Potatoes

— Production guideline —

agriculture, forestry & fisheries

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Potatoes

— Production guideline —

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PART 1: GENERAL ASPECTS

1. Classification

Scientific name: *Solanum tuberosum* L.
Common names: Table potato, Irish potato
Family name: Solanaceae

The potato may be classified as an annual, although it can persist in the field vegetatively (as tubers) from one season to the next.

2. Origin and distribution

According to legend the first potatoes for planting purposes in South Africa came from Holland to provide food for mariners visiting the Cape. Since then the potato industry has grown to become one of the important food providers in South Africa.

Within the South African context, the gross value of potato production accounts for about 43% of major vegetables, 15% of horticultural products and 4% of total agricultural production. On average domestic potato farmers harvest about R1,6 billion’s worth of potatoes a year. The latter comprise about 1 700 potato farmers (including approximately 400 seed growers) and 66 600 farm workers.

3. Major production areas in South Africa

3.1 SOUTH AFRICA

Potatoes are grown year round owing to the country’s unique geography and climate. Potatoes are classified by harvest season, skin type and intended market use. Market use classification includes fresh market, processing, seed potatoes and specialty varieties for the local farmer markets. Spring, summer, autumn and winter potatoes are harvest classifications, while reds, russets, yellows and whites are skin types. All classifications of potatoes are grown within all major potato-growing regions in the country.

Potatoes are produced all over South Africa in different climatic regions (Limpopo, North West, Gauteng, Mpumalanga, Northern Cape, Western Free State, Eastern Free State, Kwa-Zulu-Natal, Sandveld, Ceres, South-Western Cape, South Cape, Eastern Cape and North-Eastern Cape). This results in a continuous supply of potatoes throughout the year.
Consequently, domestic consumers have almost continuous access to fresh potatoes.

The Eastern Free State has been described as the major dryland producing area which 9,094 ha of dryland potatoes and 1,506 ha potatoes under irrigation. Limpopo, with 6,973 ha under irrigation, is the region with the most potatoes under irrigation. The region with the most producers is the western Free State with 174, followed by the Sandveld and the eastern Free State with 151 and 132 producers, respectively.

4. Description of the plant

The potato tuber is an enlarged portion of an underground stem, although these stems sometimes grow above ground as well, in which case they are termed stolons. The term stolon is commonly used in the potato literature for both rhizomes and stolons.

4.1 BOTANY

4.1.1 Roots

Potato plants may develop from seed or from tubers. Plants grown from seed form a slender tap root with lateral branches. Plants grown from tubers form adventitious roots at the base of each sprout and, later, above the nodes of the underground part of each stem. Occasionally, roots may also grow on stolons. In comparison with other crops, the potato root system is poor. Therefore, good soil condition is necessary for potato growing. The type of root system varies from light and superficial to fibrous and deep.

4.1.2 Stem

The potato stem system consists of stems, stolons and tubers. Plants grown from true seed have one main stem; while from a tuber a number of main stems may be produced. Lateral stems are branches of main stems. Stems are round to angular in cross-section. At the angular margins wings or ribs are often formed. Wings could be straight, undulate or dentate. Stem colour is generally green; sometimes it may be reddish-brown or purple.

The stolons (technically rhizomes) have leaf scales located alternately on their surface in the same manner as the above-ground stems. The tubers originate from the tips of stolons, and occasionally tubers form along the stolon itself.
4.1.3 Leaves
When all or most leaves are arranged at or near the base of short stems and are near the soil surface, the plant has a rosette or semi-rosette habit.

4.1.4 Flower
Potato flowers are bisexual. They possess all four essential parts of a flower; calyx, corolla, male elements and female elements.

4.1.5 Fruit
The initiation of young tubers at the tips of the stolons usually occurs when the plants are 15 to 20 cm high, or from 5 to 7 weeks after planting. Tuberisation is not dependent upon flowering. Potato plants will form tubers without any flowers ever appearing on the tops.

5. Cultivars
Potato cultivars available in South Africa can be divided into three groups according to the length of their growing periods. In the group for early cultivars (less than 100 days) Vanderplank is the most popular cultivar. The medium-growing season cultivars (100 to 120 days) form the bulk of potatoes grown in South Africa, of which BP1 and Up-to-Date are the most popular cultivars at present. Together BP1 and Up-to-Date constitute almost 77% of the potatoes grown in the country. In the third group of cultivars are those cultivars with a longer growing season (longer than 120 days) such as Sackfiller, Late Harvest, Kimberley’s Choice and Cedara.

6. Climatic requirements

6.1 TEMPERATURE
The potato has long been classified as a short-day, cool-season crop, but does very well at high temperatures when water is supplied in uniform quantities sufficient to meet evapo-transpiration...
demands. The highest yields are currently being produced in areas where the daytime temperature is often over 38°C during the hottest part of the growing season and nights are cool 18 °C.

7. Soil requirements

7.1 SITE AND SOIL

Potatoes grow well on a wide variety of soils. In some areas where potatoes are commercially grown the soils are acid, whereas in others they are alkaline. Ideal soil for potato growing is deep, well-drained and friable.

High soils in organic matter such as peat or muck, if adequately drained, can also produce high quality potatoes, particularly for the fresh market. Sandy soils, which contain little clay or little organic matter and have almost no soil structure, when properly irrigated and fertilised, will produce high yields of tubers with excellent culinary and processing quality.

Potatoes are more tolerant to low pH than most other crops. Incidence of common scab tends to be less of a problem where soil pH is lower than 5.4. For cultivars that are susceptible to common scab, the disease is often managed by maintaining soil pH in the range of 5.0 to 5.4. Although potatoes tolerate acid soil, there are benefits from raising the pH of acid soils up to 6.0 to 6.5.

PART 2: CULTIVATION PRACTICES

1. Propagation

Potato is usually cultivated by planting tubers. Purity of the cultivars and healthy seed tubers are the primary requirements for a successful crop. However, seed tuber is the costliest input in potato cultivation. The tuber seed should be disease free, well sprouted, 30 to 40 g each in weight, and at the right physiological age (2-3 months from harvest).

2. Soil preparation

Potato growers commonly use a mouldboard plow or chisel plow for their primary tillage method. Autumn ploughing offers advantages by decreasing the work that has to be done the following spring. Autumn tillage generally results in warmer soil temperatures in the spring, which allows for earlier planting and greater breakdown of crop residues. The freezing
and thawing action of winter helps to break up clods and improves tilth. However, the disadvantage of autumn ploughing is that the more the soil is exposed by tillage, the more susceptible it is to erosion. Autumn tillage, especially moldboard ploughing, can leave the soil exposed for a long period. It is preferable to plough sloping lands in the spring to help prevent erosion. Strip and/or contour ploughing of sloping lands will also help control erosion.

Autumn bedding allows for soil preparation work to be done when the growers typically have more time and labour available to them. In this system, growers usually irrigate, broadcast fertiliser as needed, plow, and then form beds which they plant into the following spring.

In the spring, unless beds have already been formed, fields that have been ploughed are disked or harrowed ahead of planting as soon as conditions permit. If fertiliser is going to be broadcast, it is usually applied ahead of spring tillage. A relatively small number of growers will broadcast a portion of their fertiliser after planting operations are finished and just ahead of cultivating.

In some irrigated areas, as a final pass, dammer-diking equipment is run through the field at final cultivation after planting. This equipment forms small catchment basins between the rows. These indentations through the field help prevent water runoff between the rows, and promote uniform infiltration by holding the water in place.

3. Planting

Crop growth is affected from the time of planting until harvest. Fertilisation, cultivation, rainfall and/or irrigation, and weed, insect, and disease control all have an influence on the crop growth.

3.1 WARMING SEED PRIOR TO PLANTING

Tubers of seed potatoes should be warmed to 10 to 15.6 °C before handling and cutting to minimise the potential for bruising. Seed should be warmed and removed from cold
storage 7 to 14 days before planting. Tubers should never be taken from 4.4 °C storage and planted directly.

Condensation occurs on the surface of tubers with a pulp temperature of 4.4 °C when planted in soil temperatures warmer than 4.4 °C. Free moisture on the surface of tubers contributes to seed piece decay, particularly with cut seed.

3.2 TYPE AND SIZE OF SEED

Some growers prefer to plant uncut, small, seed tubers (single-drop seed). The use of uncut or whole seed tubers reduces the hazard of spreading disease in the cutting operation and helps ensure a better plant stand, particularly under adverse field conditions. The desired size range for planting whole tubers without any cutting ranges from 43 to 85 g. Cutting seed tubers less than 85 g in size results in seed pieces weighing less than 43 g and results in excessive waste.

Seed pieces, either freshly cut and planted or properly healed before planting, can be just as productive and healthy as uncut seed tubers. Seed tuber size affects the productivity of cut seed pieces as well. Seed tubers greater than 255 to 284 g give a higher percentage of seed pieces without eyes (blind seed pieces) when cut than smaller tubers. This can be a substantial problem in cultivars with uneven eye distribution across the tuber surface. Seed pieces less than 43 g produce fewer stems than do large ones. Excessively large seed pieces can produce too many stems per hill, increasing tuber set and reducing tuber size as well as increasing the cost of seed. Seed pieces that are too small or large can inhibit proper planter operation. The seed piece size for optimal productivity, planter performance, and seed cost, per unit area, ranges from 43 to 85 g.

3.3 PLANTING PERIOD

Planting time varies considerably in different regions, depending on local weather conditions, potato cultivar and intended market use. The major portions of potatoes grown are planted from April to early June. Some typically plant from November to February while others typically plant during March and April. In general, potatoes should be planted when the soil temperature is higher than 7 °C and lower than 21 °C. At the time of planting, soils should be moist but not excessively wet. In irrigated desert areas, irrigation is usually applied prior to planting to add moisture to dry soils. Planting into soils that are excessively cold, hot, wet, or dry may increase the potential for seed piece decay. Within reasonable limits, the
early establishment of a crop may increase yield and dry matter potential. In regions where the growing season length doesn’t limit the plant’s ability to fully mature, planting dates are often selected in an effort to provide the crop with a growing environment that will produce the highest economic yield for the desired market.

However, the months November and December are avoided because of high temperatures combined with long day lengths which are not conducive to planting.

3.4 PLANTING DEPTH

If high yields and large tubers are expected, a deeper planting depth and a wide hill may provide a more favourable environment for mature tubers than a shallow planting depth. A favourable environment for mature tubers provides a protective layer of soil that limits tuber greening caused by exposure to the sun. It also protects the tubers and roots against temperature and moisture extremes throughout the season.

