Rotations for Organic Horticultural Field Crops

An agricultural or horticultural rotation is a succession of crops grown in sequence so that the same crop is not grown year after year on the same piece of land. As a general guide a horticultural rotation should ensure that a crop (or a crop from the same family group) is not grown on a piece of land more than once in every four years. For example, after a cabbage crop has been harvested no crop belonging to the brassica family, such as Brussels sprouts, broccoli or cauliflower, should be grown on the site for at least four years.

The main exceptions to this rule are either where a fertility-building crop such as grass/clover ley is grown for two or three successive years or where a perennial, e.g. asparagus or biennial crop is grown.

THE ROLE OF A ROTATION

A correctly designed rotation is essential for the long-term viability, biological and financial, of an organic horticultural system. The benefits of a good rotation are listed below:

- **Maintenance of soil quality**
  A well-managed rotation will help to maintain soil structure and improve aeration, requisite conditions for a balanced and healthy soil micro-organism population. A good rotation also improves the efficient uptake of nutrients by plants, and in the long term, avoids the over depletion of nutrients, thus reducing the need to apply composted manures and other permitted soil amendments.
- **Avoidance of pest and disease build-up**
  Rotations form the basis of pest and disease control in organic systems. Successful crop rotations prevent pathogen populations from building up. This means that pest and disease problems are avoided rather than allowed to develop into situations that could reduce yields and take considerable effort to deal with. In some cases a rotation may be the only effective method of dealing with a particular disease or pest.
- **Reduction of weed problems**
  Through growing different crops which have a range of planting, harvesting and cultivation times, a carefully designed rotation can reduce the build-up of weed species. In addition, through a particular growth habit or a requirement for specific cultivations, some crops themselves suppress certain weeds. If these are included in a rotation weed management is improved still further. Most weed populations are also reduced by the inclusion in the rotation of a grazed or regularly cut ley.
- **A spread of labour costs and reduced financial risk**
  An organic holding is normally divided up into different parcels of land that at any one time are either at different stages of a rotation or have slightly different rotations. This ensures that a variety of crops are grown on a holding in any one year, thereby spreading labour requirements. It also leads to some economic stability, as if one crop fails, income

can be gained from the remainder of the crops. However, the costs of extra machinery to enable a wider range of crops to be grown must also be taken into consideration.

THE STANDARDS

There is no single definitive rotation that will satisfy the needs and situations of all organic growers. Likewise, there is no particular sequence of crops set down in the organic standards that a grower must follow. However, the Soil Association Organic Standards do contain certain rules and regulations, which conform to EU Regulation 2092/91 and must be followed for organic registration. They are presented as a series of lists categorised into required, recommended and permitted practices, as well as a few prohibited practices, and together provide a sensible framework on which a successful and sustainable rotation can be designed.

During conversion

Before converting a holding to organic status growers will need to produce a cropping plan, including a proposed crop rotation that can be presented to the certifying body. The plan should cover the conversion period as well as the time when the holding is certified as organic.

One purpose of the conversion period is to build up soil fertility in preparation for cropping. According to Soil Association Organic Standards, where the land was previously under exploitative cropping the conversion programme must begin with a fertility-building phase. The exact length of this phase is not defined by the organic standards. However, since crops sown during the conversion period are not organic and must be sold on the conventional market, it is normal that the entire twenty-four month conversion period is used for fertility building. The ideal crop for this stage is a grass/clover ley.

There are occasions when it may be tempting to reduce the fertility-building period to less than twenty-four months. However, reducing the fertility-building period is not advisable, especially where the land was previously subjected to mono-cropping for several years, or on soils that do not have a high level of natural soil fertility or a naturally good structure. The use of shorter fertility-building periods is not commonly practised and there is little information available on its long term effects on the success of the rotation.

Using a longer fertility-building period will ensure that nutrient levels have more time to build up before the rotation enters the cash cropping phase. Upon being turned in, a ley releases an initial flush of nutrients into the soil. It also forms a reservoir of nutrients that are released more gradually over several years, helping to sustain the cash crops that follow. In addition, over time grass/clover leys encourage an improvement in the soil structure, so that the greatest benefits are achieved after a long fertility-building period.

Soil testing for pH and phosphate and potassium levels is a valuable tool to assess soil suitability for cropping. More extensive tests identifying organic matter and minor elements should also be considered.

Required Practices
Once the fertility-building phase is over the cropping plan has to be established. The SA standards require that certain principles are observed:

- **A balance must be achieved between fertility-building and exploitative cropping**
  Harvesting the saleable portion of cash crops inevitably results in the removal of nutrients from the soil and the system as a whole. These nutrients must be replaces, a process that is carried out by the inclusion of fertility-building crops in the rotation. Such crops, unlike the initial grass/clover ley, are likely to be in the ground for only a limited period. They include legumes, whose presence stimulate nitrogen-fixing bacteria to increase soil nitrogen levels, and crops, such as grazing rye, that are simply good at conserving nutrients which can be turned back into the soil to be exploited by a following crop.

  Fertility, in the form of composted farmyard manure and permitted fertilisers, should also be applied to a level that provides adequate nutrients to be utilised by the cash crops. Excessive amounts of nutrients in a leachable form should not be allowed to build up as they may get washed out of the soil instead of being used by crops. To avoid any problems nutrient-demanding crops should be grown just after such applications and after green manure crops.

