Assured Produce

Crop Specific Protocol

CELERIAC

(CROP ID: 54)

January 2009

Control Document No: 00019/09

Acknowledgements

Assured Produce gratefully acknowledges the contribution of all consultees in the preparation of this protocol, particularly Robin Buck and Julian Perowne of Jack Buck (Farms) Ltd.

Preface

This crop specific protocol has been written to complement and avoid duplicating the generic principles of the scheme and appendices.

It is advisable to read the Assured Produce Generic Crop Protocol Standards and the Assured Produce Generic Protocol Guidance Notes (referred to in this document as the Generic Standards and Generic Guidance Notes) first before reading this crop specific protocol.

This protocol is designed to stimulate thought in the mind of the reader.

This crop specific protocol contains crop specific parameters and guidance, where applicable, for the requirements stated in the Generic Standards.

All statements in this protocol containing the words **"must"** (in bold type) will be verified during the Assured Produce assessment and their compliance will form a part of the certification/approval decision. The score required for these **"must"** control points can be found on the final page of this document and in the checklists produced by Assured Produce licensed certification bodies.

Disclaimer and trade mark acknowledgement

Although every effort has been made to ensure accuracy, Assured Produce does not accept any responsibility for errors and omissions.

Trade names are only used in this protocol where use of that specific product is essential. All such products are annotated ® and all trademark rights are hereby acknowledged.

Notes:

There may be other withdrawals or revocations. Products containing substances which have been revoked are shown on the PSD website (http://www.pesticides.gov.uk). Growers should check with their advisers, manufacturers, the Assured Produce website 'Newsflashes', the PSD website (www.pesticides.gov.uk)

Growers should comply with the 'Use up by' dates for all pesticide products. Growers should also be aware of and comply with changes on new product labels. There may be changes for the following reason:

- At re-registration stage after Annex 1 listing there may be: reductions of dose rates; changes in timings and/or number of applications for some products.

In the following Appendices products and use by dates are only listed for SOLAs, and in some cases new product MAPP numbers may not be available yet.

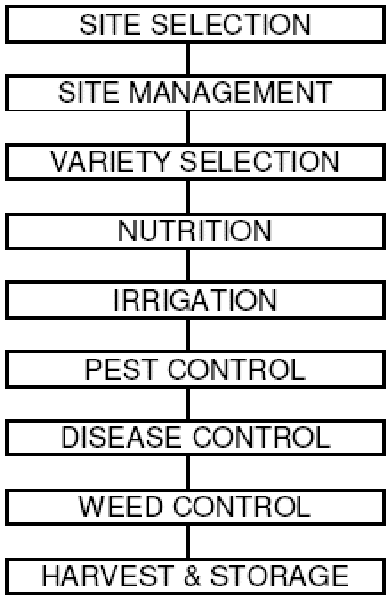
For pesticides on-label, only active substances are shown.

Any new standards have been prefixed in the text with **(NEW)**

1 General introduction

Following a systematic approach will help growers to identify and manage the risks involved in crop production. This protocol is based on a typical crop production process. Using a flowchart approach, food safety, Health & Safety, environmental and quality hazards are identified. Appropriate controls may then be established to minimise risk. Food safety and Health & Safety issues always take precedence over quality and environmental controls.

The flow chart is structured as shown below. Note that the sectional layout of both this protocol and the crop specific protocols follow the same structure.



The contents of each crop specific protocol are reviewed annually by informed farmers and growers, food technologists, scientists, the relevant fresh produce association, processors and agronomic consultants. Updated editions are issued prior to the cropping season.

The review process considers both new developments and all relevant technology which has emerged throughout the course of the previous year and which have been found to be both workable by the grower and beneficial to the environment. As one aim of the Scheme is to transfer such information and technologies to growers, attention is drawn to those features of specific relevance to ICM by using *italic* script. In order that growers may be confident that they are working to a current document, each protocol is dated and numbered. Any changes to the text have been highlighted by marking the document with a line in the margin.

1.1 Definitions

Celeriac *(Apium graveolens* var. *rapaceum)* belongs to the umbelliferae plant family, which also includes Carrots, Parsnips, and Celery. Umbelliferous herbs and spices include Parsley, Fennel, Dill, Chervil, Lovage, Angelica, Caraway, Aniseed and Cumin. Important umbelliferous weeds prevalent in the UK include cow parsley, fools parsley and hemlock.

Celeriac is a biennial, growing vegetatively from seed in the first year into a swollen stem storage organ following leaf senescence in the autumn. Re-growth in the following spring produces a flowering stalk and, following fertilisation; seeds are produced in the late spring/early summer. Celeriac is similar to Celery exhibiting similar shaped leaf petioles and leaflets. The leaf bases are attached to the stem. As swelling of the stem occurs rapidly in the autumn, harvesting is generally left until late October and into November to maximise yield.

2 Planning and records

See Generic Standards and/or Generic Guidance Notes.

3 Site Selection

3.1 Site history

3.1.1 Site situation

Celeriac originates in the Mediterranean basin and has warm temperate growth requirements. Optimal temperatures for growth lie between 15°C and 18°C, growth ceases at below 7°C and above 24°C. For this reason it is important that cold sites (eg. shaded by woods, north facing, etc.) are avoided. South facing fields offer the best thermal advantage.

As Celeriac can suffer frost damage at temperatures lower than -1°C, so harvesting needs to be complete before freezing temperatures occur in the autumn (generally early to mid November). Sites prone to late spring or early autumn frosts are best avoided.

