TECHNICAL GUIDE

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ORGANIC RESEARCH CENTRE

ELM FARM

Organic potatoes

Cultivating quality – step by step

Potatoes are very suitable for direct marketing due to their popularity and versatility. But good yields are needed for commercial production to cover the high costs of cultivation and mechanisation. The very high quality requirements at every stage of marketing require the highest care from seed preparation to plant protection, nutrient and water supply to harvest and storage.

This guide provides a good basis for achieving high-quality products. Commercial potato farms complement their knowledge with the help of experts and further literature.

2017

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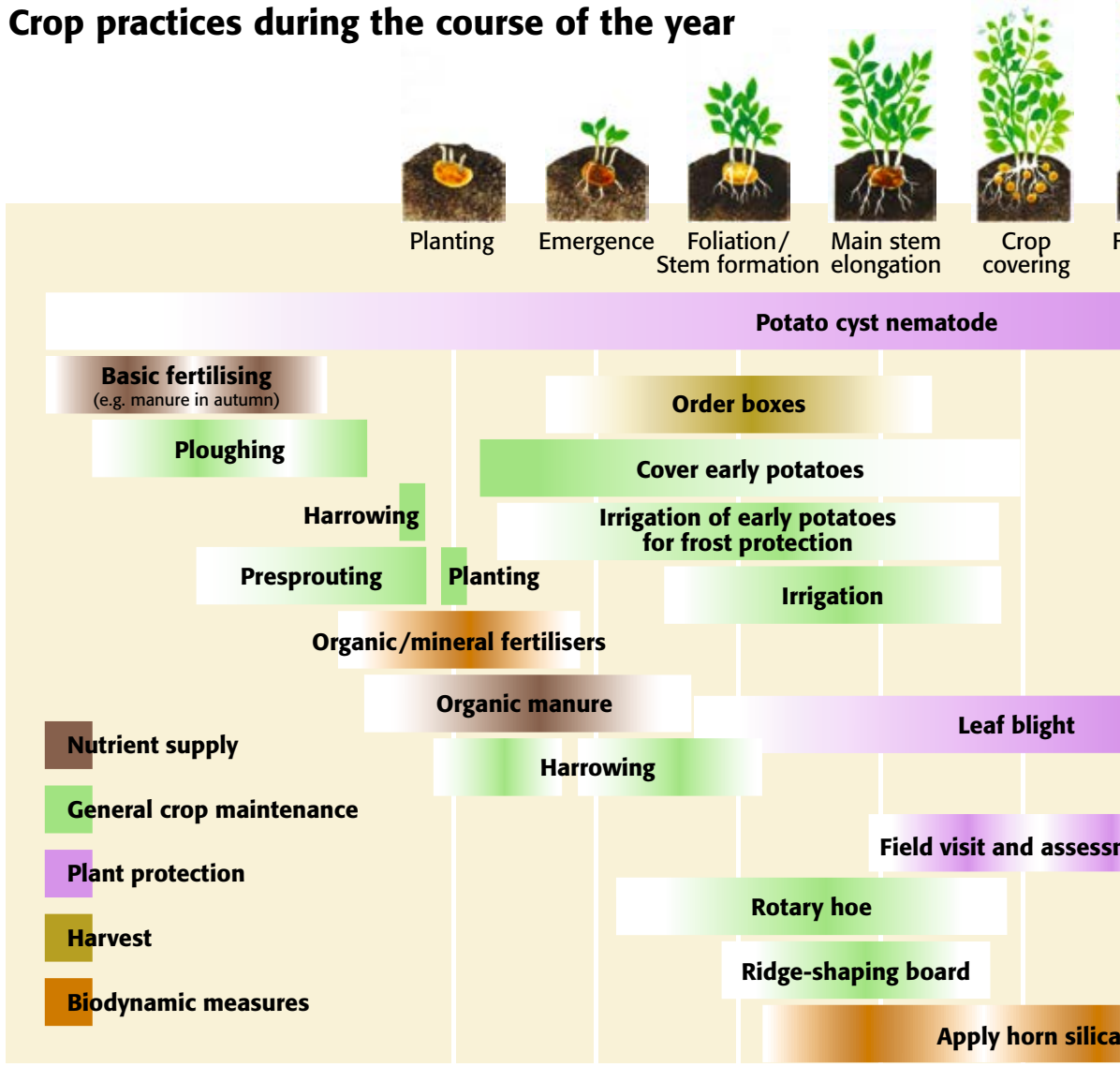
OK NET arable

Quality at every stage
The quality of potato tubers can be significantly influenced before, during and after cultivation. Measures that have a significant effect on the final product quality are marked in this manual with the sign above.

Crop practices during the course of the year



Choice of production

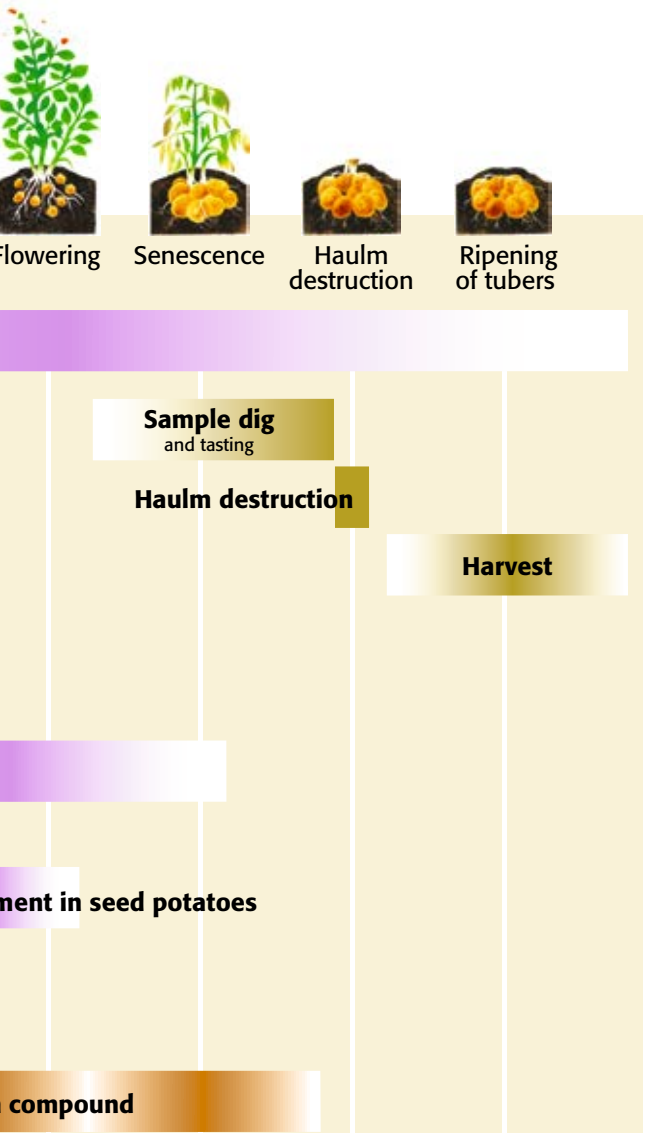
First/Second early potatoes
- Only in places with suitable climatic conditions on quickly warming soil where planting is possible from end of February/beginning of March onwards.
- Requires equipment for chitting.
- Cultivation under fleece can speed up development (see page 10).
- If a pipe irrigation system is available, it can be used to prevent frost.
- Careful harvesting is required.
- Good for farms that can attain high prices for early produce.

Maincrop potatoes
- Suitable for wholesale and direct marketers.
- Fairly stable prices.
- Sufficient distance between fields with early and maincrop potatoes to prevent transmission of blight.

Processing potatoes
- Depending on use, there are special requirements (variety, size, shape, starch content, test baking, etc.).
- Only cultivate in agreement with a buyer (cultivation and supply contracts).
- Increasingly important.

Peeled potatoes
- Direct marketing of peeled potatoes to industrial kitchens.
- Marketing to peeling companies via contracted cultivation.
- Direct marketing requires specialist knowledge of peeling processes.

Baby potatoes
- Very small potatoes that have set skins.
- Lower yields and higher prices than ware potatoes.
- Ideal for light and sandy soils without stones.
- Machinery needs to be adjusted (very close plant spacing, fine sieve belt, boxes with small gaps).
- Varieties with a high number of tubers per plant should be used.



Seed potatoes

- Only possible in contract with seed producing organisations; requires specialist knowledge.
- Cultivate with sufficient distance from other potato plots to avoid viral infection and blight.
- Production at higher altitudes results in more slow-sprouting planting material.

Heritage varieties

- Speciality: only cultivate them in agreement with buyer or sell directly.
- Conserving varieties: Organisations such as Skea Organics in the UK may be able to help with sourcing Heritage varieties, but demand is mainly from domestic gardeners.
- Often lower yields than modern varieties, higher wholesale prices.
- Planting material considerably more expensive than for modern varieties.
- Some are rather susceptible to late blight as well as viral diseases (provide regular change of seed planting material, increase distance from other potato fields, choose separate fields).

Site requirements

- Light to medium soils that warm up easily, are not too stony, and are deep with even water supply and a pH of 5.5 to 7.
- Avoid compaction and poorly drained soils.
- During flowering and formation of tubers, potatoes are sensitive to long wet or dry periods. Cultivation on plots with irrigation systems is beneficial in dry periods.

Soil type affects the shape, colour and overall appeal of the tubers. On lighter soils, most tubers develop a nicer shape and colour as well as flatter eyes. On heavy soils that are slow to warm up, the tubers turn out more smooth-skinned and occurrence of scab is lower.

Variety selection

In organic farming, mainly varieties that are in market demand and accepted by retailers are cultivated. Direct sellers have a bit more freedom in terms of variety.

Varieties that develop quickly at a young stage and form tubers early (so that a good yield has already been reached when blight starts to appear) should be chosen. They should also have low susceptibility to diseases, low nitrogen requirements and quickly develop a canopy to suppress weeds. However, the intended use and the wishes of customers or buyers play the biggest role in selection. Choosing a new variety should be discussed with the buyer beforehand: before new varieties are cultivated, a market should be ensured. In direct marketing, customers should be gradually introduced to the new variety.

In the UK, the AHDB Potato Variety Database provides independent data on GB-certified potato varieties that have undergone independent resistance testing for key pests, diseases and pathogens. Testing is undertaken through the AHDB Potatoes-funded Independent Variety Trials (IVT) programme.

Soil

- Sandy, quick-drying soils lead to rougher skins and russeting as well as raised scab infection.
- Moist soil conditions during formation of tubers lead to netted scab.
- Acidic soils, soils heavy in clay or contaminated with spores can lead to powdery scab.

Note:
In areas of high rainfall, ploughing and manure application in Autumn would be inadvisable due to the risks of leaching and erosion.

Variety selection
The risk of scab, hollow hearts, dry core, late blight, silver scurf, blackleg etc. is reduced by selecting the appropriate variety. However, there is no variety immune to all these conditions. Hence, the growing conditions in the region and on single fields must be considered when making the selection. Regional recommendations for varieties may be helpful in organic potato cultivation.

Notes:
The planting material must be derived from organic propagation (see 'Planting material' on page 5 and 'Further reading' on page 28).

The Louis Bolk Institute in the Netherlands has done a lot of work on breeding and marketing blight resistant varieties (see pages 11–12 for more information on blight resistance).

Crop rotation

- Perennial grass/clover as a preceding crop may promote infestation with wireworms, scab, dry core and slugs.
- Intensive tillage in the crop rotation reduces the risk of wireworms.
- Large amounts of organic matter with a high carbon-to-nitrogen ratio as a preceding crop can lead to locked-up nitrogen and *Rhizoctonia*.

Position within the crop rotation

General rules:

- Keep a rotation break of at least 4 years (includes early potatoes).
- Avoid soil compaction when harvesting preceding and catch crops.
- Potatoes have relatively high nutritional requirements; moreover, the nutrients should be available shortly after emergence. Hence, potatoes develop especially well after preceding crops that support the looseness and structure of the soil and leave a high amount of easily degradable organic material. Suitable preceding crops include a one-year grass/clover ley, one-year fodder and grain legumes (especially field beans and grain peas with a cover crop, field vegetables and other root crops, grains with legume cover crop).
- Tillage in spring before potato cultivation reduces the risk of nutrient leaching during the winter months; however, tillage in spring is often necessary due to frost on soils that contain more clay. In the case of an early tillage, cover crops that are killed by frost in winter should be cultivated.
- Potatoes leave a lot of soluble nitrogen in the soil, with the potential risk of leaching. For this reason, the succeeding crop to be cultivated should be one that utilises the nitrogen in autumn, such as winter cereals / brassicas or green manure with late nitrogen absorption (e.g. rye).
- Potatoes generally leave a clean seed bed for the succeeding crop. Ploughless tillage preserves the soil structure and facilitates frosting of remaining tubers to avoid volunteers.