- **Crops with differing root systems must be included within a rotation**
  Using crops with different root systems in a rotation helps to utilise nutrients at different depths in the soil, as well as maintain a good soil structure, manage weeds and stimulate soil organisms.

- **Rotations must include a leguminous crop to provide the balance of nitrogen in the soil for use by subsequent crops.**
  The roots of legumes are colonised by bacteria that take nitrogen from the air and convert it into a form that can be used by the growing host plants. Once the legumes are turned in this material is then broken down by soil micro-organisms, ultimately to be released into the soil in a form that other plants can take up.

- **Plants with similar pest and disease susceptibilities must be separated by an appropriate time interval**
  Many fungal diseases produce spores that survive in the soil or plant debris. In most cases, these spores only survive for a relatively short period of time and rarely for more than a few years. The build-up of most soil-borne diseases, therefore, can be prevented by growing non-susceptible crops for three or four years after a susceptible crop has been grown. If the time interval is sufficient, a disease can be eliminated altogether. Soil borne nematodes and pests, which inhabit the soil at some stage in their life cycle, can be avoided or at least controlled in the same way.

  Air-borne pests and diseases can also be avoided / controlled by the use of rotations. The diversity of crops associated within a rotation means that large areas of mono-cropping, which forms an easy target and a potential reservoir for disease and pest build-up, are restricted.

Recommended practices
The SA Standards also make a number of recommendations in regard to rotations. These are not obligatory, but in order to design a successful rotation they should be taken into consideration. Rotations should be designed in such a way as to:

- **Minimise the time that the soil is left uncovered by the maximum use of green manures where appropriate**
  More nutrients are leached from uncovered soil than from soil with a cover crop. This means that valuable soil nutrients can be lost and the soil's fertility depleted when the ground is bare, while at the same time creating a potential pollution problem elsewhere. It is much better to conserve nutrients within the system in the form of plant material, i.e. as a green manure, and then have it incorporated back into the soil at an appropriate time. In this way the nutrients are kept within the system to benefit the next cash crop.

- **Maintain or increase the organic matter levels in the soil**
  Fertility-building crops and other materials such as composted farmyard manure, gradually help to increase levels of organic matter in the soil. This is vital in the process of improving soil structure and also provides a reservoir of nutrients that gradually become available to the crops.

- **Vary weed susceptible crops with weed suppressing crops**
  Certain crops are more susceptible to weed infestations than others. Weed problems can be reduced if weed-susceptible crops, such as carrots or parsnips, are grown after crops that have the capacity to suppress weeds, such as potatoes.

Permitted practices
There are some situations where it is not possible to adhere strictly to all the recommended practices in the SA Standards, and in other circumstances the concept of a rotation is simply irrelevant. In recognition of this the SA identifies certain situations and allows them as "permitted practices". These are:

- **Intensive horticultural holdings that mainly rely on outside, but acceptable, inputs of nutrients such as composted farmyard manure**
  It is important that these units show that they are moving towards a system that is less reliant on outside inputs and are making maximum use of legumes and green manure crops in rotation.

- **Greenhouse production that includes mono-cropping or annual cropping of the same genus**
  Although this is true for most crops there are a few exceptions. Due to potential disease problems, all allium, brassica and potato crops must always be rotated (see prohibited practices).

- **Perennial crops such as orchards, vineyards and plantation crops**

- **Where edible plants and fruit are collected from natural areas**

Forests and hedgerows, which are sited within agricultural land that is under organic management, can be used to harvest edible plants and fruit. Within these areas rotations are obviously meaningless.

Prohibited practices

There are a number of practices that are strictly prohibited by the SA Standards. These are listed below:

- **Alliums, brassicas and potatoes must not be returned to the same land for 48 months**
  The 48 month restriction applies from planting date to planting date. This regulation is important as alliums, brassicas and potatoes are susceptible to certain serious pests and diseases, and a guaranteed break of at least four years will reduce the likelihood of a problem.

- **Continuous cropping of alliums, brassicas or potatoes in greenhouses**
  Except for these crops continuous cropping is permitted in protected cropping areas

- **Cropping systems that rely solely on outside inputs for nutrient supply, and weed pest and disease control**
  This regulation, of course, does not apply to situations defined in the permitted category

DESIGNING A ROTATION

Collection of information about the site

Before designing a rotation it is necessary to collect certain information about the site. This should include a full soil analysis that covers the composition of the soil e.g. proportions of sand, clay, silt, peat and loam; organic matter content of the soil; pH; and the soil's nutrient status (available and unavailable nitrogen, potassium, phosphorus, calcium, magnesium and trace elements). Annual soil analyses, carried out at the same time of year, can then monitor any changes that might occur to the soil in the course of the practised rotation.

The certifying body will normally suggest that a soil analysis is taken, and submitted along with the application, before conversion to organic status begins[1]

It is also important to know the history of the site. Information on how well different crops grow, whether there have been any particular pest and disease problems etc. can be very useful when designing a rotation that will suit the particular fields.