Celeriac benefits from irrigation, which facilitates steady growth. Irrigation is particularly helpful immediately after transplanting to assist establishment. In the absence of irrigation, water stress may lead to stop/start growth with resulting hollow stems. If irrigation is not available, moisture retentive silt soils are preferred.

3.2 Rotation

Site diseases

Celeriac is susceptible to the same range of diseases as Celery. The following soil-borne diseases may build up if Celeriac is cropped in a close rotation:

Grey mould rot *(Botrytis cinerea)*, licorice rot *(Mycocentrospora acerina)*, phoma rot *(Phoma apiicola)*, watery soft rot also called pink rot (*Sclerotinia minor* [Jagger]) and (*Sclerotinia sclerotiorium* [Lib.] de Bary), black rot *(Alternaria radicina)*, crater rot *(Rhizoctonia solani)* and *fusarium* rot *(Fusarium oxysporum)*.

The following diseases persist as spores in crop debris buried in soil:

Sclerotinia , *Septoria* Spot *(Septoria apiicola)* also called Late Blight, bacterial rots (*Erwinia* spp. and *Pseudomonas* spp.)

The following soil-borne diseases may attack Celeriac during post-harvest storage:

Licorice rot, phoma rot, *Botrytis* , *Erwinia* spp., *Pseudomonas* spp., and *Sclerotinia* .

These pathogens generally need free moisture and/or high humidity to develop and express symptoms on produce in store. Good air flow particularly immediately after harvest will limit most storage diseases. However, if Celeriac stems have been inoculated via wounds made at harvest, the wet flesh will allow the pathogens to develop even if dry air surrounds the stored stem. For this reason careful harvesting is a pre-requisite for successful disease free storage.

In the field all these pathogens require host plants on which to multiply and in the absence of a host the pathogen population declines. Crop rotation with several years between host crops is a useful means to ensure pathogen populations fail to build up significantly and decline in the intervening years. This allows the production of Celeriac crops to be sustainable.

A minimum rotation of one in four years should be implemented if the rotation is composed of crops not susceptible to *Sclerotinia* . If *Sclerotinia* -susceptible crops are the rotation a one in six year rotation is essential, with Celeriac following a non-susceptible crop such as cereals.

Site pests

Free-living nematodes of various species are pests of many broad-leaved crops. If there has been a history of problems of establishment or poor crop performance caused by free-living nematodes, soil samples should be taken in the previous year for laboratory assessment. Selecting fields with a minimal nematode population is a useful cultural technique to avoid crop damage.

For carrot fly it is important to be aware of other umbelliferous crops in the preceding season and so it is advisable that growers are aware of these crops and plan to be 1 kilometre away if possible.

Note: When sending soil samples for assessment, careful handling is needed as any shock (e.g. dropping) may rupture the nematodes and reduce the result.

4 Site management

4.1 Soil mapping

See Generic Standards and/or Generic Guidance Notes.

4.2 Soil management

Soil structure, cultivations, type & pH

Celeriac will not tolerate poorly drained soils so a good soil structure, which allows excess water to drain, is essential to satisfactory crop performance. Stems are prone to mechanical damage when harvested from the soil that may lead to unsightly brown discoloration of the flesh. Similar constraints apply to other root crops, so the preferred soils are those which can be managed freely and do not contain excessive stones or clods. Celeriac can suffer (slow growth) from soil compaction. It is, therefore, important that soils are free of pans or compacted layers that will ensure the roots are unimpeded. This is particularly important if irrigation is not available. Cracks on the surface of the Celeriac can occur if the growth is uneven, possibly due to wet/dry conditions.

The correct cultivation sequence can only be determined after first examining the soil structure. Examinations are best made using a soil pit, as this readily shows to what extent and to at what depth any compacted layers exist. Soil augers, spade or hand fork can be used to determine soil structure to depth at points across a field.

If compaction is found, these layers should be removed by deep cultivations and/or subsoiling. Pans are best broken whilst the soil is dry as subsoiling implements then produce a good 'shattering' effect. Wheelings in subsequent cultivations, etc. should be limited to avoid any further compaction. The use of ploughs, power harrows, bed formers, destoners/declodders, etc. will depend on the soil type, with the aim of minimising the number of operations and passes to produce a. bed with a fine tilth on top and good structure below.

A stone and clod-free bed is ideal, with a fine tilth extending 15 cm deep. If beds are drawn up well before drilling, removing weeds with a non-selective herbicide can produce a 'stale seed bed'. Early bed forming under cool spring conditions also conserves moisture by limiting evaporative losses from cultivations.

The most suitable soil type for Celeriac has been found to be sandy loams, sandy clay loams and silts, although other soil types can produce acceptable crops. Care needs to be taken if heavier soils are selected, as wet conditions in the autumn may make harvesting difficult.

Celeriac does tolerate acid soils, but yields of Celeriac may decline unacceptably if the soil pH is below 6.3. The optimum pH lies between 6.5 and 7.0. More alkaline soils should be avoided as Celeriac is prone to boron deficiency. The availability of boron is greatest in neutral soils and much less in alkaline pH soils. It should be noted sandy soils tend to be particularly prone to boron deficiency.

5 Variety Selection

5.1 Choice of variety or rootstock

See Generic Standards and/or Generic Guidance Notes.

5.2 Seed quality

See Generic Standards and/or Generic Guidance Notes.