Preceding crops	Suitability	Notes
Grains CC/GM Potato	+++	• Pure stands of legumes such as vetches, or a brassica such as fodder radish (may help suppress PCN) are ideal as catch crops and green manure after grains.
Grain legumes CC/GM	+++	• Fodder radish and, on locations that do not tend to develop iron spots, also mustard are ideal as catch crops and green manure after grain legumes. • Pure grass or grains as catch crops should be avoided. The high carbon-to-nitrogen ratio in spring leads to a slow conversion of organic matter.
Grass/clover	++	• Grass/clover before potatoes should be for one year only. Longer-term grass/clover increases risk of infestation with wireworms and the rate of turnover is slower than with one-year grass/clover.
Vegetables CC/GM	++	• Potatoes are a good component of a vegetable rotation. • There is an increased risk of slug infestation. • After late harvested vegetable varieties, sowing green manures is more difficult. • On vegetable farms, vegetables often serve as follow-on crops to early potatoes.
Maize GM Undersown crop	+	• Since both maize and potatoes have a strong demand for nutrients, this combination is only recommended for farms with a high nutrient base. • Soil compaction during maize harvesting can affect the soil structure. • Remaining stubble can increase the risk of *Rhizoctonia* in potatoes; hence, the stubble should be shredded as small as possible.
Succeeding crops		
Winter cereal	+++	• On lighter soils, barley, triticale and rye are more suitable than winter wheat or spelt due to the early sowing date and tillering in the year of sowing. • On heavy soils, winter wheat is more suitable (there is, however, a risk of nitrate loss).
CC Spring crop	++	• Spring cropping is only recommended after a catch crop. Forage rye or grass are good catch crops. Mustard also tends to develop fast and captures nitrogen. Only choose cruciferous plants if there are no other brassica plants within the crop rotation. • Possible succeeding crops are summer cereals (e.g. oat), maize or vegetables.

CC = catch crop; GM = green manure

Planting material

In principle, the planting material must originate from organic propagation. Current availability of organic seed and planting material can be checked on the organic seed database www.organicxseeds.co.uk. The range of varieties from organic propagation as well as the description of the varieties and the ordering addresses can be requested from organic advisory services or directly from seed associations. If there is no organic seed material available for certain varieties, a special derogation from the inspection body is required before purchase. Sources of seed can be found on organicXseeds.

In general, only healthy and certified planting material (seed) should be used. After receiving the planting material, one should empty the bags and bulk packs and wash a sample of the seeds. Quality defects (e. g. black scurf (*Rhizoctonia*) marks, wet rot) should be reported to the supplier immediately (keep the labels).

The same quality criteria apply when using saved, non-certified planting material. It is strongly recommended to check it for viruses and other defects like *Rhizoctonia*, leaf blight, bacterial wilt, etc. Calibrating planting material facilitates cultivation and improves the overall health of the crop.

Amount of planting material needed

- Seed rate and plant density can be estimated from target yield and optimum seed size, as well as seed age (time from emergence of seed crop to planting of current crop).
- Seed rate calculations are variety specific. For guides see on the AHDB website. Where specific varieties are unavailable interpolation is required.
- Standard (emerged 1 June): Count 50 kg sample to determine tuber seed count. Determine target yield (experience and field history) and optimum tuber size. This information will give you the seed rate. Multiplying this by the area to be planted gives you the total seed required. Within-row spacing (cm) can be calculated using plant density and row width (see page 9) according to the following formula: 100,000/ (plant density (000/ha) x row width (cm)) e. g. with a row spacing of 75 cm and planting space of 33 cm within the rows, about 40,000 tubers per ha are needed. With a grading between 35 and 55 mm, this will result in about 2,500 kg of planting material, depending on the variety.
- Plant populations below 26,000 plants/ha are not generally recommended. Planting at wide spacings can result in gappy crops particularly where planting is irregular or emergence poor. Total yield may be reduced as a result so planting at higher densities should be considered, although increasing plant density can be expected to reduce the average tuber size.

Preparation of planting material, chitting

- If possible, planting material should be chitted, or at least vernalised.
- Chitted plants emerge faster and are better weed suppressors. Moreover, chitting leads to fewer sprouts and thus to fewer stems per unit area of foliage. This, in turn, reduces the number of tubers, but increases their size.
- Disadvantages include: investment costs, additional workload and the risk of too long sprouts.
- The costs of £ 500 to £ 600 (or 500 to 600 €) per ha are reclaimed through higher yields and yield security.
- The age of the planting material, the vernalisation, the variety, the maturity group and the utilisation all influence the chitting procedure.
- Temperature has the largest influence on the number of later sprouts.
- New potatoes should have fewer sprouts in order to reach the required size quickly. Seed potatoes should have more sprouts.
- Chitted tubers should be planted only with the appropriate technology (rolling-floor planter, belt planters) to prevent breaking off sprouts.
- Empty chitting boxes and bags carefully, to prevent sprouts from breaking.

Work steps for chitting

1. Start chitting 4–6 weeks before the desired planting date (new potatoes up to 10 weeks).
2. Thermal treatment: 18–20 °C over 2–3 days.
3. Lower temperature to 10–12 °C (new potatoes: 15 °C, seed potatoes: 8–10 °C).
4. As soon as the sprouts start to show, expose the potatoes to daylight or artificial light (lamps with warm tones, >100 W per t of planting material). 8–10 hours per day. Maintain a humidity of 70–80 %.
5. At the end of the chitting period, lower the temperature to 5–6 °C for hardening off.
6. Before planting, raise the temp. to 10–15 °C.

Chitting containers	Notes
Chitting boxes: white plastic trays, 60 × 40 × 18 cm, 4 piles on a Euro-pallet	• Fill-in 2, max. 3 layers; about 10 kg per box. • At planting, take tubers directly from the crates. • Sort out sick tubers during the transfer. • Large workload for transfer, stacking, transport.
Chitting bags: hanging mesh bags on metal frames, 125 kg capacity, 5 tubers are juxtaposed	• Hardly any manual work when using a fully automated machine. • Low space requirement outside chitting period. • Clumping of tubers in case of delayed planting.
Large boxes: flat (wire) crates with a second 'cage' holding the inside up to a coat of 30 cm	• Low workload. • Unequal formation of sprouts, therefore limited suitability.

Planting material

- Certified planting material reduces the risk of infection with tuber diseases.
- Watch out for a low infection of *Rhizoctonia*.
- Dressing of planting material with antagonists (e. g *Bacillus subtilis* and *Pseudomonas* sp.) may reduce infection with *Rhizoctonia* and dry core, but potato seed dressing is not common practice in the UK.

Chitting

- Chitting is one of the most important measures for yield security: it shortens the time to harvest by 10 to 14 days, reducing the risk of late blight infection.
- Chitting accelerates emergence and thus reduces the likelihood of the sensitive sprouts being infected with *Rhizoctonia* (Black scurf) or *Erwinia* (Blackleg).

Nutrient supply

- In order to prevent *Rhizoctonia*, use only processed, well-rotted manure and apply it in autumn on the preceding or catch crop.
- For fertilising in spring, use aerated slurry or nitrogen rich manure.
- A good supply of potassium and magnesium increases the quality, prevents damage and internal bruises and improves shelf life.
- Liming before or during the cultivation of potatoes increases the risk of scab infection.
- A high nitrogen supply in late summer can have a negative effect on dry matter and nitrogen content, and hence on the flavour. Furthermore, it increases susceptibility to damage, and to discolouration in the raw state and after cooking, as well as reducing storability.

Nutrient supply

Potassium

- Potatoes are among the most potassium-hungry plants in agricultural production. Potassium is the mineral with the highest concentrations in the potato plants and tubers.
- Potassium is important for the development of starch. Moreover, it improves the shelf life and reduces the number of damaged tubers. However, too high a supply of potassium can have a negative impact on dry matter and starch content.
- A sufficient supply of potassium increases the amount of organic acids and the vitamin C content in the tubers. This, in turn, leads to a decrease of discolouration in the raw state and after cooking, as well as a reduction in bruising.
- Potassium from farm fertiliser (manure, slurry, etc.) can be fully taken into account. If necessary, organically approved potassium fertilisers (potassium sulphate) are available with prior approval.

Nitrogen

- From planting to emergence, the potato lives off the mother tuber's reserves.
- The potato crop needs the majority of the nitrogen during the short period between emergence and tuber development. An optimal nitrogen supply within the first 35 to 50 days after emergence contributes to a good tuber growth and is the most important requirement for good yields.
- The nitrogen demand of potatoes depends on the variety, local conditions and yield expectation. It varies between 80 and 140 kg available N per hectare.

Important to know

- Organic farming uses organically bound nutrients as fertilisers. Organic farmers 'feed' the microorganisms in the soil, which make the nutrients available for the plants.
- The release of nitrogen from fertilisers depends on the amount of fertiliser, or rather the nitrogen content, the type of fertiliser and the conditions for mineralisation in the soil. The more active the soil is, the higher the soil organic matter content is, and the better the aeration and weather conditions (soil moisture) are, the higher nitrogen mineralisation is.
- The P and K content of soil can be low after years of organic farming. That is why the P, K and Ca content should be checked every 5 to 10 years by means of a soil analysis. Manure and slurry are great suppliers of potassium.

- A good nitrogen supply results in stronger leaf growth. This leads to earlier crop covering and better weed suppression.
- The more nitrogen is stored in the leaves, the more tubers develop daily and the longer yield production lasts (unless leaf blight occurs). While during the formation of the tubers, the plant continues to extract nitrogen from the soil, the majority of the necessary nitrogen is transferred from the leaves. When the nitrogen supply in the leaves is exhausted, the tubers mature.
- In healthy crops, a good N supply leads to an increase in large tubers and to a higher individual weight of the tubers. However, it can also lead to an increase in hollow hearts, secondary growth, and growth tears.
- If the N supply is too high, the constant development of new leaves and stems can create a large, dense foliage. This can result in delayed formation of tubers and a decrease in growth rate. Early infestation of leaf blight could in this case lead to losses of revenue.
- An N supply that is too high, or rather too late, has a negative impact on dry matter and starch content, as well as processing properties and flavour.
- A too high release of N in late summer with a low K supply at the same time impairs maturation due to re-sprouting. This, in turn, complicates haulm destruction.

Release of nitrogen from the soil

- Biologically active soils deliver about 20 kg of N per ha (the higher the fertilisation or the amount of pre-crop residues, the higher is the N-mineralisation) under favourable mineralisation conditions during the vegetation period.
- With the first two field operations (ridging/hoeing), approximately 10–20 kg N per ha are additionally mineralised.

Nitrogen from the preceding crop

- One-year fodder and grain legumes are among the most favourable preceding crops.
- Ploughed grass/clover provides 80–140 kg available N per hectare, if the conditions for mineralisation and timing are good. Ploughing of grass/clover should be avoided in the autumn to limit the risk of leaching.
- Grain legumes leave, depending on the variety, between 50 and 100 kg of available N per hectare to the succeeding crop (grain peas: 50–80 kg, field beans: up to 100 kg). After grain peas, a catch crop should be cultivated to organically bind nitrogen during the winter and protect it from leaching.

Fertiliser

Manure

- Cattle manure is very rich in K; pig manure contains less K but higher amounts of P.
- A dose of manure can be recommended as basic fertilising. If there is danger of *Rhizoctonia* infestation, the manure should be applied to the preceding crop in autumn and not directly to the potatoes. A reduced effect of the fertiliser and the risk of nitrogen leaching should be kept in mind!
- It is recommended to use at most 25–30 tonnes of manure per hectare. Too large a dose leads to a prolonged nitrogen supply, which impedes the maturation of the crop. In the case of dryness or heavy soils, only the succeeding crop might benefit from the nutrients. The regulations limit nitrogen use to 170 kg per hectare.

Slurry

- Cattle slurry has relatively high K and N contents; on the other hand, pig slurry has higher N and P contents. The nutrient contents of anaerobic digestate depend heavily on the fermented substrates but are generally high in available N; they can be used effectively in potato farming.
- Slurry should be applied ideally during the preceding crop or before planting. It should be worked into the soil immediately after application.
- 15–30 m^3 of cattle slurry per hectare is recommended if applied in spring and immediately worked in.
- As doses increase (up to 150 kg N or 45 m^3 of slurry per hectare), yields decrease. These amounts should be applied to the preceding catch crop to avoid loss of quality and flavour.

