehydrates or is infected by decay organisms and is not capable of good growth. Erratic and slow plant growth also interferes with timely herbicide applications; and smaller plant canopies later in the season offer less competition to weeds. If pre-cutting, carefully keep to temperatures and timing according to the physiological age. Cutting, warming and storage will all advance the seed's physiological age. Pre-cutting is not recommended for all seed. Hand cutting is recommended as it allows better hygiene and grading out of diseased or damaged tubers by staff cutting seed.

Evaluation of physiological age

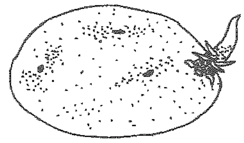
Because the factors influencing physiological age are still so difficult to quantify, comparing the history (stresses) of the seed crop during growth, handling and storage, compared with earlier years, can help estimate physiological age. A long-term relationship with your seed potato producer and store operator may be in your best interest. Knowing the purpose of the seed determines the P-age required at planting.

Accumulated day degrees also give an indication of P-age. Taking representative samples from a seed lot at the start and end of or during the storage period, and inducing sprouting at 15°C-18°C in the dark, can provide more information on P-age. The sampling time depends on when the information is required. Sprouting characteristics (sprout number, length and position) will give an indication of seed age. It is worthwhile to record the time it takes for sprouts to begin to emerge. This will give an estimate of the length of time and warming required for that particular lot to sprout.

Sprouting characteristics

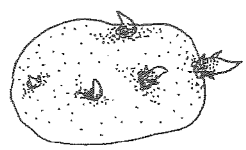
Dormant seed

If the potatoes do not sprout at all, they may still be dormant. Length of dormancy (resting period) varies with variety. Dormant seed is young.



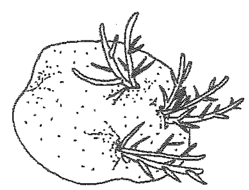
Young (apical dominant) seed

Young seed will have one or just a few sprouts. These sprouts emerge from eyes on the apical or bud end of the tuber (apical dominance). Young seed will produce a plant with few stems. A low stem number leads to a low tuber set. Larger, but fewer, tubers would be expected from young seed. Young seed is best for long growing seasons.



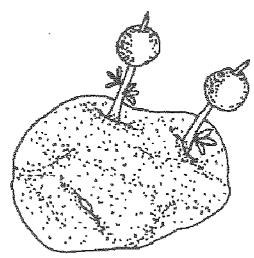
Middle-aged (medium age, multi sprouting) seed

Middle-aged seed will have multiple sprouts. All eyes on the potato could sprout. Middle-aged seed produces plants with multiple stems that lead to high tuber sets. Time of emergence will depend on whether the sprouts are broken off or not, and will be influenced by soil temperature. Both low and high soil temperatures age seed. This stage in the physiological age is best for high yielding capacity if the growing season is long enough (high tuber set combined with sufficient time for bulking).



Old seed

Old seed will have branched sprouts that can appear hairy. These sprouts are weak and will not produce a vigorous plant. Typically, plants from old seed will produce high tuber sets, but the plants lack the vigor to bulk tubers to a good size.



Small tuber syndrome (submarines)

Seed can be so old that small tubers form on the sprouts once they emerge from the eyes. Submarine is the name given to extremely old seed. It should not be used.

Which physiological age for which purpose?

A different physiological age is required for best performance for different commercial end uses, that is processing, ware or seed production. Basically, length of the growing season determines which physiological age is most advantageous to the seed buyer / commercial grower.

In short: a dormant seed tuber will produce few sprouts, especially in cool soils; often only an apical dominant sprout. It will produce a one-stem plant with a small number of large size tubers. Emergence of the plant is late compared to physiologically older seed tubers.

Processing crops

Physiologically young seed produces few but strong stems, creating a plant that grows for a long time before reaching maturity. For processing stock, where large size tubers are required, young seed in the early stage of multiple sprouting is ideal, because it allows tubers to develop during a long growing season into large tubers.

The optimal yield of a variety that has a tendency to produce a large number of tubers (eg. *Russet Burbank*) can be obtained from physiologically young, not de-sprouted seed. In a variety with a tendency to produce few stems and / or a smaller tuber number (for example, *Shepody, Atlantic*), the physiological age may be more advanced, eg. seed warmed up or cut earlier in relation to planting date.

Fresh market crops

Potatoes being produced for the fresh market (ware potatoes) may not have the same large size requirements as for processing. This means that a slightly advanced (medium) physiological age may be used to produce more stems and thus smaller tubers. Again, it is good to know the history of the crop, the stresses and temperatures during growing, handling and storage (and anticipated at planting, eg. cold or warm soil) to be able to treat seed optimally. Any stress will advance physiological age.

