# PHYSIOLOGICAL TUBER DISORDERS

potatoes aartappels SA

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# INTERNAL BROWN FLECK / SPOT

*Brown fleck occuring in vascular bundel*

*Close-up view of brown fleck*

## Symptoms

- Affected tubers do not normally display external symptoms of brown spot.
- All tubers of a single plant are not necessarily affected.
- Cultivars differ in their susceptibility towards brown fleck.
- Typical symptoms are irregular brown flecks that primarily occur in the vascular bundle ring.
- Brown fleck often occurs in large tubers.
- Brown fleck occurring near the apical section of the tuber was formed at the end of the season, whilst brown fleck near the stolon end was formed when the tubers were small.

## Causes

- **The primary cause of brown fleck** is localised shortages in calcium (Ca).
  - Shortages in Ca cause the loss of the integrity of cell membranes and cell walls under stress conditions. This results in the mixing of the content of the cytoplasm and the vacuole and subsequent cell death.
  - Sufficient Ca in the soil solution where and when tubers are formed is therefore essential. The Ca present in tubers is absorbed through the thin skin of young tubers, as well as through roots on the stolon of the relevant tuber.

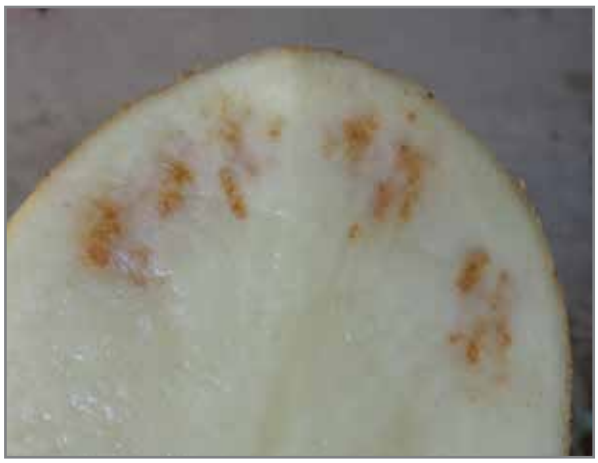
- **Environmental factors that lead to brown fleck** include air and soil temperature, soil types and soil moisture.
  - When air temperature is high, but soil temperature is low, transpiration from stems and leaves takes place normally, especially if the sun shines.
  - Uptake of water and nutrients, however, happens slowly through the roots, resulting in water and nutrients being withdrawn from the tubers. The withdrawal of water and nutrients causes stress in tuber cells.
  - Although Ca is not translocated from tuber tissue to above surface growth, a shortage of Ca in the tuber tissue leads to the loss of membrane integrity which causes cells to die and turn brown.
  - The latter takes place especially when the abovementioned conditions occur for a number of consecutive days.
  - When soil temperature is very high roots do not function optimally, resulting in insufficient water and Ca uptake.
  - As a result of an oxygen shortage under waterlogged conditions, roots do not take-up water and Ca. Heavy soils are prone to waterlogged conditions during the rain season and / or excessive irrigation.
  - Under low soil moisture conditions the Ca uptake is low as plant-available Ca is in soluble form in the ground water.
  - Plantings in sandy soil are susceptible to brown fleck because the water holding capacity of sandy soil is low, and soil temperatures tend to increase quickly.
  - Tuber initiation in numerous cultivars takes place over time or even throughout the season. Depending on the availability of Ca and environmental factors that influence Ca uptake during different times during the season, brown fleck may occur in some tubers on the plant.
  - Brown fleck can also develop during storage if the Ca content is low and if tubers were harvested under high temperature conditions.

- **Ca uptake**
  - Calcium uptake and transportation in the plant occur almost exclusively through the transpiration stream, from the roots to stems, leaves and tubers.
  - Since transpiration occurs primarily from the leaves, most of the Ca is transported together with water to the leaves.
  - Moisture loss from tubers in soil is relatively low, therefore the transpiration stream to the tubers is similarly low and consequently the Ca content of tubers is much lower than in the leaves.
  - Ca in tubers is absorbed by the skin of young tubers as well as by stolon roots. Ca must therefore be present where and when the plant forms tubers. If Ca is not

available throughout the tuber zone, it can lead to some tubers on the plant being affected by brown fleck.

- Movement of Ca applied by way of a foliage spray is extremely limited. Foliage spray is not recommend for preventing brown fleck.