Compost

- Like manure, composted manure and other composts provide a good supply of potassium and magnesium. Composted manure has a significantly lower effect on N supply than fresh manure, or rather stacked manure.
- Composts from plant material can also be used. They deliver both macro- and micronutrients to the soil.
- Compost may also offer additional benefits by suppressing phytopathogens in the soil to reduce crop disease.

The nitrogen supply has a significant impact on outer and inner quality features of the potato as well as on yield.

Note:
In the UK The Fertiliser Manual (RB209) can be used as a reference for nutrient recommendations and nutrient content of organic manures.

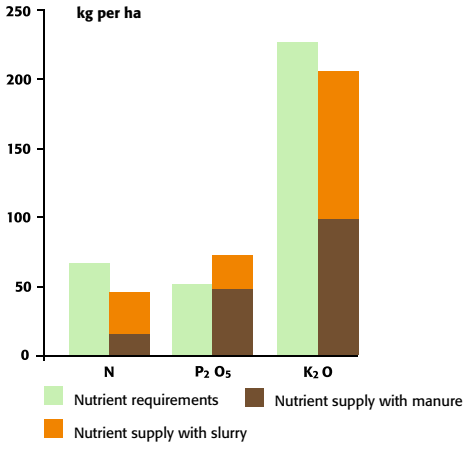
Analytical methods for assessment of the N supply

N_{min}-analysis:

- N_{min}-levels in the soil at the beginning of the vegetation period have only a small significance with regard to the estimation of the expected tuber yields.
- The N_{min}-levels at the time of the emergence of the potato plants are more suitable for the estimation of the tuber yields (ideal values: 110–140 kg N_{min} per ha).

Leaf and stem juice analysis:

- Measurements in the growing plants can be used to derive future, site-specific cultivation recommendations.
- For leaf analysis the total nitrogen content and, if necessary, further nutrients are determined in the uppermost, fully developed potato leaves. The analysis must be carried out in a laboratory. The total N content in the dry mass of the leaves at flowering of the potatoes should be between 4% and 6%.
- The stem juice analysis can be carried out relatively simply and cost-effectively directly in the field, by the farmer or the consultant. The stem juice is pressed out from the lower sections of the main stems and the nitrate content is analysed with the Nitracheck reflectometer. At flowering, the nitrate content should be between 3500 and 4000 ppm.



Nutrient requirements for a yield of 25 tonnes per hectare and supply by typical farm fertilisers (15 t of manure and 20 m^3 of slurry per ha). Soil and pre-crop also supply nitrogen.

Fertilising

- **A balanced dose of manure can have a positive effect on the K content of the tubers, whereas excessive fertilising with manure leads to a decrease of starch and dry matter content in the tubers.**
- **Doses of slurry and N that are too high can increase nitrate content and decrease dry matter and starch contents in the tubers.**
- **Compost from plant material that is applied in the planting furrows can reduce *Rhizoctonia* infestation.**

Purchased fertiliser

- Organic commercial N fertiliser enables fertilising in spring with a low risk of *Rhizoctonia* infestation.
- For potato farming, fertilisers that mineralise quickly should be used. They should be applied at time of planting, or at the latest when hoeing for the first time.
- When using ground legumes, field beans (finely ground) are preferable to peas.
- Due to the high costs, the use of organic N fertiliser is only recommended if not enough farm manure is available and the soil is not sufficiently supplied with nitrogen.
- Phosphorus needs are normally met by manure or compost. If additional phosphorus is needed, rock phosphates or organic chicken manure can be used as supplements.
- The use of mineral K fertiliser is only allowed if the deficiency is proven (soil analysis). In case of need consult your certification body. Potassium is best applied as sulphate of potash (as potatoes are susceptible to chloride toxicity).
- Lime should not be applied to potatoes or the preceding crops.
- The need to use leaf and trace element fertilisers must be documented clearly by the farmer, e. g. by performing soil or leaf analyses. It is advisable to consult the Control Body or advisory services if a specific mineral deficiency is identified. Magnesium is particularly important (particularly on lighter soils that may not supply enough), as are boron and manganese for yield and quality.

Plant and soil additives

In order to increase the plants' resilience and soil fertility, plant strengtheners and tonics can be used on organic farms. Examples are whey, stone meal, compounds with microorganisms, herbal extracts, compost teas or herbal teas. In many cases, the effect and mode of action have not yet been studied or clarified, and the resulting yield increases have not been scientifically proven.

Cost calculation (example) for applying 55 kg N per hectare of a purchased fertiliser containing N:

Fertiliser (11 % N):	£ 65 (€ 65) per 100 kg
Application:	£ 30 (€ 30) per hectare
Total:	£ 355 (€ 355) per hectare

At a selling price of £ 60 per 100 kg and an 80 % share of expenses, these costs are compensated if there is additional yield of 700 kg per hectare. An additional yield can be achieved without problems despite a low N supply if the supply can be improved by N fertilisers.

Tillage

- **Tillage or planting during wet soil conditions leads to clods, deformed tubers and damage during harvest.**
- **Cold, wet soils promote *Rhizoctonia* infection as early as during sprouting. To improve warming of soils, shallow ridges should be built from the start.**

Soil and seedbed preparation

Soil preparation

- During soil preparation, harvest ridges should be free of stones and clods because they inhibit growth, deform the tubers and damage them during harvest. If the amount of clods in the ridge is 5–10 %, the proportion of tubers and clods within the crop is the same.
- When grass/clover is tilled or soils are heavy, the use of a plough is appropriate. Using a chisel plough is recommended on medium-heavy soils and in dry areas (to conserve water).
- Primary soil tillage should only be performed if the soil has dried sufficiently. The ideal time for primary soil tillage depends on the soil conditions and the location.
- In heavy soils, the primary soil tillage should be done in late autumn, so that the soil dries faster in spring.
- Lighter soils (sand, clayey sand or sandy clay) can be tilled in spring (after catch crop cultivation), possibly with reconsolidation.

Seedbed preparation

- The less the soil is compacted before planting, the better.
- On light soils, prepare the seedbed with a spring tine cultivator including a cage roller/packer. On heavier soils, use a rotary harrow (watch out for soil moisture within the tilled area, otherwise soil smearing might occur!).
- If possible, only one operation should be performed in spring: e.g. with a front-mounted rotary harrow (possibly with shaping board) and a rear-mounted potato planter.

For soft, gentle planting, the seedbed should have settled, have fine crumbly soil, be free of clods and be dry.

Planting

Planting date

- The ideal planting date varies widely, depending on region and altitude. The most important factor to determine the planting date is soil temperature. It should be around 8 °C, or 6 °C for pre-sprouted potatoes. The soil should be sufficiently dry.

Planting depth

- The tops of seed potatoes should be level with the original soil surface.
- New potatoes should be earthed up less than ware potatoes to achieve quick emergence.

Spacing within the rows

- Basic rule: Less spacing between the plants leads to smaller tubers than more spacing.
  Standard: 30–35 cm
  Seed potatoes: 22–26 cm
  Baby potatoes: 13–20 cm
- Varieties that tend to form large tubers, or develop growth tears or hollow hearts (e. g. Agria), should be planted more closely.
- Early potatoes should be planted further apart in order to achieve the necessary size faster.

Ridge spacing

- If all row crops on the farm (potatoes, maize, sugar beets and vegetables) have the same track width, the time-consuming rearrangement of the machinery can be avoided.

Spacing 75 cm

- Standard, since most machinery is designed for a track width of 1.5 m.

Spacing 90 cm

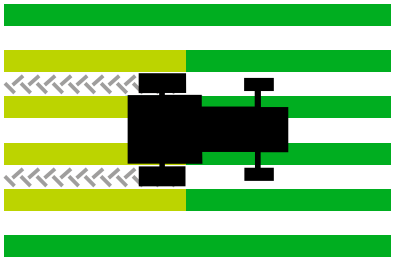
- Potatoes can also be planted with a spacing of 90 cm. In that case, the tubers should be planted at a spacing of about 25 cm within the row, to achieve a favourable plant density. This spacing is an alternative for industrial potatoes, for which large tubers are desired.
- Advantages: larger ridges, fewer green tubers, better water storage in the ridge, better aeration of the plants, better nutrient supply, and wider tyres are possible. It may also help reduce the risk of late blight spread.
- Disadvantages: more complicated road transportation of machinery (track width 1.8 m), crop covering will occur later or not at all; thus, there is a higher risk of late weed infestation.

Planting

- Quick emergence in warm soil, shallow earthing-up during planting and blind harrowing reduce the risk of infection with diseases during emergence (*Rhizoctonia* and *Erwinia*).
- To prevent sprouts from breaking off chitted tubers, the potato planter should be used with a horizontal belt for distribution.

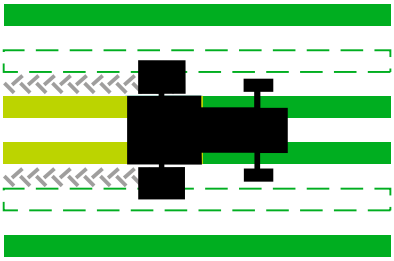
Tramlines for timely plant protection

Tramlines are not very common in organic potato farming, but they do offer an advantage: it is possible to drive on the fields shortly after precipitation with wide or twin tyres without damaging the tubers or ridges. The yield loss from omitting planting rows is partly compensated by additional yields in remaining rows. Tramlines are, however, only profitable when using larger spray booms. Repeated driving on tramlines is usually enough to suppress weeds in vacant rows.



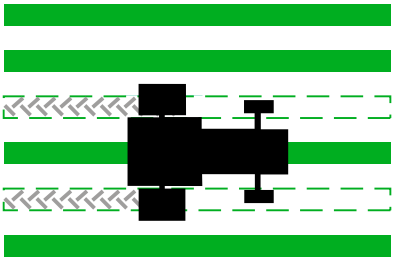
Standard: no tramlines

- Driving through is only possible with single tyres. Hence, long waiting times after precipitation on heavy soils. Otherwise, it can result in compaction of neighbouring planting rows, which can deform the tubers and impede their growth.
- Damaging the plants along the tramlines increases susceptibility to leaf diseases.



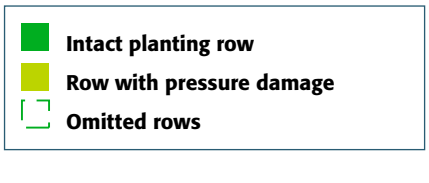
Tramline with two middle rows

- Possible to drive on wide or twin tyres.
- Compaction on the inner rows.
- Loss of yield due to empty rows.
- Additional yield in remaining rows.



Tramline with one middle row

- Same advantages as tramline with two middle rows, but without the compacted planting rows.
- Recommended version when using tramlines.



Covering early potatoes

- Covering early potatoes with a fleece, accelerates development.
- Covering requires work hours and material costs; moreover, it increases the risk of leaf blight and weed infestation. Covering is therefore only profitable for early planted potatoes and high value crops.
- The cover must be removed temporarily for weed control.
- As soon as the tubers reach the size of cherries or the temperature beneath the fleece/foil reaches more than 30 °C, the cover must be removed (choose a cloudy day or evening).
- After removing the cover, check the crop for leaf blight infection.

Crop maintenance and weed control

The goal of measures for crop maintenance is to create a large, stable, centrally positioned ridge, to open up surface crusts for better aeration and to control weed growth until crop covering.

General guidelines:

(See also maintenance plan on pages 2 and 3)

- For driving though the crop, only light tractors with narrow tyres should be used.
- After planting, the ridges should be harrowed and earthed up, alternately. The harrow gets rid of the weeds on the ridges, while the hoeing device reaches the weeds between the ridges. If both techniques are combined, the number of passes through the field is reduced. Ideal speed: 5.5–7.0 km/h.
- The ideal time for weed control is before the weeds become visible (in the white-thread stage/pre-emergence); at the latest when the weeds reach the two-leaf stage.
- Going through the rows with a harrow before emergence (blind harrowing) promotes fast emergence.
- The newly emerged plant is sensitive and should not be harrowed. As soon as the leaves turn green, only harrow gently up to a crop height of 10 cm. Plants of more than the size of a fist should not be covered anymore.
- In order to establish well-covering ridges, apply a ridge-shaping device during the last tilling round.
- Preferably, hoeing should be carried out in the evening, when the leaves are upright (less chance of covering them with earth).

Weed control

- Hoeing damages the delicate root hairs at the side of the ridge, and can also lead to damage on the leaves. Roots and leaves can thus become ways for diseases to enter the plant.
- Potatoes that experience damage on their root hairs respond with growth disturbance and lower yields.

The rotary hoe is well suited for earthing up the ridges on heavy soils.