Concerns regarding shallow planting depths may include reduced early-season moisture to plants and lower marketable yields owing to an increase in undersized, green and surface-exposed tubers. Deeper planting may provide better soil moisture, less green and surface-exposed tubers, and occasionally, larger tuber size and higher market yields. The disadvantages of deeper planting may include delayed plant emergence and development, yield reductions, and a likely increase in the soil volume that harvesters would have to lift.

In certain locations, growers “drag off” the planting ridge by removing the tops of the ridges before potato plant emergence as a weed control measure as well as to enhance emergence. When planting ridges are shaped to the grower’s preference during planting and effective pre-emergence herbicides are used, this practice is not needed. Ridging or hilling as the plant develops is usually practiced to enhance stolon development, prevent tuber greening and facilitate harvesting. Ridges or hills are sometimes built up gradually in two or more tillage operations or it may be done in one. In some low and flat areas in humid regions, it may be desirable to place the seed at a level above that between the rows. This is done to protect the seed pieces from excess water, which may stand on the surface because of poor or slow drainage.

3.5 DAYS TO MATURITY

90-120 Days to maturity.
3.6 SPACING

3.6.1 Seed piece spacing

Potato seed-piece and plant spacing often influence how large the average tuber size will be upon maturity. Along with marketplace knowledge, the right combination of environment, growing conditions, cultivar, and seed piece spacing is essential for maximising economic yield. The primary factors that determine potato seed-piece spacing are consumer demand, market needs, and the associated economic return to growers and marketers. Other important and often growth-limiting factors include season length, cultivar, irrigation and nutrient availability and soil type. Row widths generally range from 76 to 91 cm, although both wider and narrower rows are used. In-row seed-piece spacing is routinely adjusted by growers in an effort to produce the most valuable tuber-size profile for the intended market.

Because growing conditions and market needs vary in different regions, seed-piece spacing requirements for particular cultivars are not consistent across the regions. In-row spacing generally ranges from 15 to 35 cm. In-row spacing between 18 to 23 cm is probably most common. Cultivar characteristics like tuber number per plant (tuber set), average tuber-size profile, and days to reach maturity need to be defined prior to selecting the seed-piece spacing. To reduce oversized tubers, cultivars with a low tuber set that tend to produce oversized tubers should be spaced closer together than those with a high tuber set, and vice versa. Wider in-row spacings may be used to increase average tuber-size when growing late-maturing cultivars in regions having a limited season. Closer in-row spacing may be more desirable when season length, moisture and nutrients are not expected to be limiting factors.

Excessively large tubers may develop defects such as hollow heart, knobs, and growth cracks. Reducing the in-row spacing to minimise oversized tuber production may lead to higher quality tubers.

3.7 SEEDING RATE

Seed requirement per hectare is 1,200 to 2,000 kg.

4. Fertilisation

Tuber quality is also significantly affected by plant nutrition. Phosphorus deficiency and nitrogen or potassium excesses can decrease specific gravity. Excess nitrogen can delay tuberization and slow skin development.
at maturity. Vines with excessive nitrogen can create an environment more conducive to infection by certain pathogens. Growth disruptions, because of fluctuations in nitrogen supply, can cause misshapen tubers, brown centre, and hollow heart. Potassium deficiencies can result in increased black spot bruise at harvesting, darkened colour, and storage problems. Calcium deficiency has been associated with internal brown spot.

4.1 FIELD FERTILISATION

4.1.1 Fertiliser application methods

The potato plant has a poorly developed root system. Fertiliser is therefore mainly applied in the planting furrows at the time of planting. It should preferably be placed at the same level as, or under, the seed tubers. It is recommended that potato planters be equipped with bins for fertiliser application. If the phosphorus requirement is very high, some of the phosphorus may be broadcast and incorporated into the topsoil. The rest is then applied in the planting furrows along with the nitrogen (N) and potassium (K). Nitrogen top dressings are applied on either side of the plant row, where after the rows are ridged and irrigated. It can also be applied through the irrigation water. Fertiliser granules or liquids must be washed from the plant foliage as soon as possible after application to avoid scorching of the foliage.

Some types of fertiliser, such as potassium nitrate and ammonium nitrate, are more likely to result in fertiliser burn to their higher salt index. Where large quantities of N have to be applied, it is preferable to split it into a number of smaller topdressings. The best times to apply N fertilisers on soils of different clay contents are discussed under nitrogen fertilisation. If necessary, trace elements (micro-elements) can be applied as foliar sprays. Agricultural gypsum, which is used to supplement the soil calcium, is usually broadcast and incorporated before planting, but may also be applied in the planting furrows. If liming is needed to correct the soil pH, the lime should be applied and ploughed in during the previous season (before potatoes are planted), as lime has a low solubility and require sufficient time to neutralise acids in the soil.

4.1.2 Fertilisation rates

a. Nitrogen

Nitrogen is one of the most important elements needed for growth and a shortage can result in yield losses. However, an excess of N can also be detrimental because it can result in excessive foliar growth at the expense
of tuber growth. Excess nitrogen also adversely affects the keeping quality of tubers, lowers the specific gravity, and may result in the development of hollow heart disorder. Generally, the nitrogen content of a soil is not determined by means of soil analysis. Fertiliser recommendations for N are based on the yield potential and the clay content of the soil. Guidelines for N fertilisation are given in Tables 1 to 3. These guidelines can, however, be adapted according to the rainfall, soil history (previous crop), soil type, cultivar used, planting density and planting date.

Table 1: Nitrogen fertiliser recommendations (kg/ha) for different yield potentials under rainfed production on soils of different clay contents

<table>
<thead>
<tr>
<th>Clay content (%)</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10</td>
<td>80</td>
<td>95</td>
<td>110</td>
<td>130</td>
</tr>
<tr>
<td>Oct – 20</td>
<td>70</td>
<td>85</td>
<td>100</td>
<td>120</td>
</tr>
<tr>
<td>&gt;20</td>
<td>60</td>
<td>75</td>
<td>90</td>
<td>110</td>
</tr>
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Table 2: Nitrogen fertiliser recommendations (kg/ha) for different yield potentials under irrigation on soils of different clay contents

<table>
<thead>
<tr>
<th>Clay content (%)</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10</td>
<td>170</td>
<td>220</td>
<td>250</td>
<td>275</td>
<td>300</td>
<td>320</td>
</tr>
<tr>
<td>10 – 20</td>
<td>150</td>
<td>190</td>
<td>220</td>
<td>240</td>
<td>260</td>
<td>280</td>
</tr>
<tr>
<td>&gt;20</td>
<td>130</td>
<td>160</td>
<td>180</td>
<td>200</td>
<td>220</td>
<td>240</td>
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Table 3: Percentage of total nitrogen fertiliser requirement to be applied before and after tuber initiation on soils of different clay contents

<table>
<thead>
<tr>
<th>Growth stage</th>
<th>Clay content (%)</th>
<th>&lt;10</th>
<th>10 – 20</th>
<th>&gt;20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum application up to tuber initiation</td>
<td></td>
<td>50 – 60</td>
<td>60 – 75</td>
<td>80 – 100</td>
</tr>
<tr>
<td>Maximum application after tuber initiation up to 4 weeks before foliage die-back</td>
<td></td>
<td>40 – 50</td>
<td>25 – 40</td>
<td>0 – 20</td>
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b. Phosphorus (P)

Phosphorus is an important component of all plant cells. Sufficient quantities of P will stimulate early root growth and increase water-use efficiency. A shortage of P may result in poor keeping quality of the tubers. Fertilisation recommendations for phosphorus are based on soil analyses and target yield. The phosphorus content of soils can be determined according to various methods. P does not easily leach from the soil and all of it can therefore be applied once-off at or before planting.

c. Potassium (K)

Potassium is important for the deposition of starch and regulation of the stomata. An excess of K in the soil can result in imbalances of other cations (Ca and Mg), which may detrimentally affect tuber quality. K deficiencies can also adversely affect tuber quality (relative density and crisp colour). K requirement is not exclusively determined by the soil K content according to the soil analysis (mg/kg or ppm).

5. Irrigation

Water management and/or rainfall are among the most important factors determining yield and quality of potatoes. While the volume of water required for optimum growth of potatoes varies somewhat with cultivar, relative humidity, solar radiation, day length, length of growing season, and other environmental factors, the seasonal requirement for cultivars in all areas will be at least 460 mm of water. As much as 760 to 910 mm of water will be required in some specific production areas depending on soil type, weather conditions, and potato cultivar. Water should be applied to the soil frequently in light volumes to maintain the crop with an adequate
water supply throughout all growth stages of the crop, particularly during tuber initiation and tuber enlargement.

For irrigation scheduling decisions, the following considerations should be kept in mind:

1) the effective rooting depth of potatoes is 0.6 m.
2) the soil should not be allowed to dry out below 65% of field capacity.
3) moisture levels above field capacity will seriously affect yield and quality, and,
4) soil types can vary threefold in their respective water-holding capacities.

Precise criteria for irrigation scheduling have been specified in units of soil water potential (cbar = kPa) for many climates and soils. Studies in several different growing areas have shown that daily water needs increase rapidly from emergence until about two weeks after row closure. From this time the potato plants’ daily water requirements remain nearly constant until the vines begin to mature, at which time water requirements decline rapidly.

Where rainfall is the major source of moisture, water-use efficiency can be improved by not planting on steep slopes, by properly preparing the soil so infiltration is enhanced and by forming small ridges periodically in the furrows to reduce the speed of the water running down the furrows.

Where irrigation is used, several methods are usually available. The most common systems are centre pivot sprinkler irrigation, solid set sprinklers, wheel line sprinklers, hand-move sprinkler systems, furrow irrigation and sub-irrigation.

Sub-irrigation is a method used in peat-like soils or other soils where the water table can be easily raised. For this to be a suitable method, fields must be relatively level and soils uniformly porous. Otherwise, excessively wet and too dry areas will occur in the same field, impairing the development of the crop, resulting in a negative impact on potato yield and grade.

Furrow irrigation can be efficiently and effectively used in fields with a slight slope (0.3-1.5%) and where the length of rows is not too long (182-402 m). Care must be taken to ensure that water is not applied at rates that will cause excessive runoff or nitrate leaching. Uniform application rates
from one end of the row to the other are more difficult to achieve with this method than with sprinkler irrigation.

Sprinkler irrigation systems often provide the greatest flexibility and the best opportunity of efficient water application. Fields need not be flat and application rates can be adjusted through variable nozzle size, pump pressure and nozzle spacing. Sprinkler irrigation can also be used to apply some fertilisers and pesticides as long as the equipment has appropriate safety back-flow devices and operators are licensed to apply products through a sprinkler system. Several studies have shown economic advantages of sprinkler irrigation over furrow irrigation. Today, most of the irrigated areas of potatoes are most done by one of the sprinkler systems.