5.3 Seed treatments and dressings

See Generic Standards and/or Generic Guidance Notes.

5.4 Plants and nursery stock

Propagation

Celeriac seed is very small (1500 to 2000 per gram) and expensive so care needs to be taken to avoid wastage. Seeds should be soaked in thiram to provide protection against leaf spot disease. The most economical method of limiting seed wastage is to sow into module trays, germinate seed at 20°C and propagate young plants under glass over an 6 to 8 week period as early growth is particularly slow. Belgian research indicates propagating young plants above 14°C reduces the risk of bolting in the field.

Young modular plants should be planted out in the late spring (15 May to 1 June). Early planting increases the risk of premature bolting. Particular care needs to be taken not to plant the modules too deep, as the apex is short and easily buried, or losses may result.

If early (mid April) plantings are contemplated to achieve a July harvest polythene covers will be required to improve the thermal environment of the young plants early in the season.

Propagators need to be registered with DEFRA's Plant Health and Seeds Inspectorate under the EU Marketing Scheme. Propagators will also need to comply with all relevant pesticide, plant health and quality legislation.

If any plant protection products have been applied to transplants before delivery to a crop producer, due warning needs to be given as required by Health & Safety at Work Act (1974) to enable any hazard to be assessed under the COSHH Regulation (1994).

Early Crops

Early crops are produced from larger cells planted at lower densities on suitable early sites using crop covers. The covers should be removed before the crop suffers any heat stress in early June.

It is advisable that careful handling of polythene or fleece covers reduces tears and soil contamination and allows them to be reused for other crops. Once damage or soil contamination has made reuse impractical, crop covers should be recycled with a licensed recycling agent.

6 Nutrition

An inadequate nutrient supply results in indifferent yields. As almost all plant nutrients are taken up as ions, supplied from soil reserves in the soil water, managing soil nutrition requires careful attention to establish the correct soil nutrient conditions before planting. Monitoring crops during growth is helpful to enable remedial treatments by foliar feeds or top dressings, but the yield penalties incurred by early nutrient shortage are rarely overcome.

6.1 Nutrient requirement

Nutrient assessment

The key factor dictating the availability of all nutrients is soil pH so monitoring and adjustment of pH is an essential first step towards good soil nutrient management. Macro and micronutrient **must** be tested by assessing samples of soil or leaftissue. The following table indicates which nutrients are best determined by a soil analysis or leaf tissue analysis.

	Soil analysis (prediction)	**Leaf tissue (confirmation)**
Soil pH	Yes	No
Nitrogen	Yes (separate testing)	Yes
Phosphate	Yes	Yes
Potassium	Yes	Yes
Magnesium	Yes	Yes
Sulphur	No	Yes (N:S ratio)
Manganese	No (use pH + texture)	Yes
Copper	Yes	Not ideal
Boron	Yes	Yes
Molybdenum	Yes	Yes

Soil samples should be taken as 25 soil sub-samples (an auger sample volume is adequate for each sub-sample) from an area not exceeding four hectares, each to plough layer depth (usually 15 cm). The sub-samples should then be thoroughly mixed (the sample should then weigh about 1 kg) and then be sent to a laboratory for nutrient analysis.

Celeriac is intolerant of acid soil conditions and is sensitive to boron deficiency: the optimum pH for Celeriac production lies between 6.5 and 7.0. Fields with a wider range of pH values can produce satisfactory crops where supplementary boron fertilisers (basal and/or foliar) are used. The cation exchange capacity (CEC) of the soil is also important; i.e. sands have a low CEC and generally provide a poor supply of boron; pH may be less critical where soils have a CEC above 10 meq/g.

Major nutrients

Any fertiliser applications need to be made on the basis of soil or leaf tissue analyses, which enables the correct nutrient to be selected and dose rates appropriately adjusted. Information on Celeriac nutrition is limited but it is known to be a 'hungry' crop, responding well to generous (45 t/ha) farmyard manure applications. In the UK Celery fertiliser recommendations are generally followed but with adjustments to nitrogen levels, following continental European research findings. The table in Appendix 1 giving P, K and Mg values, originates from the Celery section in the 'Fertiliser Recommendations Reference Book 209 (2000) 7th Edition.' It provides a sound base to guide fertiliser recommendations and applications, based on assessment of soil samples.

Soil nitrates **must** be monitored in the growing season.

Micro nutrients

Celeriac is particularly sensitive to boron deficiency, readily producing hollow swollen stems if shortage occurs. Boron should be assessed when soil samples are sent for nutrient analysis, the following gives a general guide to soil boron availability:

Index 0	<0.5 mg/l	severe deficiency, treatment essential
Index 1	0.5-1.0 mg/l	deficiency likely, treatment recommended
Index 2	1.0 + mg/l	satisfactory for most crops

Dutch research recommends a minimum soil boron concentration of 1.4 mg/l for satisfactory Celeriac production. Caution is needed as boron is a micronutrient, and application levels need to be moderate to avoid reaching toxic levels (for many crops toxicity occurs when soil boron exceeds 4.0 mg/l).

Where treatment to soil is required boron can be applied either as Borax® at 22 kg/ha as granule (usually blended in with other fertilisers to achieve the necessary bulk to apply evenly) or alternatively as a liquid as Solubor® applied at 11 kg/ha in 200 to 500 litres water/ha. If foliar treatment is required (eg. where unsuitable soil pH reduces boron availability), Solubor® maybe applied at 5.5 kg/ha in 200 to 500 litres water/ha (higher water rates are needed on tender or young plants).