Possible devices to control weeds

Multi-purpose device: harrowing, earthing up and possibly hoeing in one go.
Rotary hoe: makes well-covered ridges; has a tricky setting; not applicable on very stony soils; less suitable for ridging at the end of the rows.
Ridge-shaping board: recommended for the last tilling round.
Rotary hiller: makes well-covering ridges; greater soil disturbance; risk of capping; only recommended for difficult, cohesive soils.
Ordinary harrow: versatile and quickly employable; affects only the ridge crest (exception: Treffler harrow).
Ridge harrow: only in combination with hoe; good adjustment to the ridge shape.
Harrow groom: compared to the tined weeder, better effect in the entire row, very effective at pre-emergence stage, greater crop damage at post-emergence stage.
Hoeing equipment with rigidly mounted duckfoot-blades: employ only when no risk of damaging roots.

Possible approach on different soils

	Light soils	Heavy soils
1st ridge formation		Rotary hiller
1st harrowing	Harrow (for a quick emergence)	Harrow
2nd ridge formation	(Harrow +) ridger/rotary hoe	Disc ridger or ridge-shaping board
3rd ridge formation	Ridge harrow + ridger/rotary hoe or ridge-shaping board	Often unnecessary

A strict adherence to this programme of equipment use is not a good idea. The equipment used and number of processes should take account of the weather, the development stage of the crop and weeds, and the sensitivity of the varieties.

Protection of the leaves from diseases and pests

Phytophthora infestans
Leaf and tuber blight


Infection on the leaf surface


Infection on the underside of the leaf


Stem infection

How to recognise

- **Leaf surface:** brown spots, partly looking oily, blurred transition to healthy tissue.
- **Underside of the leaf:** grey / black spots, and white fungal growth during wet weather (especially on the edge); the fungal growth can be cultured by keeping the leaf in a wet bag overnight to facilitate identification.
- **Stems:** symptoms similar to the leaf surface
- Not to be confused with frost damage, 'sun burn' or grey mould (grey fungal growth on the surface/underside).

Important to know

- Optimal transmission (airborne spores) occurs when the relative humidity is over 90 % and the temperature around 18 °C. If the infection is very likely, the fungus can infect an entire crop within a few days. Depending on the weather conditions, it takes between 2–3 weeks and 2 months for the plants to die off after initial infection. In dry weather, the infection stops spreading; in wet weather, the infection increases.
- In the UK, the information and alert service BlightWatch, supplied by the Met Office and supported by AHDB Potatoes, informs farmers on the current risk of occurrences of blight during the growing period. Alerts are generated and sent to users based on the update to the traditional Smith period, the more advanced Hutton Criteria (Criteria met on 2 consecutive days: Minimum air temperatures are at least 10 °C, and relative humidity is 90 % or above for at least 6 hours) or when a confirmed outbreak in your area occurs. Optimal control of leaf blight serves to protect plants and neighbouring crops that have not yet been infected, with Blightwatch alerts providing an early warning to aid management decisions.
- Containment is most likely to be possible in the early stages. Hence, close monitoring of the crop is important!
- The initial infection of the leaves can be brought on by (latently) infected planting material, volunteer potatoes or tubers on compost heaps, or it can be brought in by wind from a greater distance. Tubers are infected through seepage of spores from infected leaves, or smear infection during harvest.

How to prevent

- Select varieties that are as resistant as possible and grow tubers early (in the UK, see AHDB National Potato Variety Database). In the long run, there is a risk of breaking the resistance of individual varieties. In order to spread the risk, several varieties should be cultivated.
- The Sarvari Research Trust (SRT) breeds new disease resistant varieties of potato traded by Sarpo Potatoes Ltd. Several have excellent foliar blight resistance, including Sarpo Mira, and Sarpo Axona. Others have highly resistant tubers such as Blue Danube.
- A successful breeding programme in the Netherlands (Agrico Research BV) has also produced a wide range of blight resistant varieties for organic production in the UK. Two of the highly blight resistant organic varieties on offer are Alouette and Carolus.
- Plant only healthy looking tubers. Discarded tubers should be composted at 60 °C.
- Chit the tubers. Infected tubers start to rot during the chitting and can be removed. Plants develop earlier from chitted seed tubers and often form tubers before initial infection.
- Plant late and early varieties in separate fields. If such a spatial separation is not possible, the more susceptible (early) variety should be cultivated on the side of the field downwind of

Other diseases and pests

- Besides Leaf and tuber blight, the Potato cyst nematode, and the Colorado beetle (outside the UK) other diseases and pests can attack the potato plants. However, they are often of minor importance and there are no specific control methods in organic farming.
- The publications listed on page 28 offer detailed information on preventative measures.

Integrated systems approach

As for pest and disease management in organic farming in general, an integrated systems approach should be taken for leaf and tuber blight, too. It should integrate the use of (i) resistant varieties, (ii) available agronomic control strategies, (iii) alternative treatments (e. g. organically-based fungicides, plant 'strengtheners' and bio-control agents which can replace synthetic and copper-based fungicides) and (iv) optimisation of blight control treatments utilising existing blight forecasting systems with the aim of maximising synergistic interactions between (i), (ii), (iii) and (iv).

The development of this systems approach took place in the EU project Blight-MOP. More recently Co-Free investigated the potential for innovative methods, tools and concepts for the replacement of copper in European organic and low-input production systems.

the prevailing weather conditions. Cultivation in multiple rows and alternating between susceptible and less susceptible varieties ('mixed crop') can delay the spread of the disease.
- Cultivate a strip of at least 12m of a different species (e.g. wheat or grass/clover) perpendicular to the prevailing conditions.
- Avoid overly strong development of leaves (by adapting nitrogen fertilising) and heavy weed infestation. This means that the crops dry faster.
- Avoid volunteer potatoes in the succeeding crops (risk of primary infection). Pigs can be good at removing groundkeepers.
- Either remove potato plants from waste heaps, or flame them or cover them with earth.
- Regularly check the plants and rogue by removing the stems and foliage of plants within a 3m radius of an infection (flame or mow the leaves to leave the tubers in the soil).
- In the case of a severe infection, chop the leaves off plants with tubers that are ready for harvest and before heavy rains. Put the leaves at the bottom of the ridge.
- After the leaves have died off or have been removed, wait 2–3 weeks before harvesting. This allows the skin to set, reducing the risk of infection from sporulating leaves during harvest.
- Large ridges without dry cracks decrease seepage of spores into the ridge.

How to control

- The only copper-based product licensed for use in the UK, Cuprokylt, was granted emergency usage for the 2017 season. Certification bodies in the UK were applying for another emergency extension for the 2018 season. The long term future of copper for use in organics for blight control is uncertain so those growers still relying on it must think about adapting their practices.
- After infection, the fungus cannot be stopped from spreading through the plant.
- The affected plants must be removed and the protection of healthy crops must be increased.
- In practice, plant strengtheners/tonics are often used, such as rock dust, horsetail tea, skimmed milk or whey and compost tea.
- According to practical experience, rock dust strengthens the resistance and supports the drying of the leaves. Scientific tests by FiBL could not prove a sufficient efficacy of these agents for control of foliar blight.

Application strategy for copper

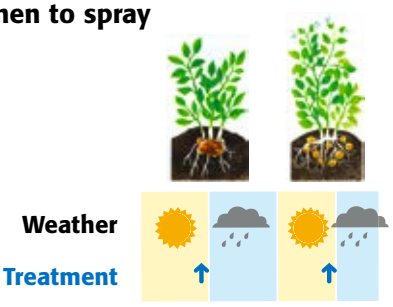
Level of infection	No infection within the region (50 km radius)	Infection within the region	Infection in neighbouring crops or within the crop, or the Hutton Criteria has been met
Risk of leaf blight	Low	Medium	High
Dose of copper	None	Low 0.75 kg/ha	High 1 kg/ha

A maximum of 6kg per ha of copper a year is permitted. Apply at 10 to 14day intervals.

The control strategy for late blight in organic farming was based on the use of copper fungicides but at the time of writing there are currently no copper products licensed for use on crops in the UK following the rejection to relicense Cuprokylt (Certis). An application by AHDB for authorisation for emergency use of Cuprokylt was accepted in time for the 2017 season and was granted for 120 days from 15th May 2017, before final prohibition of copper based fungicides in organic potato production.

Blight management should be based on estimating the current risk of infection in the crop. This depends on the infection in the region, the precipitation, the susceptibility of the variety and new growth. Sound knowledge of the current situation in the region (alert systems) and on one's own farm (frequent field checks) is required for optimal control. The Blight Watch system offers decision support on assessing the risk to a potato crop. The models use local weather data from the Met Office to calculate the current risk of infection for every crop allowing the farmer to take the necessary precautions. If the yield production has progressed rather far (assessed by taking a yield sample) at the time of initial infection (often after mid/end of July), the risk to the tubers is very low. If the crop and wider environment of the site are not yet infected, the likelihood of infection may be very low, especially in dry weather. In the case of wet weather and infection in the surrounding region or within one's own fields, the likelihood of infection is rather high.

When to spray



The treatment should be carried out early enough before heavy precipitation to let it dry, in order to protect the crop.

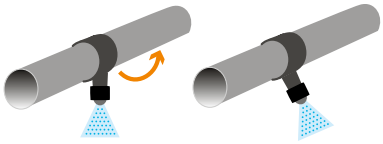
Measures for improved application

Copper products only have a fungicidal effect upon contact. An even wetting of the leaf surface and underside in the entire crop is required to ensure a good effect. To control the distribution of the spraying mixture within the crop, there is a general rule of thumb: where the leaves are moved, the agent is applied. An improved application can be achieved through various means. They vary in effect and cost. Combining them is a possibility.

Benefit: ++
Cost: +

Use enough water for spraying:

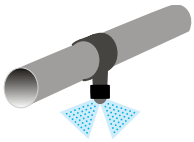
- The amount of water should be chosen to properly wet the leaves; however, the spray mixture should not drip off.
- The amount of water should be adapted to the leaf mass: 400–600 l per hectare is common. In lush crops, 600–1000 l per hectare may be needed.
- Average driving speed of 4–5 km/h is favourable.



Benefit: +
Cost: +

Improve the spraying angle:

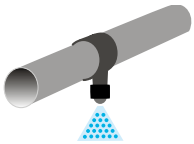
- Turn the spray pipe 40° to the front (not possible with all brands). This allows droplets to enter the crop better.



Benefit: ++
Cost: ++

Install double flat fan nozzles:

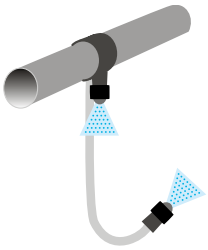
- The slanted spraying angle allows droplets to enter the crop better.



Benefit: ++
Cost: ++

Use high pressure:

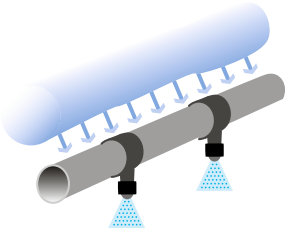
- Choose pressure of 7–10 bar.
- To reduce spray drift, install rebound or injection nozzles that form larger droplets than regular nozzles.



Benefit: +++
Cost: +++

Use under-leaf spraying:

- The spray elements specifically wet the underside of the leaves and the lower levels of the foliage (pressure: 4–5 bar).
- Installation is not equally possible on every spraying machine because the spraying elements and the tubes must not interfere with folding-in of the machine.
- The under-leaf spray elements of more recent models rarely become entangled in the dense foliage.
- More suitable with a row spacing of 90 cm (due to a later crop covering).
- The distance between the elements must coincide with the spacing of the rows in the crop. For use in other crops, the distance must be adjustable.
- Due to strong resistance only a relatively small bar width is possible.



Benefit: ++
Cost: +++

Spraying with compressed air:

- The compressed air moves the leaves and transports the droplets far into the foliage.
- Low drift.
- Less water needed.
- Larger investment and thus only useful for large-scale application.
- Especially suitable in combination with tramlines.

In UK: *Globodera rostochiensis* (yellow PCN) and *Globodera pallida* (white PCN)
Potato cyst nematode (PCN)

Nematode cysts on potato roots.