6. Weed control

Broadleaf annuals, with the exception of nightshade (Solanum spp.), are usually the easiest to control. The most widely distributed broadleaf weeds of concern in potato fields are: hairy nightshade (Solanum sarrachoides Sendtner or Solanum physalifolium Rusby), common lambsquarters (Chenopodium album L.), redroot pigweed (Amaranthus retroflexus L.), kochia (Kochia scoparia L.) Schrad., ragweed (Ambrosia artemisiifolia L.), and Pennsylvania smartweed (Polygonum pensylvanicum L.). Annual grasses such as barnyardgrass (Echinochloa crusgalli L), foxtail (Setaria spp.), wild oat (Avena fatua L.), and fall panicum (Panicum dichotomiflorum Michx.) may germinate later than most broadleaf annuals. Because of the later germination, a pre-emergence herbicide with residual activity or an effective herbicide that can be applied after potato emergence is needed for control of these weeds.

The most difficult weeds to control are the perennial weed species. The major perennial problem weeds include nutsedges (Cyperus spp.), quackgrass (Elytrigia repens L.), and Canada thistle (Cirsium arvense L.). In addition to causing yield reduction and decreasing harvest efficiency, rooting structures of perennial grasses and nutsedges can penetrate potato tubers causing severe reduction in quality. When perennial weeds are the primary problem, more than the standard number of tillage operations may be needed for effective weed control even though herbicides are used. Perennial weed control may be more effective and economical in crops rotated with potatoes, such as winter wheat.

Potato cultivars that develop and maintain a dense canopy with early row closure can be competitive with many weeds. Weed control practices in potatoes include cultivation and herbicides, and a combination of the two
is often more effective than either alone. Heavy weed infestations can require multiple cultivations. However, strict tuber quality requirements may limit the use of mechanical cultivation for weed control. Multiple cultivations can cause soil compaction, which reduces aeration and potato growth, and can produce clods that bruise potatoes at harvesting. Cultivation also may directly damage potato foliage and roots, reducing yield and tuber quality. In seed-growing areas, cultivation after potato emergence may spread diseases. Wet soil interferes with cultivation timeliness, and in-row weed control is usually not effective.

A combination of a timely pre-emergence herbicide application and cultivation as the weeds are germinating and emerging provides effective early season control. Many pre-emergence herbicides do not control emerged weeds. These herbicides work most effectively when applied shortly after a hilling operation that is performed just before potato emergence. Weeds emerged after planting are killed off by the hilling operation and herbicides are applied to a “clean bed.” Pre-emergence herbicides usually have to be incorporated into the soil 2 to 5 cm where the weed seeds are germinating. This can be done by irrigation and sometimes by tillage if adequate rainfall has not occurred after application. A few non-selective herbicides also are labelled for use before potato emergence. These herbicides control emerged weeds and have no residual activity for later-emerging weeds. Some herbicides may be applied post-emergence to the potato crop.

Other crops in a potato cropping system may not be tolerant to the herbicides used for potatoes, so crop rotation should be considered when making herbicide choices. Repeated use of herbicide(s) with the same mode of action for killing a weed can cause selection pressure for weed biotypes naturally resistant to that mode of action. These biotypes are usually present in a given weed population in very small numbers. If susceptible weed biotypes are killed off and the resistant biotypes survive, then the weed population can become dominated by the resistant biotypes. Herbicides with the same action that has been used repeatedly may no longer be effective. Rotating herbicides with different modes of action from year-to-year and/or tank-mixing herbicides with different modes of action and overlapping weed control spectrums can help prevent or delay the development of herbicide-resistant weed populations.

7. Pest control

Regular field scouting is one of the most important aspects of effective insect control.
7.1 APHIDS

Green peach, melon or potato aphid may occur in potato, colonising fields from mid June through July. Potato aphid is the largest aphid of the three, 3 to 4 mm long, and may be pink or green. Cornicles are the same as the body colour with dark tips. Plants of the rose family serve as alternate hosts to potato aphid in autumn and spring. A wide range of weeds, field crops and vegetable crops are hosts in summer. In potato they feed first in young, growing tips, spreading downward into older leaves. Damage includes leaf deformity and dieback.

Aphids spread viruses to seed and table stock potatoes, which can reduce yields and quality. High populations of aphids can cause foliage to decline.

Fields should be scouted for aphids starting in late June. Examine aphids/leaf on 50 fully grown compound leaves (5 leaves at ten locations in the field) from top, middle and bottom of the canopy. In fresh market and processing potato, the threshold for insecticide application is when an average of 5 aphids per leaf are present, or 10 per leaf within 2 weeks of vine kill. The economic threshold for table stock and processing fields is when aphids are found on 50% of the plants or one winged aphid is found within the field.

7.2 FLEA BEETLES

Adults spend the winter under plant residue along tree lines or in the field. In the early spring they feed on solanaceous weeds until they move to potato or other solanaceous crops. Numerous tiny feeding shot holes can damage the leaves and stunt young plants. Management practices include clean cultivation, crop rotation, delayed plantings, removing or avoiding spring weed hosts, use of row covers, and applying spot treatments targeting young potato plants along the field edges. Full size plants rarely require treatment for flea beetles.

7.3 POTATO LEAFHOPPER

Low levels of leafhopper feeding can severely damage plants and cause symptoms known as hopper burn. Leaves yellow, turn brown and die. Adults are light green, and wedge-shaped, while nymphs are bright green, flatter and fatter than adults, and move sideways in a crab-like fashion. Sample with sweep net and treat if more than one adult per sweep is found. Nymphs can be monitored by visually inspecting lower leaf surfaces on the lower leaves. Treat if more than 15 nymphs are found per 50 leaves.
7.4 WIREWORMS

Wireworms are the larvae of slender black beetles known as click beetles. Adult click beetles emerge in the spring from the soil where they wintered. Shortly after mating, the female beetles lay up to 300 eggs in the soil, usually around grass roots. Eggs hatch within a few weeks and the larvae begin feeding on root hairs and fungi. At this stage, they are usually overlooked as they are small and the damage they cause is negligible.

Because of the long lifespan of wireworms, damage may continue in the same field for several years, although severity will depend on weather and crop rotation. At the time of publication, Thimet was the only insecticide registered for control of wireworm. Alternative fields should be considered if populations of wireworms are high.

8. Disease control

8.1 VIRAL DISEASES

8.1.1 Potato virus Y (PVY)

The causal agent of potato virus Y is a filamentous virus of the genus Potyvirus and family Potyviridae. Infected seed potatoes, volunteer plants and some weeds can all be sources of this virus. Transmission is mainly by aphid vector, although some mechanical transmission may also occur. There are three main groups of PVY strains: PVYO (ordinary type), PVYC (stipple streak strain) and PVYN (tobacco veinal necrosis). PVYNTN (potato tuber necrotic ring spot disease) is a new strain that causes tuber necrosis.

a. Symptoms

Potato virus Y causes a range of symptoms from mild defoliation to die off, depending on the virus strain, potato cultivar and environmental conditions. It ranges from virtually none (latent), to noticeable stunting and mosaic symptoms to severe foliar damage and even the die off of the entire plant.

b. Transmission

PVY is spread by aphids in a non-persistant manner. The stylets of the aphids carry PVY particles after feeding on an infected plant and when they subsequently feed on a healthy plant they infect with their contaminated stylets. In the case of non- persistently transmitted viruses, aphids are virus free again after 1 to 2 hours. The aphids thus acquire the virus
from infected plants and lose it quickly when they probe healthy plants. The green peach aphid, Myzus persicae, is the most effective vector.

c. Hosts
Potato virus Y (PVY) infects a range of solanaceous crops including potato, capsicum, tomato and tobacco. Carryover is mainly via potato tubers (seed tubers or volunteers).

d. Control
The use of insecticides is largely ineffective in the control of PVY, because they do not act fast enough to kill aphids quickly and thereby prevent virus spread.

Methods of control include:

- Planting of certified disease-free seed potatoes.
- Spatial isolation of seed potato production from ware potato production.
- Planting of border crops in order for aphids to lose their virus inoculum before moving into potato.
- The eradication of aphid weed hosts, especially other solanaceous plants.
- Growing crops in regions where aphid pressure is low.
- Refraining from growing new crops in the proximity to established crops that might act as an infection source.
- The destruction of volunteer potatoes as they may harbour the virus.
- The destruction of haulms of seed potato crops before maturity, to prevent late infections spreading to tubers that are developing.
- The application of non-toxic mineral oils has shown to reduce PVY transmission.
- Roguing: the immediate removal and destruction of infected plants as well as adjacent plants.

8.2 FUNGAL DISEASE

8.2.1 Black dot
Black dot is caused by the fungus Colletotrichum coccodes. Like silver scurf, black dot spoils the appearance of tubers, resulting in the downgrading of tubers. Ware potatoes can be downgraded at the market because
of cosmetic reasons and the occurrence of moisture loss can result in a lower quality product. Because C. coccodes is a relatively weak pathogen it usually does not have an adverse effect on growth and development of the plant and therefore yield. Early die-off, resulting in lower yields can occur if the disease is accompanied by nematode infestations or fusarium/verticillium wilt.

\textit{a. Symptoms}

The disease is distinguished by the presence of black dots (micro-sclerotia) at the end of the season on the surface of infected tubers, stolons, roots and above and below-ground stems. Tuber symptoms can be identified as dark-brown marks on the surface of tubers that are to a certain extent similar to those of silver scurf. The marks caused by black dot are in some cases not as defined as that of silver scurf. Small, black dots (micro-sclerotia) can easily be identified with a hand lens. Micro-sclerotia are not present on tubers infected with silver scurf and are the most important distinction between the two diseases.

\textit{b. Control}

An integrated control strategy is still the best way of control of black dot, i.e.:

1. In South Africa tubers can be treated with registered fungicides. The tubers must be treated days before planting because the eyes are damaged during treatment.
2. The treatment of tubers is less successful when soils are contaminated and is therefore not recommended.
3. Plant certified, disease-free seed tubers.
4. Harvest as soon as possible once the foliage has died off. The disease spread readily when tubers are left in the soil.
5. Harvest the tubers with as little soil as possible adhering to them, because soil can also serve as a source of infection.
6. Store the tubers under dry, cool conditions.
7. If possible, remove and burn all plant residues from the field.