7 Irrigation

See Generic Standards and/or Generic Guidance Notes.

8 Crop protection

8.1 The basic approach to crop protection

Celeriac is susceptible to a number of pests and diseases but as a guiding principle pesticide inputs should be minimised through prevention rather than cure.

An integrated approach should be adopted to achieve this by involving the following management steps:

a. It is a useful principle to attempt to grow Celeriac crops in isolation, then if pest and disease infestations occur, they are late and less prolific.
b. Sensible crop rotation avoids the build up of soil-borne problems or disease carry-over from one crop to the next.
c. Include resistant varieties in cropping programmes whilst retaining quality parameters and eating characteristics.

Cultural preventative techniques

a. Any crop waste left in the field should be ploughed in immediately after harvest to promote rapid breakdown by soil microbes. This prevents the debris acting as a source of inoculum to remaining unharvested crop.
b. Any crop waste from crop stores needs to be collected together before being taken to a designated dumping zone where it is preferably buried. Returning stored waste to the source field is likely to result in the establishment of soil-borne diseases, and should be avoided.
c. Crops enjoying good plant health through nutrient supply are more tolerant to pest and disease attack.
d. General plant health may also be assisted by reducing stresses, eg. the judicious use of irrigation allows

plants to grow rapidly.

Corrective action

a. First establish the nature of any problem by receiving regular updates on monitoring and forecast services such as the Aphid Monitoring Service from Brooms Barn Research Station. These will provide information on any general prevailing threat.
b. Monitor crops at regular intervals to detect the early presence of any pests or diseases. Care needs to be taken to correctly identify any potential pest or disease so that any corrective action is appropriate.
c. Consider any prevailing factors which may mean the pest or disease becomes less significant, eg. dry weather slows disease progress, but wet weather may reduce the threat from cutworm damage.
d. The timing of an agrochemical input can seriously affect its efficacy. As a general rule, applications early after infection or infestation are more effective than late applications; therefore regular crop monitoring to detect early problems is essential.
e. If chemical control is needed the following points should be considered:

- use the least toxic and persistent product;
- use the most selective product to reduce the impact on naturally occurring beneficial organisms;
- use the minimum effective dose rate;
- use appropriate application methods with properly maintained equipment (exceeding the dose is illegal under COPR).

8.2 Plant protection product choice

See Generic Standards and/or Generic Guidance Notes.

Approved uses not included on the product label

In some circumstances product labels do not include all of the approved uses and growers and advisers wishing to check the approval notice of a particular product should note that this information is available from www.pesticides.gov.uk/psd_databases.asp

A search on the database for a product name should yield a results page. A click on the product name should link to a summary of the approval information. At the bottom of the summary are links to available notices which will give the statutory conditions of use.

In the case of products with older approval an electronic approval may not be available. In these cases growers should contact the PSD Information Services Branch for details of the approved conditions of use. Contact details are: p.s.d.information@psd.defra.gsi.gov.uk tel. 01904 455775.

8.3 Advice on the use of pesticides

See Generic Standards and/or Generic Guidance Notes.

8.4 Application of pesticides

See Generic Standards and/or Generic Guidance Notes.

8.5 Records of application

See Generic Standards and/or Generic Guidance Notes.

8.6 Protective clothing/equipment

See Generic Standards and/or Generic Guidance Notes.

8.7 Pesticide storage

See Generic Standards and/or Generic Guidance Notes.

8.8 Empty pesticide containers

See Generic Standards and/or Generic Guidance Notes.

8.9 Pesticide residues in fresh produce

See Generic Standards and/or Generic Guidance Notes.

See Generic Protocol Guidance Notes 8.9 for further background and generic advice .

Assured produce is aware that a key area in the production of fresh produce which requires continued attention by growers and their advisers is that of keeping pesticide residues to a minimum. The issue is not just one of meeting the MRL trading standard but ensuring that any individual or multi residues are kept as low as possible below this level.

The key targets are:

- **Minimising late application of fungicides and insecticides to the edible part of the crop**
- **Ensuring minimum harvest intervals are followed**
- **Ensuring that application equipment is applying products correctly**

Currently there are no residue issues associated with this crop but the awareness needs to be maintained for any future issues.

8.10 Pest, disease and weed control

8.10.1 Pest Control

8.10.1.1 Carrot fly

Carrot fly *(Psila rosae)* is widespread in the UK as a wide range of cultivated umbelliferous crops (Carrots, Parsnips, etc.) and weeds (eg. cow parsley and wild parsley) act as suitable hosts. Using land virgin to umbelliferous crops unfortunately does not eliminate the risk of carrot fly attack.

First generation adult flies emerge from pupae in May, and follow the scent from umbelliferous plants or crops by flying upwind towards the new host. Adult carrot flies prefer to live in shelterbelts adjacent to umbelliferous crops where they feed and mate. Eggs are laid in the crop in soil cracks near the host plant. Approximately 7 days later a colourless 1st stage larva hatches out and burrows into the soil to begin grazing externally on the roots. This may lead to young plants dying and plant stands becoming 'gappy'. Later, 2nd and 3rd stage larvae burrow into the root to form mines. The older 3rd stage larvae are creamy white and 8 - 10 mm long, after which they pupate in the soil close to the taproot. After further development, a second-generation adult carrot fly emerges.