Seed Potatoes

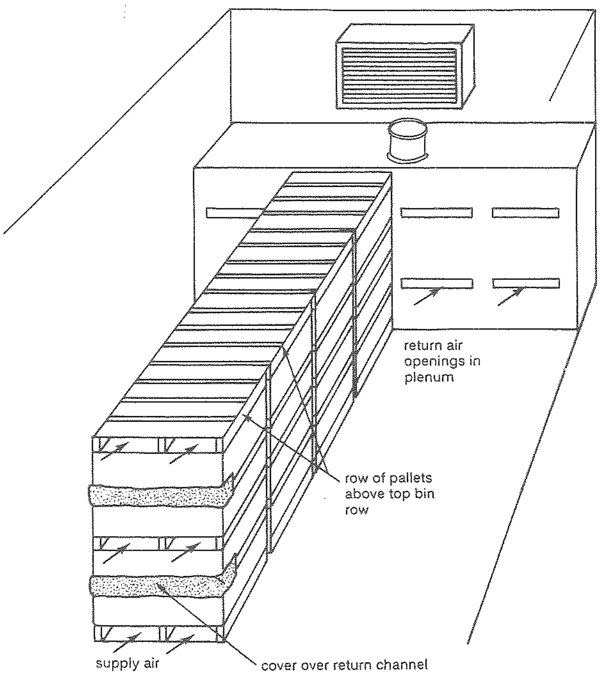
Seed potatoes need a good set, an early emergence and an early maturity for some varieties. (For others, ie *Atlantic*, growers prefer the opposite) The physiological age will determine the quality potential of the seed, that is number of stems, which is related to number of tubers and timing of maturity. Since vine (haulm) kill is early, the seed planted for the next seed generation should be physiologically advanced (medium age). Increasing tuber set through planting older seed will result in a better yield of seed size tubers. Physiologically advanced seed produces a crop with an earlier maturity, besides a larger number of stems. This is important, because for most varieties, it makes the plant less susceptible to viruses later in the season. Do not use seed in the earliest stage of multiple sprouting; it should be older. Again, it is good to know seed history, to decide whether it needs to be warmed up early or whether that should be done as late as possible. De-sprouting physiologically young seed generally will produce more sprouts, more tubers, but a smaller size. On smaller farms, green sprouting of seed potatoes may be used,

Characteristics of physiologically young versus old seed

Young seed	Old seed
Slow emergence	Rapid emergence
Few stems per seed piece	More stems per seed piece
Low tuber set	High tuber set
Long bulking period	Short bulking period
Long tuber set period	Uniform tuber set
Large tubers at harvest	Small tubers at harvest

Diagrams and Photos

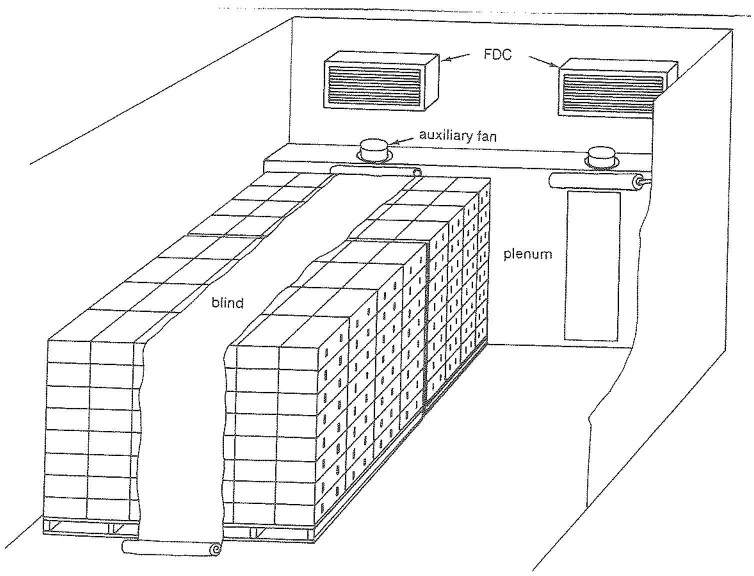
Curin

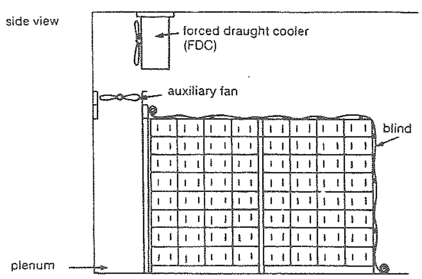


Curing set up - plenum and blind system

The plenum and blind system works in a similar fashion to the letterbox one. A fan on top of the plenum box sucks air through the bins (cartons in the diagram below). The bins are lined up in two rows on either side of the plenum opening. The rolled out trap covers the gap between the rows and runs right down the front of the stack. Rolling the blind up and down manually over bins stacked 4-6 high is not a simple process, and OH&S issues have to be considered. The blind should be sufficiently wide and reinforced with thin, strong rods across its width every 1-2 meters to prevent it from being sucked into the gap between the two rows of bins by the force of the fan. Similar to the 'letterbox' system, bins should be full, to avoid air short-circuiting.

The top diagram shows the front, and the bottom one shows the side view of the plenum and blind system, which can be installed in a conventional store.