\textbf{8.2.2 Botrytis}

Grey mould caused by the widespread fungus Botrytis cinerea, affects most vegetable and fruit crops.
a. Symptoms

The fungus attacks the leaves, stems, flowers and tubers. Lesions usually develop on the margins of older leaves, are grey green or transparent and are sometimes covered with a mass of grey spores. The disease spreads from the leaves to the stems via spores. Infected tubers show a typical dry rot symptom, and are usually covered with a mass of spores. Sclerotia often occur on infected, dead stems or inside infected tubers.

b. Conditions favourable for disease development

Since B. cinerea has a wide host range and because of the fungus’s ability to grow on dead, organic material, the spores of the fungus are widely distributed in the air. Wind easily spreads the spores to susceptible hosts, which are rapidly infected if conditions are favourable. Infection usually starts on senescent flowers or older leaves, or on plants which are under stress. The optimum temperature for development of the disease is 18 – 24 °C, provided the relative humidity is higher than 75%. A dense plant canopy will also promote the development of the disease, because high humidity below the canopy creates an ideal microclimate for disease development. Tuber infection occurs mainly after harvesting, particularly when potatoes are harvested under wet conditions. Infection can occur through stolons, or through wounds caused by mechanical damage sustained during harvesting and handling. Further development of the disease can occur during storage (even cold storage). Serious problems from Botrytis rot are likely to occur when potatoes are stored in damp conditions and the damage on the tubers has not healed completely.

c. Control

1. Plant healthy seed potatoes.
2. Avoid mechanical damage to tubers.
3. Do not harvest potatoes when the soil is excessively wet. Wet conditions are ideal for the development of the disease.
4. If possible, potatoes must be stored after packing under conditions that are favourable to healing.
5. Where this disease is known to cause damage, space the rows wider, because dense vegetation will promote the disease.
6. Either remove all organic material or plough it in deeply before the potatoes are planted.
7. No fungicide is presently registered in South Africa for the control of grey mould on potatoes.

8.2.3 Brown spot

Brown spot (“malroes”), a new or emerging disease of potatoes in South Africa, has resulted in serious yield losses in many production regions of the country over the past 5 to 8 years. The disease is caused by the fungal pathogen Alternaria alternata.

a. Symptoms

Brown spot symptoms can be seen any time from 50 days post emergence (or earlier), often before early blight (Alternaria solani). Symptoms start as small, round, brown, water-soaked lesions on the undersides of leaves. After a few days, these lesions enlarge and can be seen on the adaxial sides of leaves. Brown spot lesions are similar to those of early blight; however, they do not have concentric rings and do not become as large.

A. alternata, falls in the same genus as Alternaria solani, the fungus that causes early blight. Both are opportunistic fungus, which means that they cannot easily attack healthy plants. When fungicides are used for the control of early blight, A. solani and other fungal species are killed off, resulting in a biological vacuum. It is then easier for A. alternata to colonise and infect the potato leaves.

b. Conditions favourable for disease development

Warm and humid conditions, or long periods of leaf wetness, are conducive for the development of the disease. Large quantities of spores are produced during cyclic wet and dry conditions. Spores are usually spread by air or water, but may also survive on dead plant debris in the soil. Alternaria alternata usually infects through micro injuries, e.g. insect, wind or hail damage, and chemical scorch wounds.

c. Control

Strategies that should be followed to manage brown spot and to try and prevent the development of resistance in fungicide populations are:

1. Plant cultivars that are less susceptible to Alternaria species.
2. Remove inoculum sources, such as plant debris, weeds and volunteer plants.
3. Use non-host plants in a crop rotation programme, e.g. wheat, maize and barley.

4. Keep plants healthy: optimal fertilisation (avoid excess N) and irrigation.

5. Start spray programmes aimed at prevention earlier than normal.

6. Limit the use of any one type of active ingredient to a minimum.

7. Alternate the active ingredients.

8. Use fungicides only at recommended rates.

9. Use tank mixes where allowed in spray programmes.

An integrated management strategy is advised for the control of brown spot of potatoes. This should include choice of cultivar, good weed and insect control, optimal nutrition and irrigation and a sound fungicide application programme.

8.2.4 Early blight

Early blight is the most common disease of potatoes in South Africa and is caused by the fungus Alternaria solani. Yield loss of up to 50% in heavily infected fields has been recorded.

a. Symptoms

Dark-brown, round lesions, with concentric rings develop on the leaves. A lesion may be 5 to 15 mm in diameter, Yellowing develops round and between the lesions and the leaves may die off. Contaminated tubers develop single, round, sunken lesions on the surface in storage and are dark brown and firm to a depth of 10 to 12 mm.

b. Conditions favourable for early blight development

Hot, moist conditions, while rain, heavy dew and irrigation in dry areas promote the spread of early blight on the leaves. The disease develops most rapidly during periods of alternating wet and dry weather, particularly on light soils.

c. Control

1. Plant healthy seed potatoes.

2. Apply crop rotation to reduce the quantity of inoculums.
3. Apply optimal fertilization and irrigation to maintain strong, healthy plant growth.

4. Harvest potatoes only after the skin has set, and try to limit mechanical damage during harvesting and storage.

5. Use registered fungicides.

6. Destroy infected plant remains after harvesting by ploughing them into the soil.

7. Irrigate judiciously.

8. No commercial cultivars possess good resistance to early blight, but some are less susceptible than others.

8.2.5 Fusarium dry rot

Fusarium dry rot is caused by nine Fusarium spp. of which F. solani and F. oxysporum are the most important. Dry rot is the most important post-harvest disease in South Africa. Spores of pathogenic Fusarium species are widely distributed in almost all soils wherever potatoes are grown. Fusarium mainly infects through injuries and bruises. Infection is likely to occur during harvesting, sorting and transport or when seed tubers are cut before planting. Infection can also occur through lesions caused by nematodes, insects or other pathogenic fungi, causing tubers to rot in the soil before harvest.

a. Symptoms

The first symptoms are usually visible 2 to 4 weeks after infection, depending on environmental conditions. When infected tubers are exposed to high humidity and temperatures between 25 and 30 ºC, dry-rot symptoms may appear within one week.

Infected tubers sometimes show few external symptoms of rotting. At the point of infection, a small, brown to dark-brown, sometimes sunken, spot develops. This sunken area may not enlarge and no further rot may be noticed until the entire tuber has rotted completely. However, sometimes a large part of the tuber surface is visibly affected. In this case the skin exhibits typical wrinkling, sometimes in concentric rings, which can be covered with white or pink spores.

When a tuber infected with dry rot is cut open, a brown streak of tissue will be observed along the edges of the rotted tissue. Hollows filled with fungal spore masses and mycelia may also be found within the rotted tis-
An infected tuber will eventually shrivel and become mummified.

b. Conditions favourable for disease development

Fusarium dry rot is more severe after dry and hot growing seasons. Fusarium dry rot develops most rapidly under conditions of high RH (90 - 98%) and at moderate temperatures (15 - 25 °C).

Fusarium dry rot can also develop under the lowest temperatures safe for potato storage.

c. Control

1. Prevent mechanical damage at all costs. This can be done by harvesting only physiologically mature tubers and through the correct use of mechanical diggers.
2. Do not harvest potatoes when the soil is excessively wet or dry.
3. Handle tubers carefully during sorting, packing and transport. Avoid unnecessary handling of stored, particularly cold-stored, potatoes.
4. During sorting, remove and destroy visibly damaged and rotted tubers.
5. Apply recommended fungicides as soon as possible after harvesting, preferably within 4 to 6 hours after lifting.
6. If possible, after packing, store tubers under conditions that favour wound healing. Temperatures between 13 to 16 °C and a high RH for at least 10 days are recommended.
7. Transport and store tubers under cool, dry and well ventilated conditions (preferably at 4 - 5 °C).
8. Remove seed potatoes from cold storage at least 10 days before planting and store them at least at 20 to 25 °C.
9. Treat tubers with a recommended fungicide. The cutting and treating of seed tubers should begin the day prior to planting.
10. Use only high-quality, firm and well-sprouted seed tubers when cutting is considered.
11. Plant seed tubers, where possible, in cool, moist soil.
12. The planting of cut seed tubers can only be recommended for winter or spring plantings.

8.2.6 Fusarium wilt

In South Africa, Fusarium oxysporum and F. solani are the most important fungal pathogens associated with the wilting of plants. Under optimal conditions for disease development, up to 100% infection may occur, causing serious losses for the producer.

a. Symptoms

The first symptoms usually occur in the middle of the growing season when infected plants turn to a lighter color, followed by wilting, yellowing and curling of the lower leaves. Sometimes the growth tips of infected plants show a purple discoloration and the appearance of air tubers in the leaf axils. Both the root and the stem may exhibit an external corky decay. Stems that are bisected, show typical browning of the vascular tissues. Tubers from infected plants may also be infected, showing a sunken, wrinkled, dry stem-end rot of varying size, or a slight indication of rot of varying size, or a slight indication of rot round the point of stolon attachment. Discolouration of the vascular tissue is usually visible at harvest and when infected tubers are stored, the rot continues.

b. Conditions favourable for disease development

Fusarium wilt is more severe during hot, dry weather conditions and particularly when plants are under stress.

c. Control

a. Use a three-year crop rotation system with crops like maize and wheat.

b. Avoid susceptible cultivars, e.g. Vanderplank, in areas where Fusarium wilt is a problem.

c. Avoid planting seed tubers infected with Fusarium species.

d. Apply high levels of phosphate and potash, and low levels of nitrogen to suppress the disease.
e. Focus cultural practices on achieving low soil temperatures and high soil moisture, because temperature and moisture are critical factors in the occurrence of this disease.

f. Plant well-sprouted seed tubers deep, with narrow spacing and ridging will help to suppress the disease.

g. Avoid heavy, clay soils.

h. Select a planting date to avoid periods of hot, dry weather.

i. No affordable chemical soil treatment is available to control the disease.