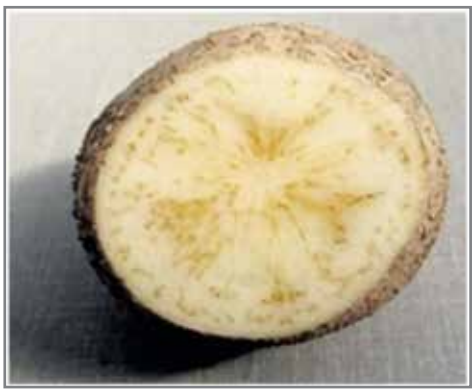
*Brown fleck near the apical end of large tubers (above and below)*



## Management

- Ensure that sufficient Ca is available for uptake where and when tubers are formed. Where granular fertilizer is used, the Ca must be available in the whole tuber zone.
- Opting for planting times to avoid high temperatures during tuber formation and harvesting, reduces the risk associated with brown fleck.
- Avoid cultivars that are prone to brown fleck, especially if it is planted during warm periods of the year.
- Avoid stress conditions at the beginning of the growing season through proper fertilisation and irrigation practices.
- Ensure that Ca uptake is not limited by an imbalance between nutritional elements or unfavourable pH.

**Internal brown fleck / spot can be confused with Zebra chip**



If small elongated brown flecks appear in the vascular bundle ring (often throughout the tuber), contact Potatoes South Africa or Potato Certification Service immediately as it may be symptoms of a quarantine disease that could hold serious consequences for the potato industry.

# BROWN CORE AND HOLLOW HEART

*Transversal hollow heart*

*Longitudinal hollow heart*

## Symptoms

- No external symptoms.
- Cultivars differ in their susceptibility to brown core and hollow heart.
- Under specific conditions, brown core and hollow heart are regarded as two different stages of the same disorder and are most probably caused by the same conditions.
- Hollow heart, however, can develop independent of brown core and tends to occur in large tubers.
- The cavities can appear lengthwise or diagonal in the tuber and also have irregular shapes.
- The tissue lining the cavities can be white or brown and skin tissue is sometimes formed.
- Cavities can appear at different places in the tuber, depending on the time in the season it develops.
- If small tubers with brown cores develop slowly and consistently, the dead brown cells spread in between the normal living cells.

*Hollow heart that was preceded by brown core*

*Hollow heart with irregular shape*

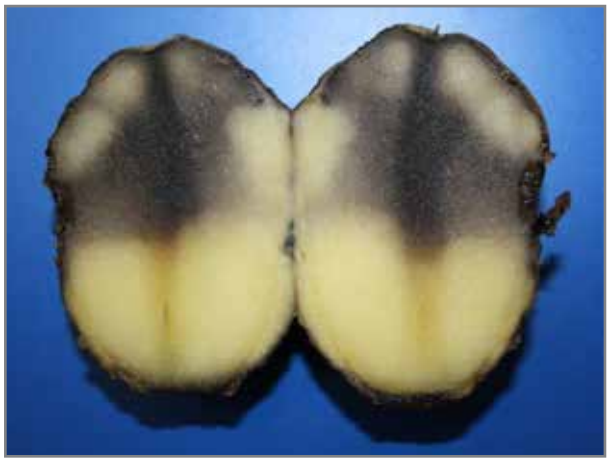
## Causes

- Brown core develops when tubers are very small and temperature is low (<15$^{o}$C), especially during tuber initiation up to the tuber reaching 50 g. Cells die, turn brown and can easily tear apart.
- If small tubers with brown core grow fast and/or inconsistently, the cells in the brown core can tear apart and as the tuber enlarges, hollow heart develops. This condition is stimulated by over-irrigation and the application of large volumes of nitrogen, especially during tuber initiation.
- Hollow heart that is not preceded by brown core, is associated with high growth tempo of tubers, fluctuating soil moisture, and sometimes with high levels of nitrogen and/or insufficient calcium.

## Management

- Prevention of brown centre and hollow heart is difficult, but measures below can reduce the risk of these defects.
- Select cultivars that are less prone to the disorder.
- Avoid over-irrigation.
- Avoid a low plant population.
- If brown centre occurs regularly in early plantings, consider planting later when temperatures are slightly higher.
- Endeavour to maintain uniform conditions throughout the season by managing fertilisation and irrigation.