Important to know

- Nematodes damage the roots and affect yield even when no symptoms are evident in the haulm.
- The potato cyst nematode is the most important potato pest in the UK, with the potential to cause major yield losses.
- The white PCN is the most common nematode due to its prolonged hatching period and the selection pressure from the cultivation of several varieties resistant to the yellow PCN.
- PCN damages the roots of potatoes, resulting in poor growth, wilting during periods of water stress, early senescence and a reduction in tuber yield by as much as 80%.
- In the UK, AHDB Potatoes offers a web based calculator tool that acts as a decision justifier, demonstrating the implications of a grower's actions on the level of infestation by the white PCN and the effect on predicted yield.
- If the infestation is very low, the yield reduction can be so low as to be unnoticeable when a crop is commercially harvested. This can lead to a false impression that PCN can be ignored due to no visible drop in the expected yield. The effect on the final population after harvest could become an issue for subsequent potato crops.
- The nematode is mainly spread by the movement of cysts in the soil attached to potato tubers, farm machinery or footwear. Cysts can also be spread by wind or floodwater.
- Under EU Directive 2007/33/EC, seed potatoes or potatoes for export must only be planted on land that has been found to be free from PCN infestation following an official soil test, undertaken by a PHSI inspector. The growing of ware potatoes is permitted subject to the implementation of a Control Programme.

How to recognise

- In the initial stages plants may appear stunted with wilting, with poor patches of growth. In more severe cases plants may start to show chlorosis.
- If infected plants are lifted, the nematode cysts should be visible on the roots.
- Nematodes have slender, transparent bodies, reaching approximately 1mm in length.
- As females mature, they swell, forming spherical cysts 1mm in diameter, which are white/cream coloured. At this stage they can be seen attached to the roots.
- As females mature and die, the cysts develop a reddish-brown hard skin. Mature cysts can be seen attached to roots but usually drop off at harvest, remaining in the soil as a source of infection for future potato crops.
- The infestation level of a soil can be determined by soil extraction. This service is available from a number of accredited laboratories.

How to prevent

- Take marginal land out of production and avoid growing on the worst affected land.
- Soil sampling should be done regularly to identify and monitor the threat.
- Biofumigant crops such as mustard can be chopped and incorporated into the soil to help kill PCN eggs.
- Clean machinery between fields

Leptinotarsa decemlineata
Potato or Colorado beetle

Eggs

Larvae

Adult potato beetles

Important to know

- The Colorado potato beetle is a distinctive yellow beetle with ten longitudinal stripes on the wing cases. Adults are up to 11mm in length.
- This species is not established in the UK and is a notifiable quarantine pest of potato (plus tomato and peppers), with the potential to greatly reduce yields.
- Colorado potato beetle has been eradicated in UK, but is widespread in continental Europe. In GUK it is most commonly intercepted in spring or early summer from Europe on plant produce (e.g. salad vegetables, potatoes, parsley).
- Potato growers in the UK should remain vigilant and contact the local Defra Plant Health and Seeds Inspector, if presence of the beetle is suspected in a crop or import consignment.

Fred Bonestroo's late blight limitation strategy

At the heart of my late blight limitation strategy is the selection of resistant varieties. I grow 6 main varieties that all offer reliability and security. The 4 most blight resistant varieties today are Allouette, Cara, Carolus, and Toluca. I also grow Agria because of its all-round use and great yield even though it's not very blight resistant but is manageable. I grew Rudolph for the first time this year which looks to be a nice potato, but I will try something different next year. Agrico run field days with trial plots of blight resistant varieties that allow me to select what to grow. Each year I try out new varieties and will give out free samples of these to the box schemes to help introduce them to the consumer.

Measures combined for late blight control:

- Number one is selecting resistant varieties, either from Bioselect or from the Sarvari Trust.
- I try to sow as early as possible as I can't extend the growing season at the other end due to the risk from blight. I do chit very early potatoes but as a small grower don't have the time, facilities or labour to chit the main crop.
- I use wider in the row spacing (approx. 41 cm) to decrease the competition between crop rows and also reduce the leaf wet period as I get more air circulating around the foliage.
- I've stopped cropping the headlands as this is often compacted and the area where the crops struggle and are least healthy.

Fred Bonestroo farms in the Cotswolds near Tetbury at Close Farm.

- I don't apply too much farmyard manure as there is usually enough fertility from the ley, but if I do use it, I make sure it's well composted. I don't believe in pushing the crop too hard. I've found that growth cracks and scab can occur when too much farmyard manure is added, and I prefer a slightly lower yield that stores well and tastes better.
- Once the blight infection has come into the crop, I'll burn off the foliage of infected plants to prevent the disease spreading to the other plants and to the tubers.

Irrigation

- Dry soil during early development promotes a wide root system.
- Early irrigation promotes the conversion of organic matter and, thus, the N supply.
- After stem elongation has started, the soil should be kept moist, otherwise tuber formation might start too early and more than one generation of tubers might form.
- Dry periods during tuber formation lead to a growth check, reduced tuber formation and thus to yield and quality losses.
- From tuber formation to flowering, the water content within the ridge should be kept to a minimum of 50 % of the field capacity.
- Depending on the soil and the potatoes' development stage, the irrigation rates are 20–35 mm per application, but the soil should not be filled up by the sprinkler application to more than 80–90 % of the usable field capacity.
- During tuber growth, sufficient water content is crucial for yield production, especially from 3 weeks after flowering until maturation.
- In case of need, it makes sense to irrigate the potatoes directly before harvesting to carry more soil onto the filter belt and thus reduce the risk of damage.
- Drip irrigation is often most effective as it reduces the humidity in the canopy (reducing the blight risk) and is more efficient in terms of water application.

Irrigation for frost protection

- Can prevent frost damage in short-term frost periods down to –6 °C.
- Turn on irrigation shortly before the temperature falls below freezing point; in the case of covered potatoes, turn on when the fleece freezes to the moist soil. Irrigation that is performed too late can lead to damage!
- Amount: 3 mm per hour (4 mm nozzles).

Irrigation contributes to yield and quality security, especially on lighter soils.

Irrigation

- **Sufficient moisture at the time of tuber formation (initiation) prevents common scab infection (*S. scabies*).**
- **Sufficient moisture during tuber development reduces secondary growth and growth tears, and leads to uniform cooking quality.**
- **Soil that is too wet at tuber initiation can promote powdery scab (*S. subterranea*) infection through lenticels and occasionally through eyes or wounds.**

Haulm removal

- Removing haulms early promotes an early harvest and reduces the risk of wireworm and *Rhizoctonia* infestation.
- Removing haulms on time can reduce the risk of tuber blight in the case of leaf blight.
- Late haulm destruction can lead to higher starch contents, better baking properties and an improved flavour.
- The use of mechanical haulm removers that are adapted to the ridge prevents damage on ridges and tubers (green tubers).

Haulm removal

Uneven soil conditions and leaf blight of various degrees within a crop often lead to uneven maturation of the tubers. A well-timed haulm removal promotes even maturation as well as early setting of skin and early harvest maturity.

Further benefits of early haulm removal:

- An early harvest reduces the risk of damage by wireworms and *Rhizoctonia*.
- In the case of leaf blight infection, the haulm removal reduces the risk of tuber blight caused by seepage of spores into the ridges.
- Haulm control can enable the management of the maturation process and thus offer a certain degree of influence on tuber size (preventing oversized tubers) and starch content.
- In the case of a strong late weed infestation, weeds can be destroyed, which will facilitate the harvest.
- In seed potato production, the well-timed removal of haulm prevents viruses from reaching the tubers in the case of high aphid pressure.

The basic requirement for successful haulm removal is visible senescence of the crop (foliage starting to turn yellow at the tips) and an appropriate starch content depending on the variety. Measures that are applied too early can lead to unripe and non-storable products with a starch content that is too low, and regrowth of leaves and net necrosis. If, due to oversized tubers, too high starch contents or the occurrence of secondary growth, green leaves need to be removed, and a multi-stage strategy is required that is adapted to the variety's properties and the weather conditions and that combines haulm removers and flaming technology.

For the sample dig, the tubers of four different plants are dug out at several locations in the field.

When to remove the haulms

- When sample digs show that the tubers have reached the required size and desired starch content. The new PotatoSize App from Agrovista and the JHI can be used to accurately determine the size of the crop (www.agrovista.co.uk/potatosize-app/185/).
- In a healthy crop, when half of the leaves have turned yellow.
- In the case of leaf blight, to prevent the blight from reaching the tubers.
- Industrial potatoes: only when starch content and test baking meet the requirements.
- Seed potatoes: the date depends on the size of the tubers. Starch content and the occurrence of aphids may be important.
- In the case of regrowth: repeat measure, or maybe use flaming.

The more advanced the natural maturation of the crop is …

- The higher the starch content …
- The higher the sporulating leaf blight infection …
- The higher the pressure of late weed infestation dropping seeds …
- The higher the risk of wireworms and *Rhizoctonia* …

… the more sensible and unproblematic the removal of the haulms is.

Methods of haulm removal

Mechanical removal

- Standard procedure; only applicable in matured crops (also depending on variety).
- Cost-effective and beneficial in terms of energy use.
- A remover that is specifically adapted to the shape of the ridge and deposits weeds into the furrows is advantageous. Flail mowers are most suitable for haulm removal.
- Flame if regrowth occurs.

Flaming

Direct:

- Can be sensible in the case of heavy leaf blight infection, to kill off the spores.
- A fast pass at 8–12 km/h can be used at the initiation of the maturing process.
- Fuel consumption (if flaming is the only measure used): about 110 kg of propane per hectare.

After haulm removal and drying:

- Heat exposure on the remaining stems prevents regrowth over the long term.
- Fuel consumption: about 70 kg per hectare.

Harvest

Before harvesting, the state of maturity, skin stability and tuber quality should be determined. The basic requirement for harvesting (except for early potatoes for certain markets) is the skin stability of the tubers.

What to watch out for

- The tubers reach skin stability at the earliest 2–3 weeks after haulm removal or after the haulms have died off completely. 18 out of 20 (90%) tubers should withstand rubbing and applying pressure with a thumb at the end of the tuber.
- As soon as skin stability has been achieved, the harvest can begin. Each additional day of unnecessarily delayed harvest significantly increases the risk of impaired quality caused by wireworms, slugs and *Rhizoctonia*. On the other hand, incomplete skin stability, a high number of tubers affected by wet rot, or very dry soil are all reasons to delay the harvest for a few days.
- If soils are very dry and cloddy, irrigation with 5–15 mm of water per m^2 can facilitate the harvest.
- In order to ensure a harvest that is as careful and gentle as possible, before harvesting, the potato harvester's settings should be checked at each strike / batch by additional digging and tuber evaluation.
- Temperatures that are either too low (<10 °C: internal bruising) or too high (>25 °C: sweating and rot) should be avoided because they can decrease tuber quality and storage stability.

Harvest

- An early harvest reduces the risk of infestation with wireworms, slugs, *Rhizoctonia* and silver scurf.
- Well-matured (skin-stable) tubers are less sensitive to damage and storage rot.
- Careful harvesting at temperatures that are not too low helps to prevent damage.

Storage

Wound healing

- To allow wound healing, dry off tubers as fast as possible within the first 24 hours (avoid high humidity and condensation and provide positive ventilation).
- Then store the potatoes for 3–4 weeks in a dry and airy environment (several air changes every day) at about 12 °C, or for 2 weeks at 15 °C. This promotes corking and wound healing, and reduces rot.

Cooling

- After drying off, cool the tubers at maximally 0.5–0.7 °C per day / 1–2 °C per week. The difference in temperature between the tubers and the outside air at ventilation should be at least 2 °C.

Long-term storage

- Only skin-stable product is suitable.
- Hot summers and high temperatures reduce the dormancy and the storage suitability.
- Potatoes intended for consumption can be cooled to 3 to 6 °C (depending on the variety; e.g. Nicola needs at least 5 °C)
- Low storage temperatures cause the sugar content to increase. This has a negative effect on baking properties, and during frying and baking, high amounts of acrylamide are formed. The amount of reducing sugar after cool storage can be decreased to some extent by warming the tubers to above 10 °C for 2–3 weeks.
- Industrial potatoes: do not store below 8 °C.
- Optimal relative humidity: 90–95%. Check storage temperature and ventilation regularly.
- Condensation on the walls indicates insufficient insulation. To avoid weight losses, the warmth can be transferred from the stored tubers to the walls and ceiling by regularly circulating air, which increases the humidity. IT-supported systems allow optimal storage.

Sprouting control according to organic standards

Spearmint oil

- Plant tonic based on mint oil and unsaturated fatty acids (commercial name 'Mitobar').
- Mint oil reduces sprouting of tubers.
- Can be applied to seed potatoes and potatoes for consumption.
- Mint oil has an intense smell. Take care in case of short-term storage or overdose!

Citronella, Clove, Rapeseed oil

- These oils can be used to inhibit sprouting of potatoes.
- Applied by spraying the storage area as soon as the first sprouts become visible in the form of white dots on the skin.
- Intense smell.