8.2.7 Gangrene

Gangrene is caused by Phoma exigua var. exigua and P. exigua var. foveata. This disease is especially problematic during the storage and handling of potatoes. If infected seed potatoes are planted, emergence can be delayed. The disease can also reduce yield.

a. Symptoms

Dark sunken lesions or “thumb marks” develop on the tubers, or at the site of injuries, eyes or lenticels.

b. Conditions favourable for disease development

As in the case of Fusarium dry rot, infection can occur in tubers through cuts, bruises and lenticels during harvesting and handling. The disease is soil and tuber-borne. Under high soil moisture conditions, infection can occur even before harvest. Optimum conditions for the development of the disease are day temperatures of less than 12 °C during harvesting, and storage temperatures of between 2 to 10°C. Higher storage temperatures suppress the development of gangrene but, on the other hand, favour the development of Fusarium dry rot.

c. Control

1. Avoid damage to the tubers, as well as exposure to cool temperatures during storage.

2. If possible, potatoes should be stored under conditions that favour wound healing. Temperatures of 13 to 16 °C and an RH of lower than 80% for at least 10 days are recommended.
8.2.8 Late blight

Late blight is caused by the fungal pathogen Phytophthora infestans. The fungus spreads rapidly under favourable weather conditions. If no control measures are implemented, entire fields can be destroyed within a short period of time.

a. Symptoms

Leaf symptoms of late blight are small, light-green, circular to irregularly shaped water-soaked spots. The lesions usually first appear on the older leaves and often begin to develop near the tips or edges of leaves, where dew drops form. During cool moist weather, these lesions expand rapidly into large, black lesions. Stem symptoms have become prevalent in South Africa and are characterised by brown lesions on the stems and petioles. Tuber infections are not common in South Africa. Tuber infections are more predominant in wet, cool soils.

b. Favourable weather conditions for late blight development include:

i. Day temperatures between 15 and 24 °C.

ii. Night temperatures no less than 10 °C.

iii. Free moisture must be present on the plant.

iv. Relative humidity of 90% and above.

v. Cloudy conditions.

c. Control

1. Plant healthy seed potatoes.

2. In areas where late blight frequently occurs, choose cultivars with good resistance to the disease.

3. Cultivate potatoes when late blight is absent.

4. Use registered fungicides.

5. Avoid using phenylamides in areas where there is resistance to this group of fungicides.

6. Ensure that the crop is well ridged at the end of the growing season, to prevent infection of the tubers if late blight was present.

7. Irrigate judiciously, particularly when the conditions are favourable for infection. This is even more important if late blight is present.
8. Avoid wet spots in the field.

9. Do not harvest during wet weather, especially if late blight has occurred on the foliage.

10. Control volunteer potato plants.

11. Fields should be inspected at least twice a week for the presence of blight.

12. Disease-forecasting systems can be used to control this disease more effectively.

8.2.9 Powdery scab
Powdery scab caused by Spongospora subterranea is a fungal disease that occurs in most potato-producing areas in the world. The pathogen can survive in the form of dormant spores for up to 6 years. The pathogen penetrates the root hairs, stems, lenticels, eyes and injuries of the damaged tubers. Soil temperatures below 20 °C are favourable for the pathogen. Optimum pH levels for disease development are 4.7 to 7.6. Favourable conditions for the development of powdery scab are moist conditions, particularly in heavy, poorly drained soils, or soils that are heavily irrigated. Disease development is enhanced by high soil moisture in the early season, followed by dry conditions later in the season. Powdery scab can also spread by means of the manure of animals that have eaten contaminated potatoes. The most susceptible growth stage is week prior to tuber formation.

a. Symptoms
The symptoms of powdery scab can easily be mistaken for common scab. Powdery scab lesions are smaller and almost round with clearly defined edges. The first tuber symptoms are light brown, raised areas as small as a pinhead. The lesions enlarge and the skin covering the lesions tears to reveal hollows filled with dark brown to black, powdery spore balls. Infected roots and stems also develop small, necrotic lesions from which milky white galls develop. These galls can be confused with those of the root off knot nematode. Under favourable conditions these galls can cause young plants to die.

b. Conditions favourable for disease development
Tuber and root infection is favoured by cool (16 – 20 °C), moist soil conditions in the early stages of infection and later by gradual drying of the soil.
c. **Control**

a. Plant symptomless seed produced in disease-free areas to avoid introducing powdery scab. Avoid planting in contaminated, poorly-drained fields.

b. Crop rotation of up to 10 years can reduce the population of the pathogen in the soil.

c. Use soil cultivation practices that will ensure proper drainage.

d. Review general hygiene in storage facilities.

e. Removing of infected tubers will not necessarily be effective because spores can move from infected tubers to non-infected tubers.

f. Avoid over-irrigation - especially if the pathogen is already present in the soil.

g. Products containing zinc result in a good level of control.

h. To date chemical agents have only given marginal control and the best results have come from crop rotation.

i. Leguminous and cabbage crops can be considered for crop rotation.

j. There are no fungicides registered for the control of powdery scab.

### 8.2.10 Rhizoctonia

Black scurf and stem canker, caused by *Rhizoctonia solani* affect potato production in virtually all regions of the world including South Africa. It spoils the appearance of table potatoes and only a limited quantity of black scurf is allowed on certified seed tubers. It also causes considerable damage to emerging sprouts if planting occurs in e.g. cool and wet soils.

a. **Symptoms**

The disease has two characteristic symptoms. Black scurf describes the fungus’ black survival structures (or sclerotia) that adhere to the surface of the tuber looking rather like soil. Stem canker refers to the sunken, brown lesions on roots, stems, tubers, stolons and sprouts.

b. **Conditions favourable for disease development**

Infection can occur any time during the growing season and the development of especially stem cancer is promoted mainly by cold, wet soil conditions.
c. Control

a. Plant certified tubers. If black scurf occurs on seed tubers, it is advisable to treat the seed before planting with a registered fungicide.

b. On lightly contaminated soils, variable success was obtained with chemicals that are registered as a soil treatment.

c. Use crop rotation systems of 2 to 3 years with grasses and grain crops to reduce infection, however, these systems will not eliminate it completely.

d. Avoid cool, poorly drained soils.

e. Harvest the potatoes early after skin set.

8.2.11 Sclerotinia rot

Sclerotinia rot is caused by Sclerotinia sclerotiorum. The disease is generally not regarded as a serious problem in this country, although severe losses resulting from this disease have been reported.

a. Symptoms

The disease is characterized by water-soaked lesions, covered with a white mycelium growth, which occurs on the leaves, petioles and stems. If infected stems are cut open, large, black structures known as sclerotia (up to 10 mm in diameter) in the stems will be observed. The disease can develop quickly under favourable conditions and destroy the entire planting within a few days. Dead plant material on the soil is usually covered with a white mycelium growth. Small, mushroom-like structures (about 0.5 mm in diameter), known as apothecia, may develop out of the sclerotia. Spores that develop from the apothecia can be spread by wind, and lead to further infection.

b. Conditions favourable for disease development

Low temperatures (16 to 22 °C) and a high relative humidity (95 - 100%) are favourable conditions for the development of sclerotinia rot. Under these circumstances, sclerotia germinate and form apothecia, which release spores, which can infect plants. Mycelia can also develop directly out of the sclerotia and infect plants.

c. Control

1. Effective management practices are the only way of controlling sclerotinia rot effectively.
2. Avoid excessive irrigation, particularly at night.

3. Use a crop rotation system with grain crops for 4 years or longer.

4. Space the rows wide in areas where this disease is a problem.

5. There is no registered fungicide for the control of this disease.

6. Avoid planting host crops on soils in which potatoes are cultivated.

8.2.12 Sclerotinia wilt

This disease is caused by a fungus known as Sclerotium rolfsii.

a. Symptoms

Infection of stems usually occurs at or just below the soil surface. The lower leaves turn yellow (chlorotic), after which the entire plant wilts. The thick, white fungal growth and the formation of light-brown, round sclerotia (0.4 - 2 mm) at the base of the stem are very characteristic. Tubers can also be infected by means of stolons of infected plants or through injuries. A thick, whitish, mycelium growth on the tubers is also very characteristic, as is the formation of sclerotia. The rotted tissue of infected tubers is characteristically a saffron (bright yellow) colour.

b. Conditions favourable for disease development

The disease is promoted by high temperatures (28 - 30˚C) and by a high relative humidity. The fungus is soil-borne, and can survive for long periods in the soil. The disease spreads mainly by mycelium fragments, as well as by sclerotia in plant remains and infested soil. Infection can take place at any of the plant’s growth stages.

c. Control

i. Effective management practices are the only means of controlling the disease.

ii. There is no registered fungicide for the control of this disease.

iii. Plough plant residue into the soil after harvest.

iv. Avoid planting in contaminated soils.

8.2.13 Silver scurf

Silver scurf is a disease caused by the fungus Helminthosporium solani. The disease is of economic importance as it can result in potatoes being
downgraded on the market for cosmetic reasons. Moisture loss in infected tubers can result in reduced quality.

a. Symptoms
The disease can be identified as small, light-brown, circular spots that enlarge with time. Lesions have a shiny, silvery appearance. The circular spots appear darker at the margins owing to spore production. Moisture and weight loss of tubers infected with silver scurf are common as the skin becomes permeable to water. Plant vigour is usually not affected if infected tubers are planted under favourable cultural conditions.

b. Conditions favourable for disease development
Temperatures between 20 to 24 °C and a high relative humidity of 90%.

c. Control
1. Plant certified seed only. The ideal is disease-free, high generation seed planted in soil that has not previously been used for potato cultivation.
2. If silver scurf is suspected to be present, treat the seed with a registered fungicide.
3. Ensure optimal growing conditions so that the plant’s natural resistance is kept at its highest level.
4. Harvest potatoes as early as possible after the canopy is killed off.
5. After harvest, potatoes must be kept dry and can be treated with a registered fungicide.
6. Potatoes have to be stored at a low relative humidity and temperature. Good ventilation during storage is of cardinal importance.
7. Crop rotation practices of up to 4 years with grain crops are recommended.
8. Silver scurf cannot be effectively treated with chemical fungicides only. Good cultural practices play an important role in the control of silver scurf.

8.2.14 Verticillium
This disease occurs worldwide and is caused by Verticillium albo-a-trum and V. dahliae. Verticillium wilt is easily confused with other diseases such
as Fusarium wilt. The disease has been reported to cause large losses, and is common in tomatoes and cotton in South Africa.

\textit{a. Symptoms}

Chlorosis or the yellowing of leaves followed by necrosis or the browning of leaves is the most common symptoms of Verticillium wilt. The disease usually starts in the lower or older parts of the plant, after which the symptoms spread to the rest of the leaves. The brown discolouration of the vascular bundle in tubers and wilted stems is another symptom of Verticillium wilt.

\textit{b. Conditions favourable for disease development}

Warm soil temperatures of 22 °C to 27 °C favor V. dahliae, while V. albo-atrum is more of a problem at lower temperatures of 10 °C to 22 °C. So far, only V. dahliae has been identified on potatoes in South Africa. The disease is usually associated with stress conditions.

\textit{c. Control}

i. Plant disease-free seed potatoes.

ii. It is important to do a disease risk assessment of possible planting sites.

iii. Avoid fields with a history of Verticillium wilt.

iv. The disease may be controlled by a variety of soil fumigation treatments such as chloropicrin or metham-sodium, depending on the inoculum level of the soil.

v. A crop rotation of 3 to 4 years with grass or grain crops may reduce the prevalence of the disease in the soil. The use of broccoli as a green manure crop can help to control the disease.

vi. Avoid planting susceptible hosts such as tomatoes and cotton on soils in which potatoes have been cultivated.

vii. Sanitation is important in preventing the introduction of the pathogen into wilt-free fields and in reducing losses from wilt in infested fields.

viii. Deep ploughing, particularly where the soil is completely inverted, can be effective in reducing losses.

ix. An effective weed control programme is important.

x. An effective nematode control programme is important.
xi. An effective control programme for tuber borne and foliar diseases will reduce plant stress and therefore susceptibility to Verticillium wilt.

xii. Select a planting date to avoid periods when the temperature is between 20 °C and 28 °C during the tuber initiation stage.

xiii. Fertilisation should be limited to levels for optimal yield, using a pre-plant soil analysis as foundation.

xiv. Very good irrigation management early in the season is recommended, because high soil-water content during tuber initiation supports infection, whereas low soil water content after infection, enhances symptom expression.