Consideration of market outlets

There is little sense in growing a crop, however well it fits into a rotation, if the harvested produce cannot be sold. Therefore, the market for each crop should be organised at the planning stage of a rotation. In addition, the type of market available might well influence the quantity and range of crops grown, which obviously has a bearing on the rotation. Typical outlets for organic produce are wholesale and marketing co-operatives,

[1] A nutrient budget may also be required in some cases (and in any case may be of value in designing a rotation).

supermarkets or a direct marketing system. Often a co-operative will need to know the acreage of the various crops a grower intends to grow each year, and cropping plans may need to be adjusted according to what the co-operative can market. As with the wholesale market the supermarket buyer will need to know the cropping plan. Continuity of supply within a specified period or season may be important.

If it is intended to direct market a wide range of crops, different varieties and successive sowings will need to be grown to supply the range of produce for as long as possible over the year. This can make rotation planning complicated, but the wide range of crops grown can also ensure that a more robust rotation for pest and disease management can be used.

Consideration of potential crops

Plants from the same family tend to be prone to the same pests and diseases. It is essential, therefore, that crops from the same family are not grown on the same site in successive years (see Table 1)

Table 1: Vegetable plant families

Beetroot Family	**Cucumber Family**	**Carrot Family**	**Cabbage Family**	**Pea & Bean Family**	**Lettuce Family**	**Onion Family**	**Potato Family**	**Grass Family**
Beetroot	Cucumber	Carrot	Brussels Sprouts	French bean	Chicory / endive	Garlic	Aubergine	Sweet corn
Spinach	Squash	Celeriac	Broccoli	Runner bean	Lettuce	Leek	Pepper	Grazing rye
Swiss chard	Courgette	Celery	Kale	Broad bean	Salsify	Onion	Potato	All grasses
Spinach beet	Pumpkin	Fennel	Cabbage	Pea		Shallot	Tomato	
	Marrow	Parsley	Swede	Clover				
		Parsnip	Kohlrabi	Lucerne (alfalfa)				
			Cauliflower	Lupin				
			Calabrese	Trefoil				
			Radish	Vetch / Tares				
			Turnip					
			Mustard					
			Oriental Brassicas					

Other important factors that should be taken into account include the different crops' nutrient demands, as well as their rooting depth. High nutrient-demanding crops should follow the fertility- building phase so that the best use is made of the first flush of available nutrients. Where possible, deep rooting crops should be alternated with shallow rooting crops, so that nutrients at different depths in the soil are utilised.

A further consideration is the expected harvesting time of particular crops as this inevitably influences the order of crops in a rotation. For example, autumn-sown crops need a site that is clear early enough in the summer / autumn to allow the necessary cultivations, thus these crops are restricted to following crops that are out by the summer. Conversely, summer-sown crops, such as winter brassicas, normally have to follow overwintered vegetables or green manures, which leave the land free earlier than any spring-sown crop.

In addition to harvesting time, the harvesting procedure is also a significant factor. For instance, field scale carrots require harvesting operations that, in a wet autumn, can churn the land up and so seriously damage the soil structure that a structure-building ley has to follow.

Green manure crops

Fertility-building green manures can be divided into legumes and non-legumes, and into one or more than one season growing period. See Table 2 for a list of fertility-building green manure crops.

Legumes: Legumes that can be used as a green manure include clover, vetch, trefoil, beans, peas and lucerne. These crops have an association with nitrogen-fixing bacteria in which nitrogen is taken from the air so that it becomes available to the crop and eventually to other crops via the soil. In addition, some legumes are particularly deep rooted so that they are able to extract nutrients from deep soil depths and improve drainage.

Provided they are not allowed to become over mature and seed, legumes break down relatively quickly once incorporated into the soil. They tend to start releasing nutrients in a form that is available to plants within two or three weeks of being turned in. It is preferable that the following cash crop, which should go in as soon as possible after incorporation to make best use of the newly released nutrients, is transplanted rather than sown. Transplants, do not need such a fine seedbed as drilled crops, and being more advanced, will be able to make better use of the nutrients. In addition, as green manures break down they release substances that can cause poor germination in drilled crops but which transplants are less susceptible to. Transplants can normally be planted three to four weeks after the incorporation of a legume green manure, however, if a drilled crop must follow a green manure it is advisable to wait at least five or six weeks before sowing.

Table 2: Examples of fertility building green manure crops

Crops suitable for one year fertility-building	
Suitable for over-winter	
Legumes	**Non-Legumes**
Red clover	Grazing rye
White clover	Ryegrass
Vetch	Mustard
Field Beans	Phacelia
Lucerne	Chicory

Suitable for summer	
Legumes	**Non-Legumes**
Red clover	Grazing rye
White clover	Phacelia
Vetch	Chicory
Field beans	Mustard
Lucerne	
Crimson clover	
Lupins	
Trefoil	

Crops suitable for two or more years of fertility-building	
Legumes	
Grass / clover ley	
Red clover	
White clover	
Lucerne	

Non-legumes: Non-legumes that may be used as green manures include grazing rye, phacelia, mustard, chicory and grass. These crops do not form an association with the nitrogen-fixing bacteria so will not increase the nitrogen content of the soil. However, they do keep the ground covered and take up nutrients that would otherwise be washed out of the soil. Grazing rye, which is especially good at doing this, grows relatively quickly in the autumn, making it a good overwintering cover crop. Once a green manure is turned in the nutrients it has taken up are released back into the soil for the following crop. Non-leguminous green manures tend to be more fibrous than legumes, which means that they are good at improving soil structure and that the nutrients they release become available over a longer period of time than with legumes. When grazing rye is used it is especially important to make sure that the ground is not left bare the following autumn.