Ethylene

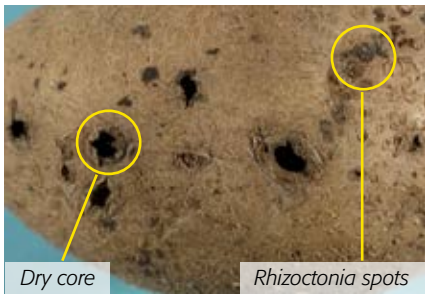
- According to the EU-Organic Regulation, ethylene can be used to inhibit sprouting of potatoes. Can be applied to seed potatoes and potatoes for consumption.
- In processing potatoes, it can have a negative impact on the baking colour.

Storage

- Dry the potatoes off before storage to prevent rot.
- To avoid susceptibility to damage, warm the potatoes up to at least 10 °C before sorting, washing or packing.
- To avoid spreading diseases, only use clean boxes and expose them to the sun or disinfect them.
- Clean off fine dust during sorting to reduce the spreading of silver scurf.

Holes in the tubers

Rhizoctonia solani
Dry core



How to recognise
- Round, approx. 1–4 mm sized holes with a black, frayed edge, filled with dry tissue.
- Depth: about 2–8 mm.
- Often together with *Rhizoctonia* spots.

Important to know
- Planting material with *Rhizoctonia* spots and simultaneous occurrence of wireworms bears a high risk of dry core, as damage on the skin serves as entry point for the fungus. If the soil moisture content is high, infection can also occur via lenticels.
- The risk of infection is increased in the first few years after perennial grass-clover leys.

How to prevent
- Avoid grass-clover leys as preceding crop.
- Wash the planting material and check for spots / dry core. In the case of a severe infection, replace the planting material. It is best to use uninfected planting material.
- Properly chit the planting material and plant it in warm soils. Dressing with antagonists has a limited protective effect.
- Choose a long crop rotation.
- Harvest as soon as skin stability has been reached to reduce risk of infection.
- If the preceding crop is a grain, encourage the rotting of the straw.
- Compost fresh manure; apply it in the previous year and work it in well.
- Expose the planting material to light during preparation to build up solanine.

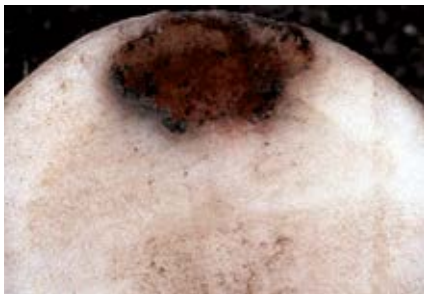
Larvae of *Agriotes* spp.
Wireworms

How to recognise
- Round, approx. 2–4 mm sized holes with a sharp outline.
- Depth: a few millimetres up to the entire tuber.

Important to know
- The click beetles lay their eggs in the soil (with a preference for grassland) at a depth of 1–2 cm during May and June. The entire life cycle takes 3–5 years (depending on the species and the weather conditions).
- Larvae in their second and third year of development cause the greatest damage.
- Increased risk within the first three years after perennial grass-clover ley.
- The risk of damage from wireworms is lower after a short term (1 year) grass-clover ley than after a long term grass-clover ley.

How to prevent
- Avoid too many grass-clover leys in potato crop rotation.
- If possible, do not cultivate potatoes within the first three years after perennial grass-clover ley.
- Harvest the tubers as early as possible (but skin stability required!).
- Specific tillage after the beetles have laid their eggs between May and June, e. g. after over-winter green manure, or an intense stubble cultivation.
- Cultivating legumes (peas, field beans, bush beans) and brassicas (cabbage, fodder radish, mustards) can reduce the damage caused by wireworms.

Deroceras spp., *Arion* spp. and others
Slugs



How to recognise
- Early damage: irregular dents in the tuber.
- Holes of approx. 2–6 mm diameter on the surface and significantly wider within the tuber. Sometimes they contain faeces, eggs or slugs.

Important to know
- Caused mostly by smaller slug species (up to about 2 cm).
- Heavy soils, damp locations or proximity to grass-clover leys, grassland or fallow land are high-risk environments.
- Increased risk in vegetable crop rotation (e. g. with spinach).

How to prevent
- Avoid grass-clover ley, non-permanent pasture, green fallow, vegetables and rape as preceding crops.
- Harvest the tubers as early as possible (but skin stability required!).
- Slug pellets may be used if justified but permission from the certification body will be required.

Tuber damage

The risk of tuber damage depends strongly on the variety, but it can be reduced by appropriate cultivation measures.

Holes in the tubers can be also caused by e. g. couch grass roots. Refer to specialised literature for more detailed information.

Damage on and in the tubers can only be determined on washed and sliced tubers. The tolerance for tuber damage is specified on page 25.

Defects on the skin

Streptomyces spp.
Netted, russet, erumpent and pitted scab


Netted scab


Erumpent scab

How to recognise
- Brown, fissured, partially corky spots; shallow (russet and netted scab), raised (erumpent scab) or crater-like (pitted scab).

Important to know
- The infection occurs via contaminated soil or infected plant material.
- Varieties differ significantly in susceptibility. Highly susceptible varieties include Agria, Desirée; less susceptible varieties include Charlotte, Nicola.
- Badly infected planting material forms fewer shoots.

Netted scab:
- The bacterium *Streptomyces reticuliscabiei* infects only potatoes.
- Damp, poorly aerated or waterlogged soils of 13–17 °C during tuber formation facilitate an infection.

Russet, erumpent and pitted scab:
- Caused by at least three *Streptomyces* species *(S. europaeiscabiei, S. stelliscabiei, S. scabiei)*; infect other host plants as well (e. g. carrots, sugar beet).
- Well-aerated, dry soils with temperatures of 19–24 °C during formation of tubers facilitate an infection.

How to prevent
- Do not cultivate susceptible varieties on plots with a high risk of infection.
- Use infection-free planting material.
- Irrigation in the first few weeks after formation of tubers reduces russet, erumpent and pitted scab infection.
- Grow potatoes max. every 4th year!
- No potatoes after grass-clover.

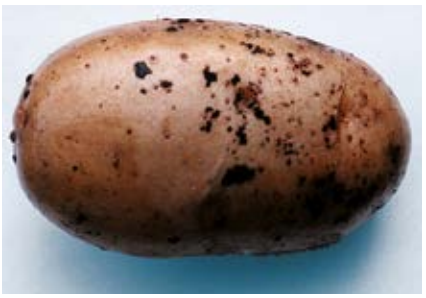
Spongospora subterranea
Powdery scab

How to recognise
- Crater-shaped pustules, empty or filled with spore powder.
- Often remains of burst skin.

Important to know
- The fungal infection occurs mainly via contaminated soil or infected planting material.
- Irrigation facilitates the spread of powdery scab in contaminated soils.
- Big differences in susceptibility between varieties. Highly susceptible varieties include Agria, Almera, Estima; less susceptible varieties include Santé, Desirée, Sarpo Una, Lady Balfour).

How to prevent
- Do not cultivate susceptible varieties on contaminated soil!
- Use infection-free, certified planting material in order to avoid soil contamination.
- Do not grow potatoes more than every 4th year!

Rhizoctonia solani
Rhizoctonia or black scurf



How to recognise
- Black dots or spots (can be scraped away with the fingernail).

Important to know
- Badly infected planting material may lead to tuber deformities and dry core. The crop yield is significantly reduced.

How to prevent
- See 'Dry core' (page 18).

Green tubers

How to recognise
- Slight or intense green colouring of the skin on one side.

Important to know
- Result of the tubers being exposed to light in the field or in storage.

How to prevent
- Plant in a straight line and at regular depth.
- Shape your ridges high and wide.
- Cover the tubers after harvest; store them in the dark.
- Ensure that planting and hoeing machinery have the same number of rows / coulters.

Defects in the flesh

Impact damage (black or blue bruising)

How to recognise

- Spots of a blue-grey colour, locally restricted, 0.5–1.5 cm beneath the skin (only become visible after peeling)
- At a late stage, the spots cork.

Important to know

- Impact damage can result from pressure and bruising during harvest, storing, sorting, loading, washing, packing and transporting. The spots only become visible after a few days, when the discolouration takes place.
- Stones and clods can damage the potatoes during harvest.
- The higher the starch content, the more sensitive the tubers are.
- Varieties differ in susceptibility.
- Modern machines generally cause less impact damage than older models.

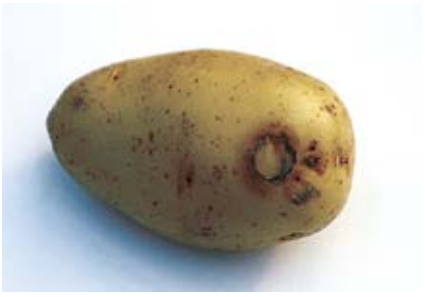
Fall heights above 25 cm should be avoided to prevent impact damage.

How to prevent

- Make sure the potassium supply of the soil is sufficient.
- Don't apply late doses of nitrogen (delays maturation).
- Let the tubers mature properly before harvesting.
- Check a sample of tubers: 24 hours after harvest, stored at room temperature.
- Do not harvest at low temperatures; do not start too early with the harvest after cold nights. Measure the inner temperature of freshly dug-up potatoes (must be at least 12 °C; for varieties susceptible to impact damage at least 15 °C).
- The soil must be neither too wet nor too dry during harvesting (ideal moisture content depends on the soil type).
- Reduce the speed of the sieve belt or increase driving speed to contain as much soil for as long as possible as a cushion. Turn off the machine when turning around and do not let it run dry. The share flap should be set to an appropriate angle and depth so as to include a cushion of soil. Adjust lifting depth to the position of the tuber cluster.
- The casing should be intact and made from plastic or rubber.
- Do not transfer, sort or wash cooled potatoes: they tend to be much more sensitive than warm potatoes (ideal temperature: 12–15 °C).
- Do not run the machines at high speed. Minimise rolling of potatoes. Regularly remove dried-up clods of earth and jammed stones.

Virus PVY^{NTN}

Necrotic ringspots (potato tuber necrotic ringspot disease, PTNRD)



How to recognise

- Spots, brown arches or rings on the skin. The flesh has turned brown on the surface.

Important to know

- Viral necroses have only occurred for a few years.
- The infection starts from infected plants and is spread via aphids.
- Tuber damage is most severe in dry, hot summers.

How to prevent

- Cultivate resistant varieties: Lady Balfour(PVYO), Carolus (PVYN), Sarpo Mira (PVYO) Pentland Javelin (PVYO). Take special care with varieties Nicola (PVYO), Charlotte (PVYO), Marfona (PVYO).
- Use clean, certified planting material, grown in low risk areas. The main source of PVY inoculum is infected seed tubers.
- Eliminate infection sources by early rogueing of diseased plants.

Deformation

Pectobacterium spp.

Black leg and soft rots in tubers (in field and during storage)

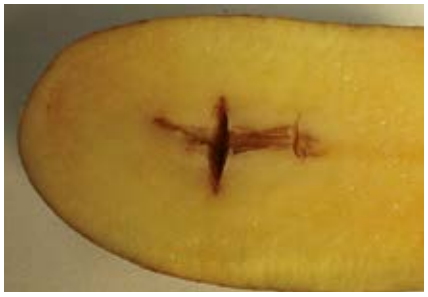
Important to know

- Soft rot forms when the conditions (especially sufficient water) for bacteria to thrive are optimal and the resistance of the tuber can be overcome. Bacteria thrive in cooler wet conditions.
- Healthy tubers are rarely infested. Infection is promoted by tuber blight (dry rot), tuber damage (e.g. by slugs or mice), impact damage, frost damage or waterlogging.
- A dormant infection can spread after the tubers have been washed (e.g. in plastic bags, due to warm and humid conditions).

How to prevent

- Source seed carefully.
- Promote quick emergence.
- Avoid de-sprouting at planting.
- Prevent tuber blight (see p. 11–12).
- Avoid waterlogging and do not over-irrigate.
- Avoid short rotations.
- Harvest the crop as early as possible. Only harvest skin-stable tubers, avoid mechanical damage and store tubers in dry environments.
- Protect stored tubers from frost.
- In case of infection, avoid spreading it into healthy fields (clean the machinery).
- **Caution:** infection can be spread during sorting! Clean grader prior to grading.
- Avoid sweating and condensation during storage and transport. Ventilate using dry air.
- Market infested tubers unwashed.
- Additionally *Dickeya* spp. (formerly known as *Erwinia chrysanthemi*) has been increasingly found to cause wilts and stem rots in warmer seasons, producing blackleg-like symptoms.
- A new more aggressive strain, *Dickeya solani*, has established itself in several European countries.
- In England, *Dickeya 'solani'* has been detected since 2007 on both seed and ware crops, all grown from seed of non-UK origin. These bacteria are mostly spread via seed and can be controlled through good hygiene. The Safe Haven Certification Scheme, originally designed to protect against ring rot introduction, offers significant benefits for controlling the movement of *Dickeya* spp. on infected seed.