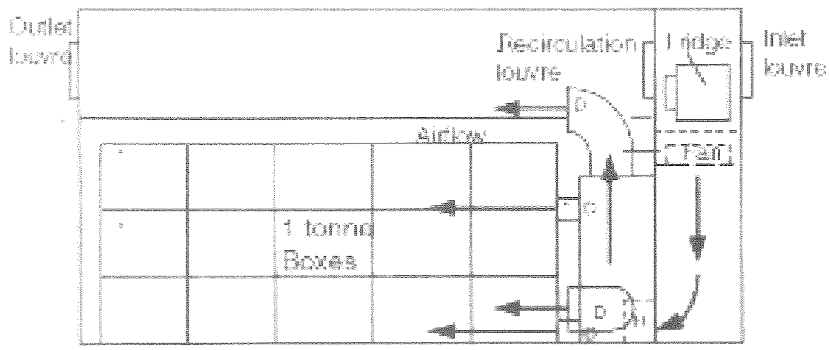
Internal view of potato stores

Internal view of a bin loaded potato store with large roof space, which is important for even air distribution and inspection of top bins for moisture.

Courtesy Farm Electronics Ltd, Lincolnshire, UK.

Store set up for bins

The diagram below shows set up of a potato store for bin storage with fresh air inlet and re-circulation facilities (louvers) and fans to provide air exchange in bins.



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Glossary

Chitting or green sprouting: pre-sprouting seed

Chitting ages seed (refer to 'physiological age') resulting in earlier emergence, tuberisation, bulking and maturity, enhancing yield capacity. Chitting is warming seed tubers to 15°C-20°C until the sprouts just emerge (white point stage), then exposing them to light.

Dew point

The dew point is a temperature at which the air becomes saturated with moisture. In a store, condensation forms when air temperature has cooled to dew point temperature. It means that air temperature and dew point temperature are the same, and relative humidity is 100%.

Dormancy

Dormancy is the rest time after harvest when tubers will not sprout, regardless of temperature, light or moisture. The dormancy period depends on variety and storage conditions, especially temperature.

Ethylene

Tubers are moderately sensitive to ethylene and should be kept away from ethylene sources (gas and diesel forklifts, fruit). Ethylene is a colourless gas and plant growth regulator (like a plant hormone). It encourages ageing and senescence. Potatoes have low ethylene production rates.

Oxygen (O_2) and Carbon Dioxide (CO_2)

Oxygen and carbon dioxide are two gases in air. Air generally contains 21% oxygen, 0.03% carbon dioxide.

Pathogen

A pathogen is a bacterium, fungus or virus that can cause disease in plants or animals.

Physiological age (P-age)

Physiological age of seed potatoes determines how well they might yield by influencing the stem number of each seed piece (given uniform seed piece quality), and so stem density per hectare. Sprouting capability is so far the best way of determining P-age.

Seed cutting and physiological age

Cutting seed shocks the tuber to sprout buds (eyes) if the tuber is past dormancy. In this way, seed cutting compensates for improperly aged seed by promoting early sprouting of some eyes. It is important to properly warm and size seed before cutting it.

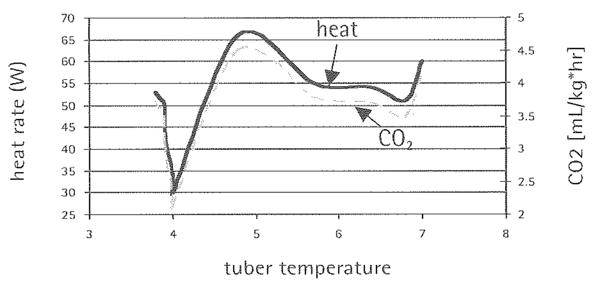
Soil temperature at planting and physiological age

When soil temperature is low, sprouting (especially of very young seed) is delayed, and the result may be late emergence. That's when Rhizoctonia and Fusarium can attack sprouts. So when planting physiologically very young seed it is important to match soil and seed pulp temperature. On the other hand, when seed is very advanced in physiological age, cold soils can result in small tuber syndrome ("potato no top"), and no yield can be expected at all from such seed.

Respiration

During respiration (breathing), potatoes change stored sugars into energy to stay alive. In the process, they consume O_2 from the air and release water, carbon dioxide (CO_2) and heat. Potatoes have relatively low respiration rates. Still, freshly dug potatoes release heat of about 30 [W/t], which, after curing and storage under ideal conditions, can fall to about 20 [W/t]. Slowing respiration lengthens tuber life i.e. reduces the speed of physiological aging.

Tuber temperature and respiration rate



Respiration of potatoes is lowest at a tuber temperature of about 4°C. Usually delivery air has to be set below the required pulp temperature. Monitor pulp temperatures as well as delivery and return air.

Rot

An infection or disease that leads to wet or dry breakdown symptoms.

Suberisation

The process of wound healing during curing to reduce the chance of disease entering the tuber.