A significant proportion of the nutrients released from its biomatter becomes available to plants at this stage, and unless there is a cash crop or another green manure in place to make use of the nutrients, they will simply be washed out and wasted.

As with legumes, it is better to follow a non-leguminous green manure with a transplanted crop rather than a drilled one. Apart from substances inhibiting germination it can be very difficult to create a seedbed suitable for drilling, especially after grazing rye where there is usually a huge quantity of material to turn in. The exception to this is probably overwintered phacelia. This crop tends to die back over winter or even freeze off altogether, which could be useful on a heavy clay soil where soil conditions limit the opportunity for cultivations in the spring. The drawback of phacelia is that its seed is expensive.

Undersowing: Normally, undersowing is only recommended for cereals, and white clover is usually used as it is less competitive with the crop than red clover. In an autumn-sown crop the clover is generally sown at around the same time as the cereal. For a spring crop the clover is sown later than the cereal when soil temperatures have warmed up. Although the clover does not grow much while the cereal crop is present, it helps to keep weeds down

and once the cereal is harvested the clover is already established and will produce a good ground cover by the autumn. This system is a useful way of establishing an overwintering clover crop while keeping the number of cultivations required to establish clover to a minimum.

Example Rotation

A typical rotation that might be employed on a horticultural holding selling its crops on the wholesale market might start with a 2 year fertility-building crop, followed by a 3 year cash cropping phase. The cash crops could, typically, be potatoes or a brassica, onions/leeks and finally a deep-rooted crop such as carrots or parsnips.

Fertility-building phase: Where land is going into conversion to organic status, the fertility-building period should be for at least two years as this will coincide with the period required for conversion. Often a grass/clover ley on a stocked system will be grazed. If the holding has no stock the ley should be mown every three to four weeks during the growing season, at a cutting height of 12-15cm, and the mowings left to rot down. Regular mowing or grazing is essential to stop weeds setting seed and to maximise the genera; productivity of the sward.

Where land is already organic and under arable/horticultural production a one year fertility-building period for every three years of cash cropping may suffice. However, this system is only suited to well-structured soils, and green manures need to be fitted in between cash crops wherever possible e.g. over the winter. This type of rotation is also likely to require supplementation with composted manures.

A rotation that relies solely on fertility-building crops for nitrogen supply will probably need a longer fertility-building phase, for example two years of grass/clover ley followed by two or three years of cash cropping (and short term green manures wherever possible), then returning to two years grass/clover ley.

Cash cropping phase: After the fertility-building phase cash cropping can begin. Normally a high nutrient-demanding crop, such as potatoes or a brassica, is grown after the fertility-building phase. Being demanding these crops will be able to make the best use of the large amounts of nutrients that become available when the ley or green manure is first turned in. Due to their growth habitat and the cultivations they require, potatoes are also good at keeping the land free of weeds.

The second crop will usually be a vegetable that can make use of some residual fertility and can benefit from the weed clearing abilities of the previous crop e.g. onions, leeks.

The last crop in the rotation is usually a low nutrient demanding crop e.g. carrots or parsnips.

When the rotation has completed one full cycle it should return to a fertility-building crop.

Planning a rotation

It is useful to draw out a year planner to cover a full cycle of the rotation. Divide the years up into months and mark in when particular crops are to be planted and harvested. It is then possible to see at a glance if the rotation is going to be feasible or if certain cropping sequences will be impossible to follow because the previous crop is not out of the ground. Another problem to look for is whether there are excessively long gaps between crops. Some gaps can be usefully filled by growing a green manure, but longer ones might indicate that the rotation is too generous and needs to be altered. It is also important to bear in mind that the rotation is not written in stone, it continually has to be adapted to take into account the demands of the market, pest and disease problems or nutrient balance.

If the land is in conversion, mark in the planner when the land reaches full organic status. It is then possible to check that crops you intend to market as organic will in fact be planted after that date.

Nutrient budgets and soil types
Nutrient budgets can give a rough indication of whether a rotation is balanced in terms of the nutrients by estimating the nutrient gains and losses of a particular rotation. Once the gains are set against the losses the rotation can be adjusted to make the figures balance or manures and allowable fertilisers can be applied to correct any deficiencies. The values and figures, however, in a nutrient budget are not precise and the results need to be treated with caution – the main purpose of nutrient budgets is to identify differences between rotations rather than quantifying precise shortfalls / fertiliser requirements. If it is necessary to know the precise nutrient status of a soil specific analyses should be used.

Financial budgets
In a similar way that nutrient budgets are used to calculate the feasibility of a rotation in terms of nutrients, a financial budget can be used to compare the financial returns from different rotations. The simplest way to do this is to use Gross Margins (output minus variable costs). See *Organic Farm Management Handbook* for more details.

As important as the financial budget is, there is little point in examining the financial implications of a rotation if it is not first balanced nutritionally. The ideal is to maximise financial returns from the rotation at the same time as maintaining the nutrients in balance.