8.3 BACTERIAL DISEASES

8.3.1 Bacterial wilt

This disease is caused by a bacterium known as Ralstonia solanacearum and is also known as “vrotpootjie” or brown rot.

a. Symptoms

The most notable symptom is the green wilting of the plants, even when the soil is moist. Only one or two stems of the plant may show wilting at first, but later the entire plant wilts and dies. If the infected plant has already formed tubers, these tubers will probably also show symptoms. A brown vascular ring will be observed when the tuber is cut through. When an infected tuber is cut through and squeezed, slimy drops of bacteria will ooze from the vascular ring. In addition, when an infected stem is cut and placed in a glass of water, a milky bacterial suspension will flow out of the stem.

b. Conditions favourable for disease development

Warm, moist soil conditions are very favourable for the development of bacterial wilt. The disease is not spread by the droppings of animals or by the potato tuber moth.

c. Control

a. Plant only certified seed potatoes.

b. Do not plant on fields with a history of bacterial wilt infection. Research has shown that the pathogen can survive in soil for many years.
c. Limit the spread of disease by removing infected or suspect plants and destroying these.

d. If the infestation is severe, stop irrigation to prevent spread by runoff and ground-water.

e. Do not use irrigation water which may possibly be contaminated. e.g. where the runoff of an infected field may contaminate an irrigation dam.

f. Sanitise all implements after use on an infested land using 0,5% Jeyes Fluid.

g. Avoid movement of vehicles, animals and humans through an infected field.

h. No bactericide has been registered against the disease.

Where a potato field has already been infected, the following measures may limit survival of the bacteria in the soil:

a. Drying of the land by regular tillage.

b. Removal of volunteer potato plants and weeds (some weeds may serve as hosts).

c. Applying crop rotation with non-host crops such as maize, grains and grass varieties.

d. Cultivating table potatoes in the cooler season. There is always the risk that the bacteria may be latently present in the tubers. If such symptomless tubers are used as seed, the disease may still develop under favourable conditions.

8.3.2 Common scab

The main causal agent of common scab on potatoes is Streptomyces scabies, however, common scab can be caused by a genetically and phenotypically diverse group of Streptomyces species apart from S. scabies. The disease occurs in all potato-producing regions of the country. Producers experience significant losses because of desertification of seed and a growing consumer demand for blemish-free produce.

a. Symptoms

Common scab disease symptoms appear as superficial, raised or deep-pitted, brown to dark-brown corky lesions on potato tubers. Lesions can
occur as single and isolated, round and coalesced (5-8 mm in diameter) or erumpent and spread over the entire tuber surface. In some cases lesions can also be seen on the roots and stolons. No above-ground symptoms are observed.

**b. Favourable conditions**

Warm, dry weather conditions and continued cropping with potato or other susceptible crops (e.g. beet, sugar beet, carrot, turnip, groundnut) are favourable for disease development. Cultivation of spinach and the incorporation of red clover as cover crop can also lead to an increase in disease incidence. The pathogen occurs naturally in most of the older potato fields, but can also be introduced to fields by means of infected seed. These seed pieces can appear scab free but might still be infected with the pathogen if the seed lot has a history of scab. The pathogen can survive on roots of living plants and, especially, decaying plant material. Severe disease incidence has been recorded on fields that were fertilised with animal manure. Common scab can also be present in virgin fields. The potato plant is only susceptible to common scab infection during tuber initiation and enlargement. The common scab lesions develop and spread with the expansion of the newly developed tubers. No additional disease development occurs during harvesting and storage.

**c. Control**

1. Plant only certified seed. If any common scab lesions are visible or if the disease is suspected in the seed lot, it is recommended that a registered seed treatment be applied.

2. Soil treatment of infected fields can result in insufficient control. The efficacy of the product is determined by soil type (texture and structure) as well as method of application.

3. Disease development can be limited by lowering the soil pH (below 5.5). The addition of elemental sulphur or an acid based fertiliser e.g. ammonium sulphate is recommended. Application of lime to raise soil pH can increase disease incidence, whereas the addition of gypsum has no effect on soil pH and is the preferred practice.

4. Irrigation scheduling during the early stages of tuber initiation can deter infection, however, the evaporation rate of the irrigation water must be monitored closely.

5. A 3 to 6 year rotation with non-host crops is recommended. This practice leads to a decrease in soil inoculum but will not eradicate the
pathogen. Suitable rotation crops include wheat, rye, oats, soya bean, sorghum and lucerne.

6. Green manuring with brassica crops (e.g. mustard, cabbage), rye, clover, bean or grasses can reduce common scab incidence.

7. No resistant potato cultivars are currently available, however, some cultivars show a certain level of tolerance to the disease.

8.3.3 Erwinia black leg

Pectobacterium carotovorum subsp. atrosepticum (black leg) is associated with potatoes. These bacteria do not survive well in the soil for more than one year, unless present in diseased tubers, other potato plant debris or volunteer plants. Most seed tubers are contaminated to some degree, but the bacteria are usually dormant and do not cause disease symptoms unless environmental conditions are favourable.

a. Symptoms

The most characteristic symptom of black leg is that the stem near the soil surface becomes black or brown and rots rapidly. Symptoms may be observed during all growth stages. Infected plants usually appear dwarfed, with light-green or yellowish leaves. The upper leaves are stiff and straight, and curl upwards at the leaf edges. If wet weather persists, the plants may wilt quickly and deteriorate. The seed potato rots quickly, and in serious cases, young tubers may rot from the stem end. With more moderate infestations, most tubers may appear healthy, only to rot later during storage.

b. Conditions favourable for disease development

In general, it may be accepted that black leg will be present if low inoculum density with accompanying cool, moist conditions prevail. The bacteria do not survive well in warm soils.

c. Control

1. Avoid heavy, poorly drained soils.

2. Avoid excessive irrigation.

3. Seed potatoes should preferably not be cut, but if they are, the knives should be sterilised regularly with a 3,5% solution of sodium hypochlorite (household bleach).

4. Destroy all potato rests (rotted tubers and stems), which may serve as a source of inoculum.
5. As far as possible, limit damage to tubers during handling.
6. Avoid abnormally high nitrogen applications.
7. Remove infected plants to prevent spreading of bacteria to healthy plants as soon as possible.
8. Apply fungicides to prevent secondary fungal infections.
9. No bactericide has been registered against the disease.

8.3.4 Erwinia wilt

Aerial stem rot or Erwinia (Pectobacterium) wilt is caused by Pectobacterium carotovorum and Dickeya dadantii (formerly E. chrysanthemi). These pathogens occur in infested soil and infected plant residue. The pathogens can be introduced into the crop by irrigation water, wind-blown rain and insects. They can also survive in lenticels, on the skin, vascular ring and cracks inside the tuber. There is no chemical agent registered for Erwinia diseases, which makes control very difficult.

a. Symptoms

The most characteristic symptom is a slight wilting of the youngest leaves on one side of the plant. These symptoms may spread to the lower leaves, until the entire plant has wilted. Wilting is normally confined to a single stem of the plant. Severely wilted plants appear dried out. Plants showing only mild signs of wilting may recover overnight or during cool weather. Infected plants sometimes show rotting of the base, or pith necrosis, which leads to a hollow stem. Vascular bundle discolouration, which occurs at the stem base of plants, as well as soft rotting of the mother tuber, is usually associated with wilted plants.

b. Conditions favourable for disease development

Long periods of high soil moisture and moderate soil temperatures are conducive to rotting of infected seed potatoes. Soil moisture transports bacteria from rotting mother tubers, and causes surface infestation of tuber progeny. The developing progeny of infected plants may also be infected via the vascular tissue. Warm, humid conditions favour the development of wilting symptoms.

c. Control

1. Use certified seed potatoes.
2. Do not cut the tubers.
3. Use a recommended fertilization programme.

4. Avoid damage to tubers during handling as far as possible.

5. Remove infected plants to avoid spreading of the bacteria to healthy plants as soon as these are noted.

6. Do not wash or dip seed potatoes.

7. Avoid condensation of water on the skin of potatoes.

9. Other production considerations

The purpose of cultivation includes maintaining proper soil aeration, shaping beds to allow space for maximum tuber growth and minimising tuber greening, establishing irrigation furrows, and controlling weeds. The kind and extent of cultivation will depend on the planting method, kind and severity of weed infestation, irrigation method used, and to a lesser extent, the potato cultivar grown.

If potatoes are planted in such a manner as to leave the field quite flat, one or more post-planting bed shaping or hilling may be necessary. If potatoes are planted into premade beds or if the beds are formed at planting, bed (hill) shaping may be the only cultivation necessary. The implements used for shaping hills vary considerably; however, when used properly, all can form acceptable beds. No matter what type of cultivating or hilling implement is used, tillage should not take place in wet soils. Working wet soils results in compaction and clods that will present problems at harvesting time.

Working the ground to aerate the soil should be practised only if the grower is certain the benefits from aeration will more than offset the compaction in the furrows that results from the operation.

Some cultivars tend to set tubers higher in the beds than others. To prevent tuber greening from exposure to sunlight, additional soil may be required to cover the tubers. However, late cultivation can also be harmful owing to root and stolon pruning.

Cultivation can be a very effective method of weed control. The principal benefits come from post-plant, pre-emergence cultivation (to kill off early emerging weeds) and cultivation during the first 30 to 40 days after emergence (to control weeds in the furrows and on the sides of the beds). Thereafter, shading and herbicides must be depended upon for weed control.
9.1 Warming Seed Prior to Planting

Seed potato tubers should be warmed to 10 to 15.6 °C before handling and cutting to minimise potential for bruising. Seed should be warmed and removed from cold storage 7 to 14 days before planting. Tubers should never be taken from 4.4 °C storage and planted directly.

Condensation occurs on the surface of tubers with a pulp temperature of 4.4 °C when planted in soil temperatures warmer than 4.4 °C. Free moisture on the surface of tubers contributes to seed piece decay, particularly with cut seed.