# COLD DAMAGE



*Tubers showing symptoms of cold damage (Photos: Potato Certification Service)*

## Symptoms

- The extent of symptoms depends on how long the tubers were exposed to the cold, as well as how low the temperature was.
- Cold damage and symptom expression can differ between cultivars.
- Cold damage can occur on the surface of tubers exposed to sub-zero temperatures, but symptoms of cold damage are mostly inside the tubers, often in the vascular tissue and the stem end of the tuber.
- Exposure for short periods to temperatures around 2°C - 0°C can result in grey or reddish tissue. The tissue can also turn dark grey or black.
- Where exposure to sub-zero conditions is long enough, ice crystals can form in the tissue. When thawed, the cells die and decay into a watery mass.
- External symptoms are not necessarily visible.
- The ability of seed potatoes with cold damage to sprout, are often affected negatively.
- If tubers with cold damage are fried, the chips turn dark in colour. If tubers are cooked, the tissue of such tubers goes grey or black.

## Causes

- Exposure of tubers to temperatures that vary from just above freezing point (2°C) or below freezing-point.
- Tubers close to the soil surface, especially after foliage die-off, are exposed to cold damage.
- Seed potatoes that are transported in the winter without the necessary protection, are exposed to the risk of cold damage.
- Seed potatoes that are stored under conditions of insufficient protection against low temperatures and cold winds, e.g. stacked under trees.
- If the temperature drops too low during cold storage.

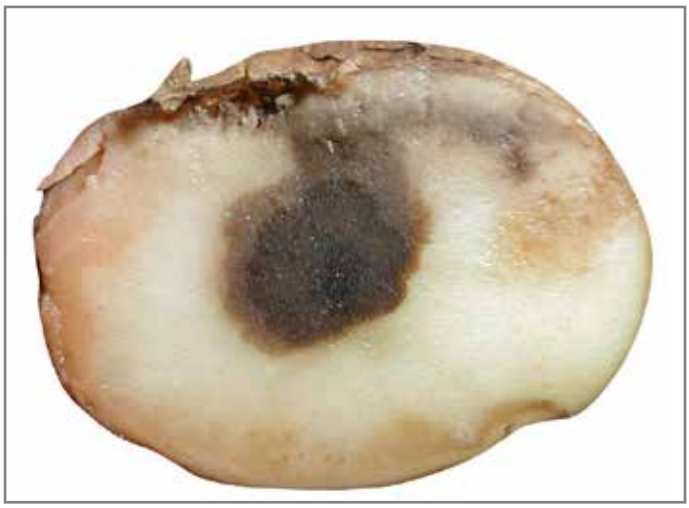
## Management

- Do not leave harvested tubers on the land overnight, especially if low temperatures are expected.
- Avoid cultivars that tend to bear shallow in regions with low temperatures at the end of the growing season.
- Do not store seed potatoes on the farm if the correct conditions are not available. Isolate stacks by covering it with grass and/or hessian bags, but preferably store it in a storeroom with temperature control and ventilation.
- If seed potatoes must be transported in winter, the consignment must be properly covered and it must be done during the day.
- Ensure that mechanisms are in place for proper temperature control during cold storage.
- Harvest plantings with tubers close to the soil surface before the first cold front is expected.

## Cold damage can be confused with soft rot symptoms

*Photo: J. van der Waals (University of Pretoria)*

# BLACK HEART



*Black heart*

*Black heart developed into a cavity. The tissue lining the cavity is leathery or hard*

## Symptoms

- No external symptoms.
- The inside of the tubers are greyish black to black and the affected tissue is normally well defined.
- A cavity can form inside the black heart. The affected tissue is hard and leathery.
- Because the symptom is not a result of rotting, no bad odour is present.
- Black heart often occurs in large tubers.

## Causes

- Develops as a result of an oxygen shortage or an over-supply of $CO_2$ which causes the tissue to die, especially if the oxygen shortage is accompanied by high temperatures. High temperatures trigger increased respiration with an accompanying increased oxygen need.
- Black heart can develop during storage and transportation if oxygen is insufficient as a result of poor ventilation, especially at high temperatures (32°C).
- Black heart can also occur in the potato field if high temperatures follow excessive rain which causes an oxygen shortage in the soil.
- When harvested tubers are left on the land for a long time.
- When seed planted by hand lie in furrows for a long time before being covered by soil, especially when it is very hot.