Labour and machinery demands
Demands on labour and machinery must be considered when planning a rotation. Organic holdings require constant management, and more than anything, operations need to be carried out in a timely fashion. Rotations, therefore, must be planned so that labour requirements for the major tasks can be managed as far as possible in a co-ordinated manner. Drawing out a year planner of the whole holding for each year of the rotation should identify any potential labour requirement clashes.

Balancing the range of crops
Having planned out a rotation that fits all the biological, financial and labour / machinery demands the rotation must be put into practice. The holding needs to be divided into appropriate areas / fields. In practice, a rotation is easiest to plan and manage if the holding is divided into the same number of areas as there are years in the rotation. For example, a four year rotation will work best if the holding is divided into four areas, or multiples of four. With this system different areas of the holding will be at different stages of the same rotation at any one time so that the full range of crops are always being grown at any particular time.

It is uncommon for all the land on a large horticultural holding to be converted to organic status at the same time. Usually, just a third or a quarter of the land is targeted in any one year. As a result converting farms can adjust to the system of staggered rotations quite naturally. However, the restrictions of parallel cropping should be noted if the conversion is staggered and the farmer wishes to grow the same variety of a crop organically and conventionally. Smaller horticultural holdings may enter conversion all at once, and the rotation has to be planned accordingly.

In some cases certain parts of a holding need to follow a different rotation in order to balance the acreage under fertility-building crops with cash crops and to achieve the right balance of crops for marketing. To check this, consult a year planner for each area/field for at least two full cycles of the rotation. Work out how much acreage will be down to a particular crop in any particular year.

Monitoring the rotation
All rotations require constant monitoring, not just for nutrient status but also for subtle soil structure changes that may indicate a deterioration in the soil conditions. Symptoms that may reflect a problem include gradual changes in the land, for instance, staying wet for longer, more passes required to make an adequate tilth, compaction at deeper layers, and fewer earthworms being found in the soil. Deterioration in soil conditions means that the rotation is not sustainable and must be reassessed.

Likewise, the workability of the rotation, in terms of compatibility of the crops, marketing needs, demands on labour etc. must be continually be assessed. Rotations are not set in stone and if circumstances change or the rotation needs to be adapted to solve a problem that develops, then it should be altered as necessary.

ROTATIONS FOR DISEASE, PEST AND WEED CONTROL

Rotations for disease control
Many fungal and bacterial diseases either persist on plant debris or can survive in the soil as spores or in a free living state. Rotations can help to reduce the levels of many diseases and, in some cases if the rotation is long enough, cause the disease to die out completely. If there is no history of a particular disease on the land or if the known diseases can be relieved by a break of three or less years, then a four year rotation will be sufficient to prevent the build-up of diseases. However, some disease pathogens, such as club root and white rot, are long

lived and an extended rotation or even elimination of the susceptible crop from the rotation will be necessary. If these diseases arise in an established four year rotation the easiest way to deal with them is to substitute the susceptible crop with a non-susceptible one. For example:

Original rotation: Year 1. Fertility building
Year 2. **Cabbage: club root develops**
Year 3. Onion
Year 4. Carrot

Modified rotation: Year 5. Fertility building
Year 6. Potato
Year 7. Onion
Year 8. Carrot

Year 9. Fertility building
Year 10. **Cabbage**
Etc.

If the farm is only divided into four sections or fields, and cabbage is still required every year a compromise is to divide the cabbage growing section in half and alternate between cabbage and a non-susceptible crop on each half.

For example: Year 1. Fertility-building
Year 2. **½ cabbage and ½ potato**
Year 3. Leek
Year 4. Carrot

Year 5. Fertility-building
Year 6. **½ potato and ½ cabbage**
Etc

All crops belong to a particular plant family such as the umbelliferae (carrots, parsley, fennel, etc.) and brassicas (cabbages, broccoli, swedes, etc.) In general, crops belonging to the same family suffer from the same pests and diseases. Therefore, crops from the same family should not be grown in succession, and, ideally should have a three or four year gap between plantings.

The families that various crops belong to is given in Table 1. Table 3 lists fungal and bacterial diseases that affect either plant families or individual crops and which research evidence shows can be controlled or reduced by rotations. Where possible the length of a break from a susceptible crop, to either prevent the problem arising or alleviate it if it is already present is also given.

Rotations for pest control

Some pests persist in the soil as cocoons cysts or larvae so, as with diseases, rotations can help in their control. In certain cases an extended rotation, in the same way as described for

diseases, might be necessary. Other pests tend to build up in grassland so crops susceptible to these pests should not be grown directly after breaking a ley.
Many soil-borne nematode pests can also be controlled by using rotations.

Table 4 gives a guide to the types of pest problem that can be alleviated by rotation.

Rotations for weed control
Rotations allow different types of cultivations to take place at different times of the year so that a particular weed species is less likely to become dominant. Alternating leafy crops, which compete well with weeds (e.g. brassicas and potatoes), with those that do not compete well (e.g. onions and carrots) or those which do not germinate quickly (e.g. parsnips) will keep weeds in check.

Grass breaks can also control weeds, especially those troublesome in horticultural crops. In addition, tight grazing the year before a ley is ploughed in can sufficiently weaken pasture weeds so that the subsequent ploughing and cultivations can eliminate them.