Second generation carrot flies are usually first detected in late July or early August depending on the season. If is the second generation that is considered to be the most serious as the mining of the roots spoils their

Control Document No: 00019/09

appearance and reduces the crop value. Carrots and Parsnips are often stored over winter in the ground, which means they may be a source of first generation carrot fly the following spring if poor control was achieved.

Carrot fly control is best achieved by integrating several cultural measures. The following points are helpful:

a) **Site risk assessment:** Some sites are inherently at more risk of carrot fly pest attack than others, therefore select low risk fields. Factors that increase probability of attack are:

- Close vicinity to previous umbelliferous crops. Carrot flies can travel some 1.5 kilometres from one crop to another but damage will reduce very significantly over 1 kilometre.
- Over wintered Carrot and Parsnip crops pose particular risk to crops planted in the following spring.
- Proximity of ditches, hedges etc. which allow broad leafed weed plants to provide shelter along field edges (fields which are long and thin with suitable shelter along a long edge present particularly high risk).
- Close umbelliferous crop rotations, (this generally means umbelliferous crops in close vicinity to each other in and between years).
- Poor disposal of heavily infested crop material (a cull pile may translate into a carrot fly insectory if not properly destroyed).

b) **Use of sticky traps:** Yellow sticky traps still present the best means of monitoring carrot fly activity on a field by field basis and **must** be used. Traps need placing from early May onwards to detect first generation.

A minimum of four traps should be used per monitored field, placed in a line in the second bed in and facing a suitable shelterbelt at the field edge. Traps need to be positioned so that they are angled at 45 degrees with the top edge towards the field margin. Trap height needs to be adjusted to just above crop height, as this is the flight level of carrot flies. Trap height will need adjusting upwards as crop height increases through the season.

Traps need to be changed weekly and sent for assessment where the insects caught can be properly identified and counted. The onset and peak of the first generation provides an excellent guide to general earliness of carrot fly in any one year. Once the first generation numbers have declined to very low levels, any subsequent increase provides a good indication of start of the second generation and allows the efficacious timing of insecticide sprays. This is particularly important, as it is the second generation of larvae that mine into the Celeriac's swollen stems to cause severe spoilage.

A sequence of insecticide sprays is often appropriate whilst second generation flies are prevalent. However from about mid September onwards the flies appear less able to lay eggs, thus late insecticide sprays are often not needed even though flies may continue to be found on traps (exact timing of cessation of insecticide sequence will depend on prevailing temperature).

a. **Chemical control measures:** Soil applied sprays at transplanting offer good protection from first generation attack in May and should be used if high risk sites are to be cropped. Celeriac crops transplanted in May are particularly at risk if this coincides with first generation fly presence. Early attacks may result in young plants failing to establish and a subsequent reduction in plant population.

   Second generation carrot fly potentially presents a more serious economic threat, therefore, close monitoring is essential to time the first insecticide spray application. The first application is the most effective for damage limitation and usually occurs in late July or early August. Sticky traps have been shown to offer the best means to time first and subsequent sprays.
b. **Carrot fly forecasting:** Horticulture Research International/Horticulture Development Council offer a carrot fly forecasting service based on a combination of trap catches and a thermal day degree driven model to predict carrot fly development. This service is useful in providing a general overview of high or low infestation years and general earliness of lateness of infestation.

It is important to note however that risk of carrot fly attack may vary widely from field to field, thus a general forecast will not be sufficiently meaningful to cope with particular 'hot spot' fields. The limitations of a general forecast mean that fields identified as being at particular risk should be monitored more closely with sticky traps.

8.10.1.2 Aphids

Several aphid species attack Celeriac but only one, the peach-potato aphid *(Myzus persicae)*, has shown resistance to insecticides. It is important to identify which aphid species is present to determine whether a resistance control strategy is appropriate.

Aphid populations generally increase by females reproducing without mating, under suitable conditions populations may increase very rapidly. As a general principle, good aphid control is obtained by early treatments so regular monitoring to detect aphids and predator presence allows timely decisions to be made.

Predators are useful in controlling low aphid populations so care needs to be taken to decide if an insecticide is needed at all. If it is, a selective insecticide should not affect predators that should then control later infestations.

The following guidelines indicate how insecticide efficacy may be improved.

In general medium sized droplets work well, but if weather conditions permit fine droplets are ideal as these provide better cover of the foliage and increase the probability of direct contact. The standard rate of water is 250 l/ha but heavy aphid infestations require increased water rates up to 500 l/ha. Water rates below 250 l/ha applied conventionally increase the probability of poor control and need for re-application.

Pyrethroid insecticides are prone to breakdown by ultra violet light so early evening application is preferable as the aphids are likely to be mobile at night and so pick up insecticide more readily.

Anticolinesterase pesticides should not be mixed unless label instructions allow such mixing, for operator safety reasons.

Pirimicarb has both contact and vapour phase action, working best between 15 - 25°C under still conditions (effectiveness is largely lost when windy).

Nicotine is a broad-spectrum contact and vapour phase action that works best between 15 - 25°C. It is general metabolic poison with no known resistance but it generally only achieves a partial kill.