Hollow heart



How to recognise

- Sliced tubers with longitudinal and lateral tears in the centre that turn brown in storage.

Important to know

- Form during sudden growth spurts

How to prevent

- Maintain a regular water supply to maintain uniform growth.
- Only cultivate resistant varieties. Agria shows an increased risk of hollow hearts.
- Limit size: check for high number of sprouts during presprouting; plant more closely.
- Apply moderate fertilising in varieties that tend to form oversized potatoes.
- If necessary sort out large tubers during harvest.
- Sliced potatoes: lower pH value by using ascorbic acid.

Growth tears

How to recognise

- V shaped split along the tuber (growth tear).

Important to know

- Results from a quick change of soil moisture from dry to wet around the tubers.
- Risk situation: light soils.
- *Rhizoctonia* infection can lead to similar deformation.

How to prevent

- Cultivate resistant varieties. Take special care with varieties such as Agria.
- In long dry periods, irrigate during tuber growth (which also reduces the risk of secondary growth).
- Don't apply too much nitrogen fertiliser.

Secondary growth

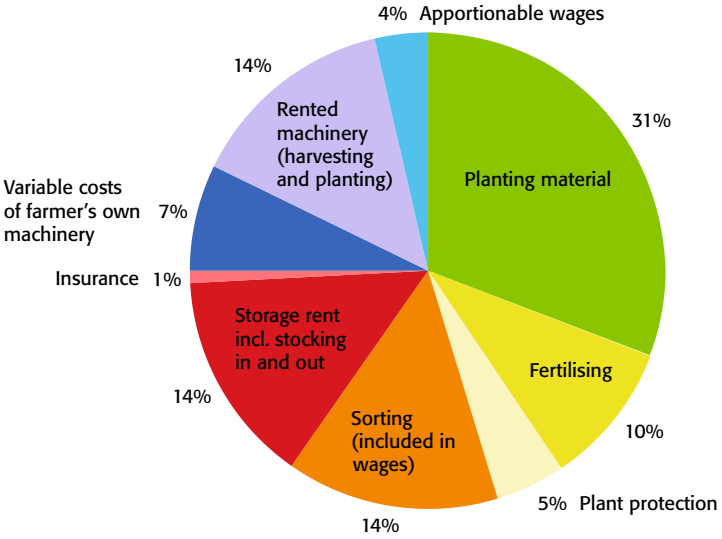
Secondary growth has a similar cause as growth tears. The varieties Granola, Exquisa or Filea show a tendency towards secondary growth.

Economics

Production cost

- Planting material is a major cost factor. The costs for organic planting material are significantly higher than for conventional planting material. They vary from about £ 1000 to £ 1500 (€ 1000 to 1500) per hectare, depending on the variety and amount, and whether certified seeding material and controlled seed saving are used.
- The fixed costs for special potato machinery vary greatly depending on the equipment and the intensity of production. Prices for potato planters (e. g. a two-row device with added hand loading) start at £ 3000 (€ 3000); for a four-row device to plant pre-sprouted tubers prices start at £ 25,000 (€ 25,000).
- The costs of plant protection and fertilising are lower in organic farming than in conventional farming. A one year old grass-clover ley as a preceding crop provides about 80–150 kg N per hectare and replaces fertilising costs of £ 450–550 (€ 450–550). Another £ 70 (€ 70) per hectare is needed for use of sulphate of potash fertiliser.
- The costs of plant protection can reach up to £ 300 (€ 300).
- Variable machinery costs of £ 20–40 (€ 20–40) per hectare and 5–10 man-hours are needed for application.
- For cultivation (1× harrowing, 3× earthing up), variable machinery costs are estimated to be £ 45 (€ 45) per hectare, and 10–20 man-hours are expected.
- The advantage of having one's own harvesting machinery is the ability to harvest at the right time and having an influence on handling sensitive harvested crops. The costs for a single row grubber range from £ 35,000 to 40,000 (€ 35,000 to 40,000). Amortised over 10 years (without interest), the costs amount to £ 3,500–4,000 (€ 3,500 to 4,000) per year. The higher the utilisation, the greater the profitability. Harvesting leads to wage costs of about £ 500–600 (€ 500 to 600) per hectare.
- In addition, storage, sorting (and packaging) cause high variable costs (depending on the operational and marketing system), especially for personnel. The exact values vary widely due to the differences in operating structure and equipment between direct marketers with small quantities and a lot of personal contribution, and suppliers for the food retail sector.
- The wage costs for sorting and filling into pallet boxes and storage rent vary from £ 15–35 (€ 10 to 35) per 1000 kg, depending on the quantity and quality, and the personnel and processing equipment needed.

Structure of the variable costs in organic potato cultivation

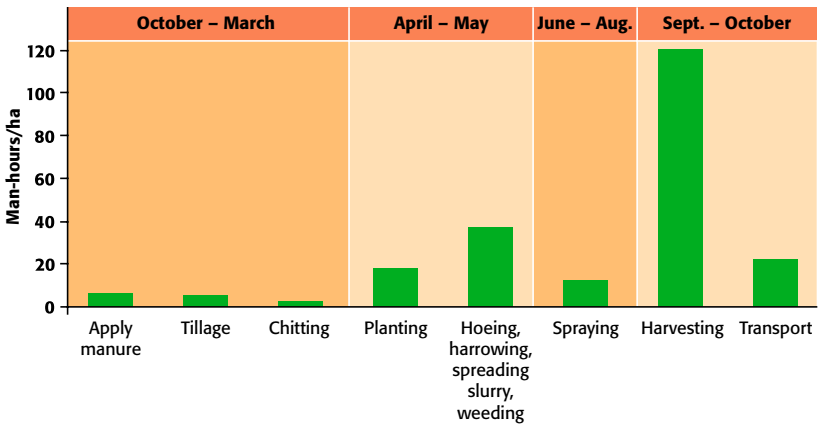


Required work

The required work is higher in organic potato cultivation than in conventional farming (mechanical weed control):

- Preceding year until February: basic fertilising, tillage, chitting. The amount of work for chitting depends on the chosen method (see also page 5).
- The start and the number of plant treatments depend on the weather and the development of the leaf blight epidemic. In humid weather, many treatments against leaf blight may be necessary (see page 12). In continuously hot dry weather, they can be omitted entirely.
- Harvesting and grading cause the greatest amount of work. The workload greatly depends on the amount of stones, clods of earth and unmarketable tubers that must be sorted out.

Required work



Costs and performance of organic potato production in the UK

Maincrop potatoes						£/ha		*(£/ac)*
Marketable yield	23 t/ha	*(9.2 t/ac)*	@	300 £/t		6900		*(2792)*
Output	70% of gross yield	Gradeout: 15% farm, 15% packer					**6900**	*(2792)*
Seed	2.5 t/ha	*(1.0 t/ac)*	@	600	£/t	1500		*(607)*
Fertilisers		Standard rotational with additional potash/manure				54		*(22)*
Irrigation	75 mm		@	2.5	£/mm	188		*(76)*
Weed control	2 ridge-up & knock down		@	25	£/ha	50		*(20)*
Casual labour – planting	25 h/ha	*(10 h/ac)*	@	10.00	£/h	250		*(101)*
– harvest & grade	33 t/ha	*(13 t/ac)*	@	22	£/t	726		*(294)*
BPC levy						43		*(17)*
Transport	28 t/ha	*(11.2 t/ac)*	@	46	£/t	1290		*(522)*
Haulm removal	1 topping		@	20	£/ha	20		*(8)*
Other	Occasional hand rogueing, foliar dressings of seaweed					40		*(16)*
Total variable costs							**4161**	*(1684)*
Gross margin							**2739**	*(1109)*
Adjustment for wholesale sales								
Marketable yield/output	28 t/ha	*(11.2 t/ac)*	@	460	£/t	12903		*(5161)*
less commission @	15%					1935.45		*(774)*
Additional casual labour	28 t/ha	*1 h/t*	@	10	£/t	281		*(112)*
Packaging	28 t/ha	*40 bags/t*	@	20	p/bag	224		*(91)*
Additional transport	28 t/ha	*(11.2 t/ac)*	@	44	£/t	1234		*(499)*
Gross margin (wholesale)							5068	*(2027)*
Sensitivity analysis	*Change in value (+/–)*	*Change in gross margin*	*Value range*		*Gross margin range*			
			Low	*High*	*Low*		*High*	
Marketable yield	1 t/ha	*223 (89)*	15	40	959	(388)	6523	*(2640)*
Packer price	10 £/t	*230 (92)*	225	475	1014	(410)	6764	*(2737)*
Casual labour	10 h/ha	*100.0 (40)*	50	150	2215	(896)	3215	*(1301)*

Early potatoes						£/ha		*(£/ac)*
Marketable yield	12 t/ha	*(4.8 t/ac)*	@	600	£/t	7200		*(2914)*
Total output	85% of gross yield	Gradeout: 5% farm, 10% packer					**7200**	*(2914)*
Seed/chitting	3.0 t/ha	*(1.2 t/ac)*	@	700	£/t	2100		*(850)*
Fertilisers		Standard rotational with additional potash/manure				54		*(22)*
Weed control	2 ridge-up & knock down		@	25	£/ha	50		*(20)*
Casual labour – planting	30 h/ha	*(12 h/ac)*	@	10.00	£/h	300		*(121)*
– harvest & grade	14 t/ha	*(6 t/ac)*	@	22	£/t	308		*(125)*
BPC levy (standard rate)						43		*(17)*
Transport/bulk	13 t/ha	*(5.3 t/ac)*	@	46	£/t	612		*(248)*
Other	Occasional hand rogueing, foliar dressings of seaweed					40		*(16)*
Total variable costs							**3507**	*(1419)*
Gross margin							**3693**	*(1495)*
Adjustment for wholesale sales								
Marketable yield/output	13 t/ha	*(5.3 t/ac)*	@	830	£/t	11039		*(4467)*
less commission @	15%					1656		*(670)*
Additional casual labour	13 t/ha	*1 h/t*	@	10.00	£/t	133		*(53)*
Packaging	13 t/ha	*40 bags/t*	@	20	p/bag	106		*(43)*
Additional transport	13 t/ha		@	44	£/t	585		*(237)*
Gross margin (wholesale)							5052	*(2044)*
Sensitivity analysis	Change in value (+/–)	*Change in gross margin*	*Value range*		*Gross margin range*			
			Low	*High*	*Low*		*High*	
Marketable yield	1 t/ha	*528 (211)*	10	20	2637	*(1067)*	7918	*(3204)*
Packer price	10 £/t	*120 (48)*	350	925	693	*(281)*	7593	*(3073)*
Casual labour	10 h/ha	*100 (40)*	30	100	3301	*(1336)*	4001	*(1619)*

Source: Organic Farm Management Handbook, 2017. Organic Research Centre Elm Farm.

How do the main factors affect the revenue?

Yield: A prerequisite for good yields and good quality is a good, healthy soil. A good supply of nitrogen is important too. This depends on the crop rotation, on fertilisation and on the weather conditions, which all affect the N mineralisation and the N supply of plants. Also the yield is affected by the time a variety needs to reach the juvenile stage, whether the sprouting of the plant material was stimulated (chitting) and the course of the leaf blight epidemic.

Early, waxy salad varieties like Charlotte, Nicola and Ditta often create lower yields than semi-waxy varieties. However, the prices for waxy varieties are usually higher.

Quality: Grading out defective tubers causes a considerable amount of work and costs. Exceeding the tolerances for quality defects results in price deductions; for severe quality defects, the goods will be rejected. Rejected goods may be used for the food industry or for peeling companies, depending on the type of defect and the variety, but the price will be significantly lower.

Price: The price of organic potatoes is above the price for non-organic goods; however, they are still linked. It is subject to supply and demand, but currently much more stable than the prices of conventional potatoes.

Prices vary considerably, depending on overall production, quality, season, outlet and national production.

On average, organic farming reaches yields between 20 and 25 tonnes per hectare. Goods meant for consumption usually account for about 70 to 80 %. However, yields may vary greatly from year to year, due to different growth conditions and the release of nutrients in the soil as well as the development of the leaf blight epidemic.

Marketing

The demand for organic potatoes has risen steadily in recent years and is expected to rise even more. In principle, the marketing needs to be planned before cultivation! In the case of supply to the wholesale trade or to the industry, a purchase agreement and supply contract should be made.

For which buyer should the crop be produced?