GRANT AID

Set-aside and fertility-building period
On arable farms where vegetables are grown it may be possible to claim set-aside payments, under the Arable Area Payments Scheme (AAPS), for land on which grass/clover leys are used for fertility-building. This can provide a valuable source of income from land which otherwise would not generate an income. There are, however, a number of key conditions:

1. To be eligible for registration for AAPS the land on which set-aside is claimed must not have been in permanent grass, permanent crops, woodland or non-agricultural use on 31st December 1991.
2. Set-aside land must be registered on an annual Area Aid application form to be completed by 15th May each year.
3. Each block of set-aside land must be a minimum of 0.3 hectares and at least 20m wide.
4. Land must be set aside from 15th January to 31st August, and restrictions on the use of set-aside land also apply during the period 1st September to 14th January.

There are different types of set-aside, and the rules tend to change annually. Therefore, it is best to contact your MAFF Regional Service Centre for further details. The most relevant to the organic grower are flexible set-aside and voluntary set-aside. Flexible set-aside allows a farmer to rotate a set percentage (fixed each year) of his AAPS area around the farm; voluntary allows the farmer to set aside up to 50% of his AAPS area, for a reduced payment rate.

It is permissible to sow a ley on set-aside. Registered existing organic or in-conversion growers are eligible to apply for an exemption to use more than 5% legumes (by weight in the seed mixture) in grass / clover leys. In this way even total legume mixtures, to build fertility, are a possibility within set-aside.

As a further concession, organic farmers can apply to transfer the eligibility of AAPS land around the holding. Contact your MAFF Regional Service Centre for more details on this, including transfer deadlines.

Organic Farming Scheme
Provided that the terms and conditions of both set-aside and the Organic Farming Scheme (OFS) can be fulfilled, land entered under the Organic Farming Scheme can also benefit from aid under the Arable Area Payments Scheme. Therefore, land can receive income from set-aside as well as organic aid.

It is worth investigating whether a grower can benefit from other schemes such as the Countryside Access Scheme, which offers additional payments for providing public access to set-aside land. It is important to check with your local MAFF Regional Service Centre, since the rates of payment, rules and regulations are constantly being changed.

CASE STUDIES

Following are three examples of rotations employed on actual organic holdings.

Case 1: Intensive horticultural with livestock

This is an intensive, 7ha holding, with approximately 50% down to grass and 50% in vegetables.

Basic rotation:
Year 1: Grass/clover ley 3-4 years, grazed by sheep and cattle
Year 2: Alliums: leeks and onions
Year 3: Brassica: cauliflower and Brussels sprouts
Year 4: Squash, celery
Year 5: Potatoes
Return to grass/clover ley

The land is divided into five parcels of land which, with a 5 year rotation, means that each parcel is at a different stage of the rotation.

The grower finds that potatoes fit well at the end of the rotation. They are harvested in August so that the grass/clover ley can be established that autumn. This is an important point, as establishing a spring-sown grass/clover ley has proved difficult on the holding. A further factor specific to the holding is that if potatoes were grown at the beginning of the rotation the higher yield likely to be produced would increase the need for specific harvesting and grading equipment, which the grower does not have, as well as better storage facilities.

Nutrients: In addition to the fertility-building grass/clover ley, composted cattle manure is applied to all the vegetable growing areas each year at a rate of approximately 10t/hectare. This is a common problem in the area and become apparent when the sheep suffered from pine disease.

Pests and diseases: No major pest or disease problem has occurred on the holding. Slugs, which can be a problem when it is wet, are controlled by ducks that are also raised on the holding.

Weeds: The grass/clover leys and sheep grazing have controlled most weed problems, including chickweed. Docks are being dug out, and thistles chopped down and eaten by the sheep.

Market: The ideal rotation for the holding has been compromised to include vegetables for which there is a market. The grower would like to grow a legume in the rotation and has tried green beans. However, the market for these was limited so the grower had to drop them. As the market for squash is also limited the grower plans on replacing it with red clover.

Labour: The grower feels that labour considerations are an important factor in the development of a workable rotation, and was the reason for modifying an earlier rotation. The current rotation, with crops chosen for their differing labour demands at different times of the year, was designed to fit in with the labour available on the farm.

Case 2: Existing organic livestock holding with new vegetable unit

Approximately 75% of the produce is sold to wholefood shops, the remainder is sold through the grower's own box scheme. Since the farm has livestock, it has its own supply of composted cattle manure. The rotation is primarily for pest and disease avoidance rather than for fertility.

Basic rotation:

Year 1: Long established grass/clover ley plus 20 t/ha composted cattle manure
Year 2: Potatoes
Winter Leaf crop (e.g. Chinese salads or spinach) followed by 20t/ha composted cattle manure / winter green manure (50% vetch: 50% grazing rye)
Year 3: Carrots / parsnips
Composted cattle manure applied at approx. 20 t/ha
Year 4: Squashes / courgettes / leafy salads / brassicas / onions etc

Return to fertility crop, which is on year of green manure or grazed grass/clover ley for 3 to 4 years, depending upon nutrient status of soil.

Pests and diseases: The rotation has only been practised for four years, and so far there have been no problems.

Weeds: Weeds, also have not caused any problems so far. The carrots and parsnips, which are probably the most vulnerable to weeds, follow the potatoes as they clear the land of weeds.