## Management

- After harvesting do not leave tubers in the sun on trailers under tarpaulins.
- Ensure sufficient ventilation during storage and transportation.
- Avoid fields with poor drainage if rain is received in the after season.
- Make sure that lifted tubers are picked up as soon as possible.
- Cover seed tubers in furrows as soon as possible after planting.
- Seed potatoes with black heart should not be planted as they are susceptible to soft rot pathogens.

**Black heart can be confused with soft rot.** Black heart symptoms differ from soft rot symptoms in that tissue with soft rot is soft and watery, and can often develop on the surface of the tuber. With secondary infection of tubers, a distinctive unpleasant odour is present.

*Photo: J. van der Waals (University of Pretoria)*

# VASCULAR BROWNING

*Tubers showing vascular browning. Note necrotic tissue near stolon end.*

*Vascular browning that originated from the stolon end*

## Symptoms

- No external symptoms.
- Vascular browning of variable intensity develops at the stolon end, but in serious cases it can extend throughout the whole vascular ring.
- Vascular browning appears as speckled, light brown to brown and even dark brown stripes.
- Immature tubers are susceptible, but vascular browning more often appears in tubers approaching maturity.
- The browning can be found in tubers in the potato field as well as in storage during the first one to two months.
- Necrotic tissue near the stolon end is sometimes formed and soil-borne pathogens can enter tubers through this tissue.

## Causes

- Physiological vascular browning is generally associated with a combination of low soil moisture (moisture stress) and sudden foliage die-off as a result of chemicals, frost or mechanical removal.
- High temperature during foliage die-off normally increases the seriousness of discolouration.
- Vascular browning can also be caused through infection by tuber-borne pathogens such as *Verticillium* and *Fursarium* and leaf roll virus.

## Management

- Irrigation prior to foliage die-off decreases the incidence of vascular browning, irrespective of the method of foliage die-off.

# GREENING

*Tubers showing verious degrees of greening*

## Symptoms

- Greening of the tissue immediately under the skin.
- The intensity may differ and may also be accompanied by sunburn.

## Causes

- Greening occurs when tubers are exposed to light (sun or artificial). Chlorophyll then forms in cells immediately under the skin.
- Tubers appearing near the soil surface, whether through planting too shallow, soil cracks, erosion, or cultivars prone to form long stolons or carrying shallowly, are exposed to sunlight.
- Greening may also occur when tubers are exposed to light after harvesting, during storage or during display in stores.
- Excessive nitrogen application early in the season may cause stolons to grow longer than normal.
- The effect of light is accumulative. If tubers are exposed to light on the land, exposure after harvesting will aggravate greening.
- Greening is irreversible. Green potatoes kept in the dark, do not recover.

## Management

- Avoid cultivars that are prone to bear shallowly.
- Avoid high nitrogen application, especially with cultivars that are prone to form long stolons.
- Plant in well prepared soils.
- If possible, irrigate to prevent cracks occurring during dry weather conditions.
- If tubers are exposed after foliage die-off, it can be ridged to cover it with soil.
- Do not expose tubers to light for long periods after harvesting.
- Use packaging material that provide sufficient protection against light transmission if potatoes are exposed to light for more than a few days. White paper transmits more light than brown paper.

## Impact

- Greening not only affects external quality, it also tastes bitter and can pose a health risk as a result of glyco-alcaloides which can be moderately toxic for humans, if consumed in large quantities.

# MALFORMATION

*Knob-like protuberances*

*Secondary tubers*

## Symptoms

- Tubers may exhibit different types of malformation depending on when in the growing season malformation took place, i.e. dumbbell, elongated, bottleneck or tubers with multiple knob-like protuberances.
- More than one tuber are borne on a single stolon in chain form.
- Tubers form secondary tubers, some on short stolons and others directly on an eyelet.
- No cultivar is resistant to malformation, but cultivars with an elongated tuber shape are more prone to it.