9.2 Physiological Disorders

Common physiological disorders of potato foliage include frost, hail, lightning, wind-burn and air pollution damage. Damage from these disorders can be distributed uniformly across a field, but may also occur in a pattern associated with a specific topographic feature such as a low spot or ridge. Foliar disorders are often mistaken for insect, disease or herbicide damage.

Tuber physiological disorders are usually not detected until after harvest, which makes it difficult to identify patterns of occurrence in the field. Physiological disorders reduce the marketability of tubers by damaging their appearance or reducing processing quality. In some cases, these defects also make the tubers more susceptible to decay. Common disorders that produce symptoms on the outside of the tuber include growth cracks, secondary growth (also called knobs, dumbbells, and malformed), heat sprouts, enlarged lenticels and greening. Growth cracks and secondary growth are associated with non-uniform growing conditions. Heat sprouts are caused by high soil temperatures that cause the stolons to elongate and emerge from the soil. Lenticels may become enlarged when the tubers are exposed to very wet soil for prolonged periods. The tubers turn green in response to light exposure in the field or after harvest.

Disorders that produce symptoms on the inside of tubers include hollow heart, internal necrosis (also called heat necrosis and internal brown spot), sugar end (also called translucent end, dark end and jelly end rot) and blackheart. Hollow heart is caused by non-uniform plant growth early in the development of tubers, especially when accompanied by cool, wet soil conditions and excessive nitrogen fertilisation. Internal necrosis is associated with hot, dry weather and high soil temperatures during tuber bulking. Sugar end is associated with high soil temperatures and water stress during early tuber development. It most commonly occurs on the stolon end.
of the tuber and is not apparent until after processing. Blackheart occurs when tubers are exposed to low oxygen conditions. Improper storage ventilation, high temperatures after harvest, or extended low temperatures in storage can lead to blackheart.

Many of the defects discussed above are associated with extremes in environmental conditions that cannot be controlled by growers. However, proper cultural management can help promote uniform crop growth and minimise the impact of these environmental stresses. Establishing a uniform stand, monitoring soil moisture, applying irrigation in a timely manner, fertilising based on soil tests for a reasonable yield goal, and establishing proper storage conditions will help reduce losses owing to many of these physiological disorders.

9.2 THINNING

When thinning potato plants, thin to four to six plants. The potatoes will grow in the space below, and regrow after harvest if they are removed the potatoes carefully without disturbing the roots.

9.3 SEED TREATMENT FOR DISEASE CONTROL

The need for seed piece treatment varies in different regions. Seed treatments primarily affect disease pathogens present on the surface of tubers, but it only results in minimal prevention of transmission of viruses or bacterial growth. Seed treatments are applied as a powder, dust or as a liquid. There may be some benefit from the drying action of a powder or dust on a freshly cut seed-piece surface. Seed treatments also provide some protection from invasion of the seed pieces by soil-inhabiting organisms, and therefore may result in a reduction of seed-piece decay following planting. Seed treatment is not to be considered as being a cure for poor seed handling or for a poor seed environment, either before or after planting.

10. Harvesting

Across these areas, potatoes are harvested every month of the year and probably every day of the year in most parts of the country. In some areas, potatoes are harvested while the vines are still green and the tubers comparatively immature. Such potatoes usually go directly from the field to the fresh market or into processing. This is especially true in the early producing areas—those designated as winter, spring, and summer.
Traditionally the autumn crop is harvested when the vines and tubers are mature. The use of improved production and pest-control techniques has tended to delay plant die-off and tuber maturity to a point where potatoes in many production areas benefit from cutting of the foliage to help set the tuber skins. Mature tubers are usually higher in dry matter, which makes them of a better quality for most processing uses. They also have tougher skins that are more resistant to skinning and bruising during the harvesting operation. Excessive skinning spoils their appearance and predisposes the tubers to rot-causing organisms resulting in an increase in weight loss during storage. In general, it is considered desirable for the foliage to have died and dried up before harvest, especially where potatoes are to be stored for some length of time.

10.1 HARVESTING METHODS

Harvesting can be carried out in three ways; manual, semimanual and mechanical.

The manual method is the simplest. It is usually used by the small-scale producers and involves the use of a digging stick to lever the tubers out of the ground.

Semi-manual: This is the most frequently used method and involves the removal of the foliage with the help of a harrow which clears the foliage from the area to facilitate the final harvesting. The elimination of foliage must be carried out 24 hours before harvesting. After the foliage is removed a double mould-board plough is passed down the centre of the hill, leaving a ridge in between the original two and ensuring that the soil does not cover part of the adjacent ridges. The tubers exposed after the first pass are picked up by hand and removed prior to making a second pass. Tubers are then again collected by hand.

Mechanical: This system is ideally and most suited to the conditions in South Africa. Where this system can be applied, satisfactory results can be achieved with a potato harvester. With this equipment the tubers can be collected in bulk in the field or on a trailer running alongside the harvester. The presence of foliage or inadequate soil preparation can make this type of harvesting more difficult.

10.2 HARVEST RECOMMENDATIONS

Physical damage to potatoes causes stress and leads to physiological aging of the tubers. Potato tuber damage of greatest concern is skinning and bruising. Skinning typically occurs during the physical handling of the crop
such as harvesting, however, the influence of skinning on the physiological age of potato seed has not been evaluated thoroughly. Seed potatoes are managed to set skin prior to harvest to minimise the potential for skinning during harvest and placement of the crop into storage. Defoliation of seed potatoes is done to decrease potential for disease and virus occurrence and promote skin set. However, defoliation results in soils exposed to direct sunlight, which can lead to increased soil temperatures. Some years and for some cultivars, defoliation is done early to prevent transmission of potato viruses, but this will result in even warmer soils. Accumulation of heat units after defoliation can increase the physiological age of potatoes. Soil temperatures exceeding 3.3 to 4.4 °C contributes to physiological aging of seed. Seed potatoes should be dug as soon as possible after defoliation to minimise physiological aging if young seed is desired. In contrast, delaying harvest after defoliation can increase the physiological age resulting in shorter dormancy in storage and more stems and tubers per plant. Optimal defoliation and harvest timing for managing disease, skin set and physiological age have not been studied thoroughly and likely varies by cultivar.

Defoliation

Defoliation does not necessarily result in improved tuber quality but it can help achieve a desired skin set and may help reduce bruising and increase the ability to store the crop. Internal quality must be established before harvest through the proper production techniques.

In the past, it was not unusual for foliage to have died and dried up from various causes before harvest. Pest damage, lack of fertility, or decreased moisture was often responsible for the foliage dying-off. Foliar feeding insects, Verticillium wilt, and late and early blight diseases contributed to the dead foliage well in advance of harvesting.

New pest control materials and strategies have reduced the insect and disease effects on potato plants. Better irrigation and fertiliser practices also contribute to maintaining healthy green foliage later into the season. The improvement in these and other cultural practices has resulted in increased yields and has enhanced the economics of potato production. It also has made it necessary to include the practice of artificial defoliation in preparation for harvesting. In areas that produce late-fall potatoes, frost sometimes kills-off the foliage, especially during the late part of the harvest season; however, during the early part of the harvest, even in these areas, artificial defoliation may be necessary. The length of time between the application of defoliation and leaf desiccation and skin set depends on a number of factors.
Two general methods used for defoliation are mechanical and chemical. Flail beaters and rotary choppers are popular mechanical methods. Machines should be adjusted to avoid disturbing the soil so that the tubers will not be exposed to sunlight, frost or suffer mechanical damage. Propane gas or oil flames are used in some areas to burn vines. Rolling foliage before defoliation can lead to virus spread and tuber damage. Because conditions vary in different areas, local recommendations for methods and rates and timing of materials must be understood and followed.

Harvesting is easier after defoliation. Under some conditions, defoliation is necessary to control tuber size. This can be especially important for growers of seed potatoes. Early defoliation can be used to prevent the spread of virus diseases when there is a late-season aphid infestation.

Timely defoliation allows the skins of the tubers to toughen so the tubers can be harvested with a minimum of skinning and bruising. Bruised and skinned areas detract from potato appearance, an important quality parameter for the fresh market. These tuber blemishes also increase waste and costs when they are processed.

When late blight or pink rot is present at harvesting, a higher rate of tuber rot in storage can result. The organisms can enter the tubers through harvest damage such as skinned and bruised areas. In storage, infected tubers continue to break down. The presence of these diseases is not always readily apparent at harvest. The safest precaution is to have completed defoliation and the tuber skins set at harvest time.

The foliage is difficult to kill off when soil moisture is high or the plants are large, green and growing vigorously. It takes more time for these plants to die off than plants that are naturally maturing. Cool and cloudy weather conditions also retard defoliation which should be done two to three weeks before harvesting. Cultivar, fertility and growth conditions can have an effect on defoliation. Defoliation is an additional cost and has been known to adversely affect the internal quality of the tubers.

Discolouration of the vascular ring at the stem end of tubers can occur when defoliation occurs rapidly. Usually the discoloration is confined to the stem end but on occasion it extends over the entire length of the tuber. The problem is usually more severe when soil conditions are dry and weather is hot at the time when defoliations are applied. Chemicals that result in rapid die-off of the plant are more likely to cause discoloration than those that have a slow action. Removing the foliage by cutting, burning, or pulling seldom results in discolouration of the vascular tissue.
Vascular discolouration may be severe enough to lower the tuber grade for the fresh market. Tubers with discoloured vascular rings do not make good chips or French fries as the discoloured parts show up as a dark area in the finished product. This discolouration has no effect on seed quality but often causes concern because it resembles the vascular discolouration caused by Verticillium wilt or Fusarium wilt.

To reduce the danger of severe vascular ring discolouration from defoliation, the following practices are suggested:

1. Avoid using a chemical defoliant during hot weather, particularly if the soil is dry.
2. If defoliation has to be done when soil is dry and the weather is hot, reduce the rate of the substance used and use a slow acting chemical.
3. If irrigation is available, have the soil moisture adequate at the time of defoliation.

Effectiveness of defoliation can be increased by practicing the following:

a. Do not apply defoliation chemicals during cool, damp, or extremely hot, dry weather.

b. Under some conditions, split applications of chemical defoliants may be more effective than a single application. If the labelled use permits, use less than the full application rate, followed by a second application several days later.

c. Use spray adjuvants that are recommended.

d. Increased effectiveness has been shown with applications late in the day.

10.3 HARVESTING EQUIPMENT

Most potatoes grown are harvested with mechanical harvesters. Single-row harvesters are not common with most harvesters straddling two or in some cases, four potato rows.

In most areas windrowing is the usual practice. With this method, two, four or more rows are harvested with a windrower and the tubers are placed in the furrow between two unharvested rows. The unharvested rows are then dug with a conventional harvester and the windrowed rows are picked up simultaneously. With windrowers, harvesting 12 rows together is not uncommon. Windrowing increases the areas that can be harvested with one
machine during a harvesting season, reduces machine traffic over the soil, and increases the volume of potatoes within the harvester. Windrows must be operated using the same bruise reduction concepts as the harvester, i.e. all conveyors must be kept full of potato tubers at all times.