If peach-potato aphids are present the following table provides a guide for effective product types:

a. **Esterase resistance:**

S	**R1**	**R2**	**R3**
Pyrethroid	Pirimicarb	Nicotine	Nicotine
Pirimicarb	Nicotine	Pymetrozine	Pymetrozine
Nicotine	Pymetrozine		
Pymetrozine			

Note: As resistance increases from S to R3 aphid colour changes from lime green to rosy pink.

b. **Modified acetylcholinesterase (ie. MACE) resistance:** MACE-resistant peach-potato aphids only show resistance to pirimicarb, other aphicides are effective. However, in 1996 when MACE resistance was discovered, it was only found in association with Esterase resistance, this then gives the following table of effective products:

MACE + **S**	**MACE +** **R1**	**MACE +** **R2**	**MACE +** **R3**
Pyrethroid	Pymetrozine	Nicotine	Nicotin
Pymetrozine	Nicotine	Pymetrozine	Pymetrozine
Nicotine			

8.10.1.3 Cutworm

Cutworm is a general term given to the caterpillar larvae of the turnip moth. However, in some years the heart and dart moth, large yellow underwing moth and garden dart moth larvae may also cause cutworm-type problems. Particular risk of attack occurs under dry weather conditions on a range of broad-leaved crops, including Celeriac, grown on light soils.

Adult moths emerge from May or early June until the end of July. Eggs are laid on the leaves of host plants; young caterpillars hatch 10 to 14 days later and begin feeding on the leaves. After three instars, the growing caterpillars drop to the soil surface and burrow into the soil to begin feeding on roots and tap/storage roots. Root feeding over July and August may cause serious damage to crops. Over winter the caterpillars remain underground, become fully fed and eventually pupate between February and May, after which development towards adult form progresses.

Control of cutworms depends on killing the leaf-feeding caterpillar stages. Control measures are ineffective once burrowing into the soil has occurred. Two main options for control are water droplets (ie. rain/irrigation) or insecticide application.

Water, particularly as heavy droplets, striking crop leaves 'knocks' young caterpillars to the soil surface, where they are unable to find leaves again and eventually die. A minimum of 12 mm of heavy rain or 25 mm of irrigation is effective at controlling cutworm larvae.

Note: If irrigation is to be relied upon, even applications are required as no control will be exerted in the underlaps.

Pyrethroid insecticides are effective at killing young cutworm caterpillars on the leaf, and will need to be used if rainfall or irrigation has not occurred in time.

Effective cutworm control depends on the correct timing of control measures. Various cutworm warning services provide timely warnings for control based on day-degree accumulation to indicate cutworm development, coupled with rainfall/irrigation data. If rain/irrigation has not intervened and 3rd instar development has been reached, a recommendation to apply insecticide is given. The use of this service ensures the use of insecticides is minimised yet effective control is achieved.

8.10.2 Disease control

Celeriac is botanically very similar to Celery. It is prone to the same range of diseases. Some of these diseases become apparent in store rather than in the field. Four fungicides are approved. Although these are broad-spectrum protectant fungicides, applications need to be carefully timed to coincide with the onset of infection but before symptoms are expressed.

As Celery and Celeriac share many of the same diseases, only one of these crops should be grown in the rotation, otherwise a rapid build-up of mutually infective soil-borne diseases may be expected.

8.10.2.1 Sclerotinia

Sclerotinia is an important disease of a wide range of broad-leaved crops. The sclerotia are the survival organs and consist of a waterproof, tightly enmeshed mass of hyphae. Sclerotia may survive for over 20 years in the soil, and will grow out to infect a suitable host crop when roots are in close vicinity. Susceptible crops include Carrots, Parsnips, Brassicas (vegetables and oilseed rape), Sugar Beet, and Beans. Some broad-leaved crops are less susceptible, but may still host *Sclerotinia* eg. potatoes and linseed/flax. Monocotyledonous crops are not susceptible; this includes cereals (Wheat, Barley, Triticale etc.), other graminaceous crops (Maize and Sweet Corn) and the allium family (Onions, Garlic, Chives and Shallots).

As sclerotia last for considerable periods of time in the soil, the key to long term cropping is to prevent this disease establishing to begin with. *Sclerotinia* -free land may be sustainably cropped with vegetables so long as break crops are used in the rotation. This has the effect of maintaining inoculum at low levels or to decline in the absence of suitable host crops.

Sclerotinia may be particularly aggressive on Celeriac in store, where the high humidities and wet surfaces allows the pathogen to develop freely. Managing the storage conditions may help to limit disease expression, but it is most useful if inoculum from the field is minimal at harvest. The use of *Sclerotina* -free land for Celeriac cropping is helpful.

It is advisable that crops for long storage are carefully rogued before harvest. Infected plants should be placed in plastic bags and removed from the field.

Azoxystrobin will have some impact on early Sclerotinia field infection.

8.10.2.2 Septoria

Septoria is potentially a serious foliar disease that arises from infected seed. Under wet, warm conditions foliar symptoms spread rapidly. The use of thiram-soaked seed limits disease expression to very low levels early in the season. Available fungicides may be used but, as they are only protectants, the environmental loading needs to be considered because once disease has been detected in the crop treatment is unlikely to give good control. It is desirable to use seed guaranteed to be free from infection by the seed supplier.

8.10.2.3 Phoma

Generally *Phoma* is more problematic in store rather than in the field. The fungus survives in crop debris between susceptible host crops; thus limiting soil inoculum build up by ensuring good rotational intervals between Celeriac crops is essential. The expression of disease in store partly depends on the level of wounding at harvest so gentle handling helps reduce disease levels.

8.10.2.4 Bacterial disease

A range of bacteria, mainly *Erwinia* and *Pseudomonas* species may attack Celeriac in store. Wounding at harvest and poor storage conditions (warm, wet surfaces on the swollen stems in particular) make disease expression worse.