*Tubers in chain form on a single tuber. (Photo: P Brink)*

## Causes

- Malformed tubers form when an interruption in growth is experienced during the growing season as a result of high temperature, often accompanied by moisture stress and nutrient shortage. However, each of the aforementioned factors can be the main cause of malformation.
- Heat stress alone can cause malformation as a result of increased respiration, reduced cell division, hormone imbalances and reduced translocation of nutrients to the tuber.
- When stress conditions end growth is resumed, often in tissue nearby growth points (eyelets) which causes a nodular tubers.
- Secondary small tubers often form on tubers of cultivars that are not adapted to high temperatures.
- Other factors that play a role include: poor plant population, single haulm plants, incidence of diseases such as black scurf as well as size and age of seed potatoes and insufficient fertilisation.

## Management

- Avoid production in periods when heat waves generally occur.
- Avoid cultivars that are not adaptable to high temperatures, or plant it during cooler times of the year.
- Ensure uniform growing conditions.

**Malformation can be confused with herbicide damage.**

# GROWTH CRACKS

*Growth cracks showing exposed tuber tissue*

*Exposed tissue covered by skin*

## Symptoms

- Growth cracks vary in depth and length, but normally occur in the length of the tuber.
- Initially the tuber tissue is exposed, but a thin skin is later formed.
- Some cultivars are more inclined to crack, e.g. Mondial.

## Causes

- Growth cracks occur during varying soil moisture conditions.
- Tubers crack when a dry period is followed by heavy rains or over-irrigation. Moisture uptake causes a quick increase in tuber moisture and growth and consequently an increase in tuber size.
- Uneven plant population, over-fertilisation with nitrogen and nutrient imbalances contribute to the occurance of growth crack.
- Application of large amounts of nitrogen at one time after tuber formation.

## Management

- Avoid cultivars that are prone to crack if growth cracks regularly occur and cause loss in income.
- Where possible ensure uniform growing conditions, even plant population, good irrigation scheduling and good fertilisation practices.

### Growth cracks can be confused with herbicide damage or cracks caused by pathogens

*Herbicide damage*

*Cracks caused by Streptomyces (left - photo: ARC) and Rhizoctonia (right - photo: PCS)*

# THUMB NAIL CRACKS

*Thumb nail cracks (Photo: I Vorster)*

## Symptoms

- Mechanical impact manifests often as thumb nail cracks on tubers.
- The cracks in the skin appear as being made with a thumb nail, from there the name thumb nail cracks.
- Thumb nail cracks also provides soft rot bacteria an access route to the tuber tissue.

## Cause

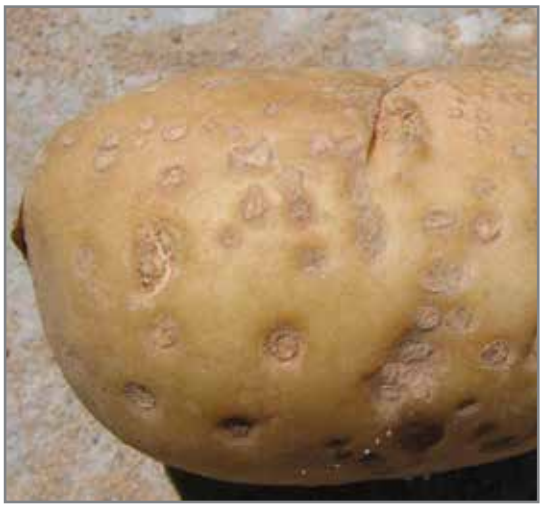
- The cracks can develop after a slight impact or injury and initially only occur in the skin (periderm) of the tuber without bruising to the underlying tissue.
- Potato tubers are especially prone to cracking if the temperature of the tuber is <10°C.
- When tubers are thereafter exposed to low humidity conditions, the tissue under the cracks desiccates and leads to the thumb nail cracks becoming more noticeable and which may lead to a drop in quality.
- Research in Germany has shown that the content of the cell-wall material in the periderm of sensitive cultivars is higher compared to tolerant cultivars. In addition it has been found that the Mg and Ca content of cell-walls of the periderm and underlying tissue of tolerant cultivars are higher compared to sensitive cultivars. The explanation is that both Ca and Mg are important components of pectin. Consequently Ca and Mg contributes to the elasticity and jelly-likeness of pectin – the compound holding cells together.

## Management

- To prevent the occurence of thumb nail cracks, tubers should not be harvested or handled when it is cold. The temperature of tuber tissue should be >9°C.
- The crop should be fertilised optimally to ensure that sufficient Ca and Mg are present in the cell-walls.