Most harvesters deliver directly into trucks. Field trucks are often used to transport potatoes from the field to the packing sheds, processing plants, warehouses or storage.

PART 3: POST-HARVEST HANDLING

1. Sorting and grading

Physical damage to potatoes causes stress and leads to physiological aging of the tubers. Potato tuber damage of greatest concern is skinning and bruising. Skinning typically occurs during physical handling of the crop such as harvesting, but the influence of skinning on physiological age of potato seed has not been evaluated thoroughly. Seed potatoes are managed to set skin prior to harvest to minimise potential for skinning during harvesting and placement of the crop into storage. Defoliation of seed potatoes is done to decrease potential for disease and virus occurrence and promote skin set. However, defoliation results in soils being exposed to direct sunlight, which can lead to increased soil temperatures. Some years and for some cultivars, vine-killing is done early to prevent transmission of potato viruses; however, this will result in even warmer soils. Accumulation of heat units after vine-killing can increase the physiological age of potatoes. Soil temperatures exceeding 3.3 to 4.4 °C contribute to physiological aging of seed. Seed potatoes should be dug up as soon as possible after defoliation to minimise physiological aging if young seed is desired. In contrast, delaying harvesting after defoliation can increase physiological age resulting in shorter dormancy in storage and more stems and tubers per plant. Optimal defoliation and harvest timing for managing disease, skin set and physiological age has not been studied thoroughly and possibly varies by cultivar.

1.1 POTATO BRUISING

It is difficult to fully measure all losses caused by bruising while potatoes are being harvested. Losses come from reduced potato value, increased shrinking in storage, reduced returns from processing contracts, as well as the direct loss caused by bruising itself. Studies in some areas have shown
that growers may lose up to 20% of their income through potato damage at harvest.

1.1.1 Types of bruising

**Black spot bruise**

This is an internal discolouration resulting from impact that damages cells in the tissue beneath the skin without causing an observable rupture in the skin. Black spot bruise can occur whenever the tubers are handled. The symptoms normally develop over a period of 1 to 3 days with the development faster at higher temperatures. These discoloured areas are not visible until a potato is peeled. Black spot bruise usually does not penetrate deeper than 6.3 mm and usually does not rupture the potato skin.

**Shatter bruise**

This injury is the result of a mechanical impact sufficient to cause splitting or cracking of the tuber’s outer surface or skin. The severity of the shatter bruise can vary with the cultivar, tuber maturity, internal tuber turgor and the magnitude of the impact. The damage is most severe when the tubers are turgid and at low temperatures.

**White knot**

This bruise is similar to black spot bruise, but does not discolour like black spot. This is more like a crushed cell effect on immature tubers.

1.1.2 Factors that influence bruising

**Soil condition**

The soil condition at harvesting determines the ease with which potatoes can be separated from the soil. Heavy, compacted and very wet soil is difficult to separate from tubers, while medium to light, loose and moist soil separates easily. Proper soil moisture for harvesting is between 60 and 80% of field capacity for loam and sandy soils. Heavy, dry cloddy soil increases damage to tubers as they are carried through the harvester. The more difficult the separation, the more the harvester chains (conveyors) must shake, which, in turn, causes further damage to the tubers. In some areas, stones present in the soil increase the extent of bruising.

**Tuber condition**

The condition of tubers is influenced by fertility level, insect and disease control, irrigation, tuber maturity and timing of defoliation. Other cultural
practices undoubtedly are important, however, these have not been studied in depth. The relationship between tuber condition and bruise susceptibility is not completely understood. Delaying harvest up to 20 days after vine kill encourages tuber skin set and resistance to skinning. Delaying harvest also appears to reduce susceptibility to serious bruise damage through increased tuber maturity. Many aspects of tuber maturity are still not understood. Cultural practices that influence tuber hydration are an important factor in the type and extent of damage tubers sustain during harvesting. Hydrated (crisp) tubers are susceptible to shatter bruise and resistant to black spot. Dehydrated (soft) tubers are resistant to shatter bruise and susceptible to black spot. At any given temperature there is a tuber hydration level at which bruise damage (both black spot and shatter bruise) is at a minimum.

**Tuber temperature**

At harvesting, tuber pulp temperature should be between 10 and 15 °C. When possible, avoid harvesting if tuber pulp temperatures are below 7 °C and above 18 °C. Optimum harvest situation occurs when the potato tuber temperature in the field and the soil temperature are the same. Soil temperature lags behind air temperature. The lowest air temperature occurs about 6:00 a.m. but the lowest soil temperature at tuber level and therefore, tuber temperature, occurs about 9:00 a.m. This is normally about a 3 to 4-hour delay. A similar delay holds true for high temperature. Highest air temperature occurs at about 3:00 p.m. but the highest soil temperature does not occur until about 6:00 p.m. As soil temperature changes, the temperature of the tubers also changes. A 12-hour harvest period for soil temperature warm enough to reduce tuber bruising would be from about 11:00 a.m. to 11:00 p.m. Harvesting during these times would help in bruise reduction when night temperatures drop below 7 °C. In spring and summer harvesting areas, where high temperatures are to be avoided, afternoon and evening harvesting should be avoided.

**Harvester operation**

Probably the major factor in minimising tuber bruise damage is harvester operation. Breakdowns delay harvesting and can cause anxiety, leading to the tendency to speed up harvesting operations. The harvester blade should be aligned so that the rear of the blade delivers the tubers onto the front of the primary conveyor, not in front of it. Bed agitation should be avoided unless absolutely required to achieve minimum acceptable soil separation. Padding placed wherever potato bruising might occur to soften
the landing of tubers and the use of rubber-covered bed links helps to reduce tuber bruising. Limiting drop height to 15 cm or less will also help.

2. Packaging

Fresh potatoes are sold in a variety of containers and grade specifications. Russet potatoes are usually packed in three general size categories: consumer packs, count cartons, and institutional packs.

The most valuable potatoes are 227 to 397 g tubers that are packed in 22,7 kg cardboard boxes. Consumer packs consist mainly of 113 to 227 g (non-size A) tubers packed in plastic, paper, or mesh bags. Consumer bags are typically 2,3 or 4,5 kg.

3. Storage

Desired storage temperature for seed potatoes after initial curing is 3,3 to 4,4 °C. Potato respiration is minimised at 2,8 °C. Storage temperatures above 4,4°C results in physiological aging of tubers and promotes premature sprouting of seed potatoes, particularly of cultivars with a short dormancy. Seed tubers stored below 2,8 °C have increased respiration and will increase in physiological age compared to tubers stored at 3,3 to 4,4 °C. Seed tubers of cultivars susceptible to cold temperature stresses that are stored at 0 °C for long periods (20 weeks or longer) can develop mahogany browning. Mahogany browning results in an internal reddish-brown discoloration often found in irregular patches randomly occurring in the tuber with irregular and indefinite boundaries.

Mahogany browning differs from freezing injury because tubers are never actually subjected to freezing temperatures. Tuber tissues with cold damage become soft and watery when placed in a warm environment.

3.1 Sprout Control in Storage

Most of the common cultivars of potatoes have a natural dormancy period of 60 to 130 days, depending on the holding temperature in storage. Potatoes stored for longer periods must be treated with a sprout suppressant or inhibitor. The most common inhibitor used in storage is chlorpropham (CIPC). CIPC inhibits sprout development by preventing cell division. Another frequently used sprout inhibitor is maleic hydrazide (MH). MH is field-applied to green potato foliage as recommended by the manufacturer.
Seed potatoes are not treated with chemical inhibitors for sprout control. Storages of seed potatoes is maintained sprout free by holding the tubers at colder storage temperatures, usually 3,3 to 4,4 °C.

At these colder temperatures, seed potatoes can be stored for 5 to 8 months in storage or until the planting season deliveries are made. Although processing potatoes can be stored sprout free for several months at these colder temperatures, reducing sugar accumulation in cold-stored potatoes usually prevents their use in the processing industry.

4. Market preparation

Quality influences consumer preference and the ability to sell the product. Good quality potatoes are clean, uniform in shape and size, have an un-marked skin and firm flesh, are free of internal defects and have shallow eyes. Consumers do not like the waste of trimming potatoes with deep eyes and surface defects. Other tuber defects that may adversely influence quality are greening, secondary growth, growth cracks, scab, storage rots, internal black spot, skinning, Rhizoctonia spp. sclerotia, bruising and skinning or other mechanical damage.

In South Africa, other than Europe's one season, potatoes are harvested in different regions throughout the year. Table potatoes are brushed or washed, graded, packaged and distributed to buyers. Approximately 40% of the main crop goes for processing, with the remaining 60% destined for the fresh table market.
### PART 4: PRODUCTION SCHEDULE

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PART 5: UTILISATION AND NUTRITIONAL VALUE

5.1 CULINARY/COOKING

5.1.1 Uses

The decline in fresh consumption has been more than offset by a steady growth in consumption of processed products. Most of that growth is attributable to frozen products. Consumption of canned potatoes has remained a small part of the total potato market.

Potato cultivars are utilised according to the end-use product that they are destined for. For households, firm potato cultivars such as BP1 and Vanderplank are favoured when making salads because they do not break easily, but the Up-to-Date cultivar is favoured for mashing and baking because it is brittle. In the processing industry cultivars that are frequently used in the manufacturing of crisps are Hertha, Pimpernel, Lady Rosetta, Fiana, Crebella and Erntestoltz. Crisps represent approximately 40% of the total domestic processed potato products. Vanderplank, BP1, Up-to-Date and Hertha are used in the manufacturing of frozen French fries. The manufacturing of frozen French fries represents approximately 41% of the total processed potato products. Vanderplank, Buffelspoort, BP1 and Up-to-Date are used for fresh French fries.

5.2 NUTRITIONAL QUALITY

Table potatoes are an ingredient in many dishes and salads. Potatoes are a non-fattening, nutritious and wholesome food that supplies many important nutrients to the diet. Potatoes contain approximately 78% water, 22% dry matter (specific gravity) and less than 1% fat. About 82% of dry matter is carbohydrate, mainly starch, with some dietary fibre and small quantities of various basic sugars.

Although potatoes contain only relatively little protein (0.6-1.2% of the fresh weight), their nutritional quality is better than cereals or soya beans. Potatoes contain at least 12 essential vitamins and minerals, are a source of vitamin C, thiamine, iron and folic acid. It is also an excellent antioxidant. Most of the vitamins in potatoes are located just below the skin.
PART 6: REFERENCES