8.10.2.5 Licorice rot

This soil-borne disease tends to be seen in stored crop. As there is no effective chemical control available, crop rotation with wide intervals is essential to prevent inoculum building up in the soil.

8.10.2.6 Grey mould rot

This disease tends to show in store, but may be seen in the field under particularly prolonged wet conditions. The fungus may reside in the soil surviving as spores between host crops. Good crop rotation intervals are the main means to limit soil inoculum build-up.

8.10.3 Weed control

There are few herbicides approved for use in Celeriac and the list is likely to diminish rather than increase. The maximum use must be made of good site selection and cultural techniques.

For early crops, especially those under crop covers, soil-incorporated trifluralin before planting is favoured. For crops planted in May, a stale seedbed technique will enable useful control of emerging annual weeds and allow some control of volunteers. Very low, well timed, doses of linuron at weed cotyledon stage can give satisfactory results. Currently approved herbicides are listed in Appendix 3.

9 Harvesting and storage

9.1 Hygiene

See Generic Standards and/or Generic Guidance Notes.

9.2 Post-harvest treatments

See Generic Standards and/or Generic Guidance Notes.

9.3 Post-harvest washing

See Generic Standards and/or Generic Guidance Notes.

9.4 Time of harvest

Harvest timing will depend on the market specification of the final root size. Celeriac crops can bulk up quickly in October so careful and regular monitoring is necessary. Early crops grown with crop covers can be ready in early August especially if irrigated.

9.5 Harvesting

Accurate topping is important, as any overtopped roots are effectively valueless. Accurate topping also minimises the amount of foliage in store. Mechanical handling can damage the root and as many of the storage diseases require wounds to enter into the swollen stem, care is needed in all harvesting and handling operations.

9.6 Storage

9.6.1 Loading stores

Storage can be either in bulk or in boxes. There is rarely a problem of compression damage in bulk stores as Celeriac can be loaded up to at least 3 metres in height. Cooling and drying should be the first priority. Careful handling is important and there must be adequate provision made for the removal of any free soil.

9.6.2 Storage temperature

Temperatures must be reduced as quickly as possible in refrigerated stores; therefore, adequate refrigeration capacity is needed. Ambient temperature stores need to be 'blown' for two days after loading to lower the initial respiration rate of the crop. In both types of store ambient air should be used initially to dry and cool the crop.

Celeriac will keep well into the New Year in an insulated store using ambient air conditioning. Such stores can be automated using a differential thermostat for efficient use of ambient air temperatures. Refrigeration is essential for longer-term storage with temperatures between 0 - 1°C.

9.6.3 Refrigerant specification

Some CFC refrigerant gases can damage the ozone layer it they escape from the refrigeration plant. Refrigeration plant should comply with the provisions of the Montreal Protocol and the EU Directive 91/549 EEC on ozone depletants.

10 Pollution control and waste management

See Generic Standards and/or Generic Guidance Notes.

11 Energy efficiency

See Generic Standards and/or Generic Guidance Notes.

12 Health and safety

See Generic Standards and/or Generic Guidance Notes.

13 Conservation

See Generic Standards and/or Generic Guidance Notes.

Control Document No: 00019/09

Appendix 1 Typical application rates for nutrients

Major nutrient requirements (kg/ha)

The following P, K and Mg table is based on assessment of soil samples and originates 'Fertiliser Recommendations Reference Book 209 (2000) 7th Edition'.

Celeriac	**N, P, K or Mg Index**					
	0	**1**	**2**	**3**	**4**	**4+**
Nitrogen (N)	180	150	110			
Phosphate (P_2O_5)	250	200	125	100	50	Nil
Potassium (K_2O)	450	400	325	210	50	Nil
Magnesium	150	100	0	Nil	Nil	Nil

Note:

Nitrogen applications can be split 2/3 base then 1/3 top dressing in July/August.

The following table shows the ADAS classification of soil analysis results into Index values.

Nutrient Need	**Index**	**Phosphate mg/l**	**Potassium mg/l**	**Magnesium mg/l**
Essential	0	0-9	0-60	0-25
High response	1	10-15	61-120	26-50
Responsive	2	16-25	121-240	51-100
Some response	3	26-45	241-400	101-175
Little response	4	46-70	401-600	176-250
No response	4 +	71-100	601-900	251-350

Appendix 2 Nitrogen fertiliser adjustment

Fertiliser experiments in a range of vegetable crops in Holland have determined the total amounts of nitrogen (from available from the soil and applied fertiliser) above which crops do not respond. If soil-available nitrogen is known then fertiliser applications can be adjusted so that the total nitrogen lies at maximum crop response. The "N min" method attempts to indicate the nitrogen that has mineralised from organic matter and is available for crop uptake as nitrate or ammonium ions in the soil water.

Soil samples 0 to 60 cm depths are needed. If 25 subsamples from each soil horizon are taken from a maximum area of 4 ha, there should then be one bulked sample of 1 kg ready to be sent for soil "N min" assessment. It is important bulked samples are frozen if they are not immediately sent for analysis as increased temperatures (and thereby increased soil bacterial activity) might otherwise lead to a false reading.

Sampling needs to occur close to planting (2 to 3 weeks) but before soil cultivations. Sampling depth is 0 to 30 cm, as results from this soil layer show the best nitrogen fertiliser response correlation.