# ENLARGED LENTICELLS

*Tuber showing white callus-like growths*



*Enlarged lenticells that dried-out (Photo: Potato Certification Services)*

## Symptoms

- Raised, white callus-like tissue on the surface of the tubers. The size may vary from inconspicuous to large.
- When tubers are removed from wet soil, the raised tissue is white, but it desiccates under dry conditions.
- When tubers with enlarged lenticels are brushed, the white tissue is removed and the underlying tuber tissue is exposed. Under favourable conditions, the exposed tissue is later covered by wound healing.
- Because tuber tissue is no longer protected, the skin is often the area where pathogens infects the tuber.
- In warm weather soft rot often develops in enlarged lenticels and rotting can be observed as dark tissue surrounding lenticels.

*Symptoms of soft rot pathogens that entered the tuber through enlarged lenticells*

## Causes

- Under normal conditions the lenticel is a small opening lined by cork cells that allows gas exchange between tuber tissue and the environment.
- Enlarged lenticels are formed under conditions of oxygen shortage and excessive moisture in the soil surrounding the tubers, or in storage as the cells beneath the lenticels expand and the cell mass breaks through the corky layer.

## Management

- Avoid fields that are prone to waterlogging.
- Reduce irrigation two weeks prior to harvesting by irrigating when the plant available water is 40 – 50%.
- If tubers with enlarged lenticels are harvested, it must be dried as soon as possible.
- Harvest tubers in waterlogged sections separately where possible, make sure that sanitation is optimal during the washing process and that the tubers are dried as quickly and as best possible prior to packing. When chlorine is used as sanitizer, the water must be replaced regularly and the pH must be maintained at >7.
- Seed potatoes from waterlogged sections must be kept separately from other seed potatoes when warm moist conditions prevail.

# SPROUTING

## Symptoms

- Potatoes start to sprout when it is harvested, especially when tubers have been left in the soil for long.
- Normally it is only the apical eyes that sprout.
- Roots can also form at the basal part of the sprout.

## Causes

- Sprouting on the land is normally an indication that the cultivar is not adapted to the cultivation practices of a specific area.
- Normally it is cultivars with a short dormant period that sprout on the land.
- Sprouting is promoted by high temperature before harvesting.

## Management

- Evaluate new cultivars for a least three years in the production area and follow normal cultivation practices to identify cultivars that are not totally adapted.

# NETTING

*Tubes showing different degrees of netting (above and left below)*

## Management

- Where possible tubers should not be exposed to varying soil moisture conditions.

**Netting can be confused with the natural Russet-skin of some cultivars (e.g. Innovator)**

## Symptoms

- Shallow fissures that give the skin a distinctive netlike appearance.
- Overseas research has indicated that netting may start immediately after tuber formation and can continue until the tubers are ready for harvesting.
- Netting occurs in tubers of all sizes.

## Causes

- Little is known about the causes of netting, but it is probably related to climatic conditions and physiological factors in the skin of young tubers.
- Field and glasshouse trials have shown that moisture stress leads to an increased intensity of the disorder.

# LOOSE SKIN (also called SKINNING OR FEATHERING) AND BROWNING

*The skin of immature tubers is easily removed*

*Tubes showing loose skin and browning*

## Symptoms

- Loose skin occurs when tubers are handled.
- The skin is totally or partially removed from the tubers leading to the underlying tuber tissue being exposed.
- Loose skin causes the tubers to be more prone to weight loss and infection by post-harvest pathogens.
- The underlying tissue browns after a few hours to cause browning.

## Causes

- Loose skin is common when young tubers are handled.
- Excessive application of nitrogen (N) late in the season and wet soil may delay ripening and promote loose skin.

## Management

- Top-growth must be completely dead 14 to 21 days prior to harvesting to promote skin setting.
- Ensure that the harvester is properly set to prevent tuber damage.

**Loose skin can be confused with skin separating from underlying tissue as a result of silver scurf and black dot**

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# PHYSIOLOGICAL TUBER DISORDERS

*Brown core*

*Internal brown fleck*

*Cold damage*

*Black heart*

*Vascular browning*

*Greening*

*Malformation*

*Growth crack*

*Thumb nail crack*

*Enlarged lenticels*

*Sprouting*

*Netting*

*Loose skin*

*Acknowledgement: Prof Martin Steyn (University of Pretoria) for technical information*