Use of green manures: The grower aims to keep all the ground covered over the winter; either with a crop or green manure.

Soil type: The light, chalky soil of the holding tends to dry out by July / August, making it difficult to establish late over-wintered brassicas, especially cauliflower. Consequently, the range of cash crops that can provide ground cover over the winter is very limited.

Case 3: Large vegetable holding with access to dairy herd

Approximately 80ha of vegetables are grown each year though some are not on the main farm. A dairy herd and other livestock make use of any grazing or silage provided by the fertility-building period, the composted farmyard manure is returned to the land. This rotation has been in place for ten years.

Basic rotation:

Year 1: 3-5 years of a fertility-building crop such as a clover/grass ley or a lucerne/red clover/grass ley. Usually this is undersown in the spring with peas, corn or a mixture of both so that Arable Aid Payment can be claimed under the IACS (Integrated Administration Control Scheme).

(Then a choice of two rotations)

	A	B
Year 2:	Brassicas or potatoes	2 years of lettuce Alliums (mainly leeks), or squashes
Year 3:	Carrots	As above

Return to fertility-building crop.

After ten years most fields have been all the way through the rotation once and are on their second cycle. The rotation was planned primarily to accommodate crops that the farmer can sell, but it was then adjusted to deal with any potential pest, disease, weed or labour problems.

Nutrients: Usually vegetables are grown for two to four years before the land is returned to a fertility-building crop. The soil type and topography of the different fields on the farm vary tremendously and this tends to dictate the number of years the land is actually in vegetables.

Every spring each field is tested for N, P, K and pH so that lime or nutrients, in the form of slurry, composted farmyard manure or municipal compost, can be applied as required. The farmer likes to apply these materials little and often. Slurry is applied to the ley and to the field just after the ley has been ploughed in. It is then incorporated into the soil with the first cultivations so that the nutrients stay at the top of the soil.

Manures are applied before most crops on the lighter soils (some of which originally had a K index of 0, over a period of years the index has been raised to 2). Municipal compost is applied before carrots, and slurry or composted farmyard manure is applied to the soil before potatoes, brassicas, etc. Well composted free range chicken manure or cattle slurry is

used before a nutrient-demanding crop. As chicken manure contains a high proportion of readily available nitrogen it is only applied at 1-3 t/ha.

Some fields tend to lack potash, and sylvinite is applied when necessary to correct this. Approval must be sought from the Soil Association before this can be used. Liming is usually carried out after the potatoes if the soil analysis indicates that this is necessary. If phosphate levels are low in the soil natural rock phosphate is applied to correct this. Again, permission must be sought prior to its use.

Pest and diseases: The carrots often suffer from cavity spot, especially on the light free-draining soils, and it is thought that the pathogen harbours in the lucerne. However, the disease does not appear to be an increasing problem at present.

Weed control: Docks and other perennial weeds can be a problem in the leys. However, the farmer has found from experience that docks can be controlled by ploughing a ley in after a first cut of silage has been taken. This allows a planting of late brassicas and controls the docks. An early ploughing, followed by early potatoes, though, does not deal with the docks.

Markets: The farmer supplies a number of different markets, such as a box scheme (30-40%), supermarkets (25-30%), wholesale (10%), while the remainder is sold through various outlets including a farm shop.

Other comments: The farmer is a little concerned about the value of the lucerne/clover/grass ley. It does not appear to give as good structure as a clover/grass ley. In addition, it is not grazed by cattle, and sheep have a tendency to go lame if grazed on it. As it is cut for silage, farmyard manure need to be spread on the lucerne / clover / grass ley to make up for the nutrients removed.

Table 3: A guide to diseases that can be controlled by rotation

Crop	**Disease**		**Minimum break from susceptible crop (yrs) to prevent development of disease**	**Comments**
	Common name	**Latin name**		
Bean (broad)	Leaf stem & pod spot	*Ascochyta fabae*	4	Rotation helpful
Beans	Fusarium wilt	*Fusarium oxysporum*	4	Rotation helpful
Beetroot	Canker	*Phoma betae*	2-3	Rotation helpful
Beetroot	Grey mould	*Botrytis cinerea*	2-3	Rotation helpful
Beetroot	Scab	*Streptomyces scabies*	2-3	Rotation helpful
Brassicas	Light leaf spot	*Pyrenopeziza brassicae*	4	
Brassicas	Ring spot	*Mycosphaerella brassicicola*	2-3	Rotation helpful, but removal of debris is a better system