If animal manures are to be applied a period of 6 weeks should lapse between manure application and "N min" sampling. Top dressing manures onto a growing crop is not recommended.

The laboratory assessment should provide a report sheet indicating the nitrogen available as nitrate and as ammonium in ppm. Most report sheets also provide a conversion of ppm into a value of available nitrogen as kg N/ha. In case no such conversion is provided the following guide may be used:

For the sampled soil horizon (ie. 0 to 60 cm) add together the nitrate and ammonium ppm values to give the total available nitrogen in ppm for that horizon. Multiply the total available nitrogen ppm value by one of the following factors to result in kg available nitrogen/ha.

Dry sand **Dry peat**	**Moist sand** **Dry loam**	**Dry clay, Dry silt** **Moist loam, Moist peat**	**Moist clay** **Moist silt**
1.0	1.1	1.2	1.4

Note:

This table assumes a soil bulk density of 1.4, if the actual soil bulk density is markedly different from this multiply the total available nitrogen ppm value by the known bulk density then divide by 1.4. To calculate the nitrogen fertiliser requirement in kg N/ha, deduct the "N min" value from the desired level. A further mineral N sample should be taken prior to top dressing. Excess Nitrogen applications can lead to impaired storage.

An Approach To Target Values (published in Enveg News June 2000) for mineral N comes from German trials. The target value is made up from 1) expected N uptake of the crop, 2) necessary N min residue in the soil at harvest time, 3) expected net N-Min mineralisation. Thus: N Min target value at planting for a 20 ton/ha celeriac crop (0-60 cm soil depth) is 180 kg/ha. Note: this was under German growing conditions.

Appendix 3 Insecticides currently approved for use on Celeriac

Active Ingredient	Product Features	Harvest Interval [1]	LERAP Category	Hazard Rating	MRL (mg/kg)
PREFERRED					
pirimicarb [2]	carbamate insecticide	3 days	none stated	Harmful	0.5
lambda cyhalothrin [2]	a contact acting pyrethroid insecticide with anti feeding	14 days	A	Harmful	0.1
pymetrozine [2]	Pymetrozine	14 days	none stated	Harmful	0.2
ALSO APPROVED					
nicotine	a contact insecticide	2 days	none stated	Harmful	none set

Notes:

(1) or latest time of application.

(2) SOLA - see Appendix 6 for specific product and expiry date.

Not all formulations of each active ingredient may be currently approved for use on Celeriac. Check before use. Label recommendations are revised regularly, read a current label before use.

Appendix 4 Fungicides currently approved for use on Celeriac

Active Ingredient	Product Features	Harvest Interval	LERAP Category	Hazard Rating	MRL (mg/kg)
chlorothalonil [(2)]	protectant chlorophenyl fungicide	28 days	B	none stated	1
difenoconazole [(2)]	diphenyl-ether triazole protectant fungicide	21days	none stated	none stated	2
azoxystrobin [(2)]	systemic translaminar protectant stobuilurin fungicide	14 days	none stated	none stated	0.3
mancozeb [(2)]	protective dithiocarbamate	30 days	none stated	none stated	0.5

Notes:

[(2)] SOLA - see Appendix 6 for specific product and expiry date.

Appendix 5 Herbicides currently approved for use on Celeriac

Active Ingredient	Product Features	Harvest Interval	LERAP Category	Hazard Rating	MRL (mg/kg)
prosulfocarb (2)	thiocarbamate herbicide	14 days post-planting	B	none stated	0.5
Asulam (2)	carbamate herbicide	12 days post-planting	none stated	none stated	0.5

Notes:

(2) SOLA - see Appendix 6 for specific product and expiry date.

Control Document No: 00019/09

Appendix 6 Specific off-label approvals for Celeriac

Number	Product Name	Ingredients	Expiry
2738/08	Asulam ®	asulox	11/02/2011
1292/01	Aphox ®	pirimicarb	31/12/2013
1747/05	Phantom ®	pirimicarb	31/12/2013
1062/05	Plenum WG ®	pymetrozine	31/10/2011
2083/03	Bravo 500 ®	chlorothalonil	31/12/2013
0989/07	Cleancrop Rio ®	chlorothalonil	28/02/2011
0261/06	Plover ®	difenoconazole	31/12/2013
0731/06	Hallmark ®	lambda cyhalothrin	13/11/2009
1862/03	Amistar ®	azoxystrobin	31/12/2011
3777/07	Defy ®	prosulfocarb	31/12/2013
0384/06	Dithane 945 ®	mancozeb	31/12/2013
1288/07	Cleancrop Silo®	lambda cyhalothrin	13/11/2009

Notes:

The off-label use may only take place if all the conditions given in the "Notice of Approval" document; the product label and/or leaflet and any additional guidance on off-label approvals have been first read and understood. The conditions of approval given in the "Notice of Approval" are statutory and supersede any on the label that would otherwise apply.

All SOLAs are conditional on the extant approval of the specified product.

Control Document No: 00019/09

Appendix 7 Control Points: Celeriac

CS.54 **CELERIAC**

CS.54.2 You must monitor soil nitrates in the growing season

- Protocol reference: Section 6.1

CS.54.4 Micro / macro nutrient deficiencies must be identified by soil / leaf / tissue analysis where appropriate

- Protocol reference: Section 6.1

CS.54.6 Sticky traps must be used to assess carrot fly numbers

- Protocol reference: Section 8.10.1.1