Food retailing via packers (table potatoes)

- See page 25 for quality conditions.
- Personal warehouse or storage possibility required.
- The variety is usually determined by the customer.
- Potatoes are increasingly sold washed. Defects in the skin are thus more obvious than in unwashed tubers.
- Large amounts of a consistently high quality are required, therefore suitable for large farms.
- Addresses of potential buyers can be obtained from advisory services.

Industrial potatoes (food potatoes, starch potatoes)

- Could increase in importance in the next few years.
- Product-specific quality criteria (starch content, test baking), but less strict requirements in terms of scab infection and dry core.
- The variety is determined by the buyer.
- No storage required.
- Delivery of large amounts possible.
- Only with cultivation and supply contract.
- Often lower prices than for table potatoes.
- Addresses of potential buyers can be obtained from advisory services.

Wholesale (reseller/organic wholesale/canteen kitchen/organic supermarket)

- Organic supermarkets and canteen kitchens may gain in importance in the next few years.
- Greater flexibility when choosing a variety.
- Suitable for farms with good storage and processing capacity.
- Requires greater flexibility of farms (need to respond to customers more specifically, e.g. for delivery).
- Higher prices possible than in food retailing.

Direct marketing

- Sale of unwashed potatoes in bags of 10–25 kg in the autumn directly from the farm (storage sale) is relatively inexpensive compared to the continuous sale of small units, probably including delivery.
- Direct marketing requires a favourable location and a warehouse.
- Provides greater flexibility when choosing a variety.
- The significantly higher costs for storage, processing and marketing justify the significantly higher prices compared to supplying to wholesalers. The added value remains on the farm.

Quality assessment, use and sorting

Quality defects are more common in organic potatoes compared to non-organic potatoes. The main quality problems are impact damage, wireworms, *Rhizoctonia* spots, dry core, slug damage and scab.

The basis for quality assessment is formed by the respective regulation of quality categories for table potatoes. It provides the framework for traded table potatoes. The practical requirements for the quality of the product arise from the wishes/demands of the end-user; thus, they can also be regulated privately. Consistent quality is required, and a continuous improvement is often expected.

Table potatoes are separated into three cooking types (waxy, all-rounder, floury). The different cooking types have to meet different requirements in terms of the starch content (see below). For industrial potatoes, the buyers set their own quality criteria depending on the intended use (e.g. test baking, starch content, size, shape). Seed potatoes must be certified. The field approval takes place during a field visit. The definitive approval is made if skin and tuber quality requirements are met and if in less than 10 %, severe viral infections are detected.

Quality requirements for table potatoes (excerpt)

General requirements:

- Intact
- Pure in terms of variety
- No serious damage, feeding damage or bruises (superficial mechanical damage and feeding damage are considered harmless)
- Minor differences in size at most
- Firm (not soft or wrinkly)
- Free from rot (wet rot, dry rot, brown rot)
- Free from frost and heat damage
- No foreign components (earth, sand, loose buds, etc.)
- No unfamiliar scent or flavour
- No deformities (secondary growth, growth tears)
- Slight green colouring at most
- Maximum 25 % of russet (or netted) scab
- Maximum 10 % of pitted scab
- Skin stability
- No iron spots or hollow hearts
- No corky ringspots, glassy potatoes, bitter pit, bruising, discolouration of the vascular bundles, heart rot, viral necroses
- No long buds

Size of organic table potatoes (guide values for normal years)

Early potatoes (harvest before 30 June)	All varieties	28 mm
Early potatoes (harvest after 30 June) and table potatoes	Elongated to long varieties	30 mm
	Round to oval varieties	35 mm
Table potatoes: Elongated to long varieties		30 mm
Table potatoes: Round to oval varieties		35 mm
Other conditions apply to seed potatoes		

Lessons learned by Tony Little from his first year of seed production

As a basic rule for potato seed production you need to leave at up to 7 years between potato crops and at the same time you should not go in too soon after grass because of the risk of wireworm. In case you do not have right stage of the rotation on your farm, you may rent a field on a nearby organic farm.

Getting the right machinery on the right settings can be a challenge for starters. For seed production you need an 8" seed setting for a decent yield and the right tuber size. Take the time to try a new machine out or at least see it in action before using it!

Another challenge may be to find a harvester with a seed net to avoid loss of undersized tubers. Undersized tubers are not a huge issue in terms of profitability, but they are valuable to the seed company. Sharing a seed net or even a dedicated machine among seed producers may be an option.

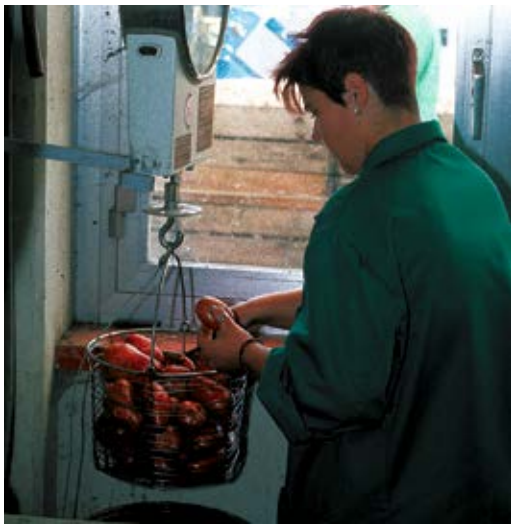
Passing APHA inspections is vital. To deal with viruses I grew resistant 'Sarpo' varieties, whereas blackleg is controlled through thorough rogueing.

Ensuring correct rates and spacings is essential for minimising gaps and weeds, and achieving financial success. Stony fields and too many weeds strongly increase harvesting costs.

Tony Little (left) is a new entrant to potato production. He started to grow potatoes on an organic upland farm near Tregaron (West Wales) to improve the financial viability of the farm.

Cooking type and starch content

The starch content has a strong influence on the cooking type. Potatoes with a low starch content are rather waxy, while those with a high starch content are rather floury. In order to determine the cooking type of single batches, the starch content of a potato batch is measured at the initial inspection.



The starch content is calculated from the tubers' weight underwater.

How can the starch content be influenced?

- Fertilisation: High nitrogen fertilisation and late mineralisation lead to low starch content and vice versa. In the case of potassium deficiency or over-supply, the starch content is low.
- Haulm removal: If the haulm is removed when still green, the starch content will be reduced.
- Blight: Sudden, heavy infestation and thereby early dying of the haulm leads to a low starch content.
- Chitting favours early stripping, so that a high starch content is achieved early.

- Raw, peeled, or mashed organic potatoes often react by the formation of raw-pulp discolouration.
- Darkening during cooking is a major problem for large-scale kitchens.
- Black spots resulting from excessively cold processing of cold-stored potatoes in combination with very cold washing and rinse water lead to complaints, often only after storage by the client.
- The formation of a 'second skin' after cooking is an important quality defect, especially for early potatoes with poor skin stability.
- Many organically grown varieties react to quick cooling with discolouration.

Processing of peeled potatoes

In large-scale kitchens, the use of semi-finished goods, or peeled raw or pre-cooked potatoes, is increasing. Because of their mostly low potassium and phosphorus contents, organic potatoes react much more sensitively to a number of processing procedures than conventionally cultivated potatoes, which had abundant supply of P and K during development. Furthermore, organic processing uses only few preservatives to stabilise the quality, such as ascorbic and citric acid.

How to deal with these problems?

- The formation of a tough and very flexible skin (a 'second skin') after cooking can only be reduced by a deeper peeling, sometimes reaching the vascular ring. As the varieties react very differently depending on their state of maturity and location, the depth of peeling must be determined case by case, and checked by storage trials and cooking trials.
- The 'cook and chill' procedure, which is common for the use of potatoes in catering, has an alternative: pre-cooking peeled potatoes that are vacuum-packed in polythene bags. While this procedure is, despite the additional working step of boiling in the convection oven, fairly easy to apply, problems persist with some varieties. The variety Princess, for instance, reacts with hardening in the convection oven, i. e. it does not become soft. In contrast, the red-skinned variety Laura, with its dark-yellow flesh colour, is very suitable for this procedure.

Gentle peeling procedures

Carborundum peeler:

- The potatoes are guided and 'abraded' on a coarse surface (similar to sandpaper) made of silicon carbide.
- Advantages: the procedure is sensible in terms of nutritional physiology, as the nutrients directly under the peel are maintained, and the gain is very high due to minimal abrasion.
- Downside: the tendency to discolour (raw-pulp discolouration) increases, as the surface becomes very coarse and many cells are destroyed.

Knife-cutting process:

- Advantage: the smooth cutting surfaces lessen discolouration.
- Downside: more peeling waste is produced than in the carborundum process.

Quality-reducing discolouring reactions

Raw-pulp discolouration

How to recognise

- Dark red-brown to brown-black discolouration of raw, peeled potatoes, grated potatoes, or squeezed juice.
- Occurs after a period of contact with oxygen in the air.

Important to know

- Damaged cell walls become permeable to oxygen.
- Enzyme complexes (polyphenoloxidases) become active and oxidise free amino acids and amides (e. g. tyrosine) or mono- and diphenols (e. g. chlorogenic acid) into dark pigment (melanins).
- Great differences between varieties and locations.

How to prevent

- Consider susceptibility of the varieties.
- A good supply of K (farmyard manure, potassium fertiliser) improves the formation of organic acids and, therefore, of low pH values, which are colour reducing.
- Avoid too high a supply of K (more free amino acids, amides, etc.).

Peeled potatoes:

- Peeling surface as smooth as possible.
- Process susceptible varieties first, as the natural vitamin C content decreases during storage.
- Add ascorbic acid (vitamin C) to the basin water of the peeling station in order to lower the pH value to under 6.7 / 6.5 to avoid discolouration (monitor pH; adding 0.1 g ascorbic acid per litre of water should give a lowering of about 0.6 units). Lowering the pH may even reverse a discolouration.

Blackening on cooking

How to recognise

- After cooking or pre-deep-frying, the potatoes (mainly at the top) or chips/fries turn greenish, grey-blue, to brown.
- The full extent of blackening can only be ascertained after cooling the cooked potato.

Important to know

- During cooking, phenolic compounds (e. g. chlorogenic acid) react non-enzymatically with free metal ions (e. g. iron, copper).
- Great differences between varieties and locations.

How to prevent

- Consider susceptibility of the varieties.
- A good supply of P and K can reduce the chemical process of discolouration.
- Adding citric acid to the last rinse water can significantly reduce discolouration of peeled potatoes. The water needs to be acidified to pH 5.3. Adding 0.023 g citric acid per litre of water reduces the pH value by 0.2 units.

Browning on chips / fries and crisps (test baking)

Left: positive, right negative test baking.

How to recognise

- Bitter-tasting brown discolouration after heating in oven.
- By using a test baking involving an evaluation of discolouration during heating (baking grade).

Important to know

- Under the influence of heat, reducing sugars (glucose, fructose) react with free amino acids to form amino sugars and further to form Amadori compounds.
- Depending on their intended purpose, minimal baking grades are specified for industrial potatoes.
- Test baking is increasingly being applied for table potatoes. Use potatoes with a high baking grade for frying, baking, and deep-frying.
- The baking grade depends on the variety, the tubers' degree of maturity, as well as storage temperature and duration.
- A good test baking result further indicates low potential for the formation of acrylamide.

How to prevent

- Cultivate suitable varieties. Discuss choice of variety with the buyer!
- For a good final maturation, avoid late nutrient application and mineralisation.
- Ensure a good supply of K.
- Prior to haulm removal, carry out a test baking; let tubers mature.
- Avoid impact damage, sprouting, and damage by pests.
- Never store or transport tubers at a temperature below 8 °C.
- After cold storage, warm up tubers for 2–3 weeks to over 10 °C.

Advice

For advice on the cultivation of potatoes in the UK please contact:
AHDB Potatoes (Stoneleigh) – Registered office
AHDB Potatoes
Agriculture & Horticulture Development Board
Stoneleigh Park, Kenilworth, Warwickshire, CV8 2TL
Tel. 024 7669 2051

Further reading

Further reading on the cultivation and the quality control of potatoes:

AHDB Potatoes
www.potatoes.ahdb.org.uk/

AHDB Potato Variety Database
http://varieties.ahdb.org.uk/varieties

Soil Association Potato Blight Control Factsheet
www.soilassociation.org/farmers-growers/technicalinformation/technical-guides/

Sarpo Potatoes Ltd. Seed Production Manual
First Edition, Spring 2017; An introduction to the requirements for growing Sarpo seed potatoes in Wales

Explanatory Guide to The Seed Potato Classification Scheme and Approved Stock Scheme for the 2016/17 season
Animal & Plant Health Agency; https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/523572/SPCS-guide.pdf

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