Brassicas	Club root	*Plasmodiophora brassicae*	7-10	4 yrs reduces chance of new infestations
Brassicas	Black leg	*Phoma lingam*	3	
Brassicas	White blister	*Albuga candida*	2	Rotation helpful but removal of infected debris is more important
Brassicas	Black rot	*Xanthomonas campestris*	2-3	4 years is necessary if an infection occurs
Carrots and red beet	Violet root rot	*Rhizoctonia solani*		Long rotation helpful (7+ yrs)
Celery	Leaf spot	*Septoria apiicola*	4-5	Rotation helpful
Cereals and grasses	Take-all	*Gaeumannomyces graminis*	1	Different strains attack different cereals
Leek	White tip	*Phytophthora porri*	5	Long rotations needed
Onion family	White rot	*Sclerotium cepivorum*	4-8	If an infestation occurs a break of 20 years is necessary
Onion	Downy mildew	*Peronospora destructor*	4-5	Resting spores survive long periods
Onion	Neck rot	*Botrytis allii*	2	Rotation helpful
Pea	Foot rot	*Ascochyta pinodella*	4	Rotation helpful
Pea	Downy mildew	*Peronospora viciae*	4	Rotation helpful
Potato	Powdery scab	*Spongospora subterranea*	7	4-5 years for prevention
Potato	Dry rot	*Fusarium spp*	4-5	
Potato	Stem canker / black scurf	*Rhizoctonia solani*	7+	Long rotation helpful
Potato	Sclerotinia	*Scerotinia spp*	4	Rotation helpful
Potato	Verticillium wilt	*Verticillium spp*	4	Rotation helpful
Potato	Watery wound rot	*Pythium ultimum*		Rotation helpful
Potato	Pink rot	*Phytophthora erythroseptica*		Long rotation helpful
Many vegetables and cereals	Seedling blights Foot & root rots	*Fusarium culmorum and other Fusarium species*	4	
Many species of brassica	Cabbage yellows etc	*Fusarium oxysporum*	5	
Many vegetables	Brown spot blight	*Pseudomonas syringae*	2-3	Different strains attack different crops
Many species e.g. lettuce, celery legumes carrots	Sclerotinia disease	*Sclerotinia sclerotiorum*	4	

Table 4: A guide to pests that can be controlled by rotation			
Crop	**Insects**		**Comments**
	Common name	**Latin name**	
Brassicas	Flea beetle	*Phyllotreta spp*	Rotation helpful
Cabbage	Stem weevil	*Ceutorhynchus quadridens*	Rotation will reduce pest build up
Carrots and family	Carrot fly	*Psilae rosae*	Rotation helps. Avoid growing early & late carrots in close proximity as provides overwintering bridge
Celery, parsnip, parsley	Celery fly	*Euleia heraclei*	Rotation helpful – at least 1 year
Cereals	Saddle gall midge	*Halodiplosis marginata*	2 years as a minimum break
Lettuce	Root aphid	*Pemphigus bursarius*	Rotation helpful, but other cultural control methods are essential
Onions, leeks, shallots	Onion fly	*Delia antiqua*	Rotation helpful, do not grow crops near infested fields
Pea (& brassicas)	Pea thrip	*Angusticeps spp*	Rotation helps. Avoid following brassicas with peas
Potato (also wide range of other vegetables)	Wireworm (click beetle larvae)	*Agriotes spp athous spp ctenicera spp*	Rotation helpful (often a problem for first 2 years after breaking a long term ley)
	Nematodes		
	Common name	**Latin name**	
Onion	Onion eelworm	*Ditylenchus dipsaci*	2 years minimum break from susceptible crops
Pea, field beans, broad beans, vetches	Pea cyst nematode	*Heterodera goettingiana*	Minimum 4 yrs, preferably 7-8 yrs. Longer may be necessary in some fields
Potato	Potato cyst eelworm	*Heterodera rostochiensis & H. pallida*	3-4 yrs break for prevention. If an outbreak occurs a rotation of 6-7 yrs is necessary
Potato, tomato, eggplant	Potato cyst nematode	*Globodera rostochiensi & G. pallida*	Rotation helps prevent build-up but very long rotation required once present
Sugar beet and red beet	Beet cyst nematode	*Heterodera schachtii*	2 year minimum, 4-5 preferable
Oats, rye, sugar beet mangolds, field bean, pea vetch potato onion carrot parsnip	Stem nematode	*Ditylenchus dipsaci*	2 yr minimum break to prevent build up. Different strains attack different crops. Leafy brassicas & lettuce not affected, therefore are good break crops. 4-5 yrs needed to reduce infestation.

Useful reading

Crop Nutrition and fertiliser use
J. Arthur
Published by Farming Press, Ipswich
ISBN No. 0-85236-175-0; 1988 (2nd edition)

Irrigated crops and their management
R Bailey
Published by Farming Press, Ipswich
ISBN No. 0-85236-205-6; 1990

NIAB Organic Vegetable Handbook 1999
Published by the National Institute of Agricultural Botany, Cambridge
ISBN No. 0-948851-12-0; 1998

Organic Farm Management Handbook
Edited by Nic Lampkin and Mark Measures
Published jointly by the Welsh Institute of Rural Studies and Elm Farm Research Centre
ISBN No. 1-872-064-29-9; 1999 (3rd edition)

Organic Farming
Nic Lampkin
Published by Farming Press Books, Ipswich
ISBN No. 0-85236-191-2; 1990

Soil Management
DB Davies, DJ Eagle and JB Finney
Published by Farming Press, Ipswich
ISBN No. 0-85236-238-2; 1993 (5th edition)

The Control of Microbial Hazards: A Produce Industry Guide
Guidelines for the application of manures prior to growing a crop for fresh consumption obtainable from Fresh Produce Consortium; £25.00; Telephone: 01733 237 117

1999 Vegetable Variety Handbook
Published by the National Institute of Agricultural Botany, Cambridge
ISBN No. 1361-2069; 1999

The Soil Association runs a mail order book service with publications on a range of related subjects. For a free list please telephone 0117 914 2446 or send an email to sass@soilassociation.org

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