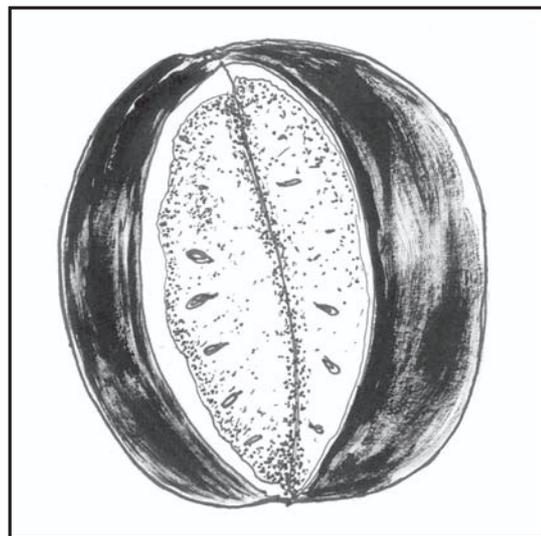
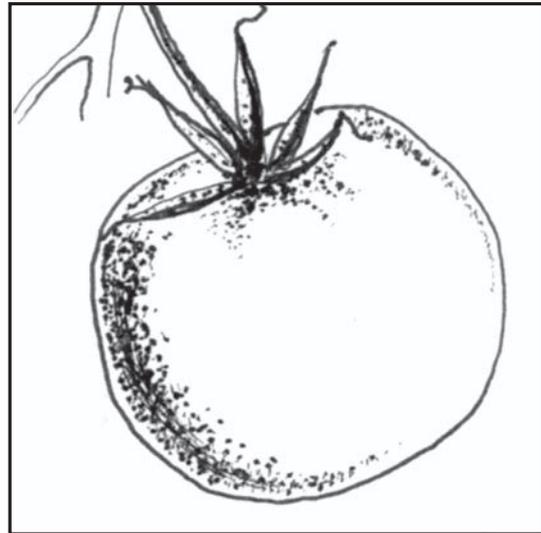
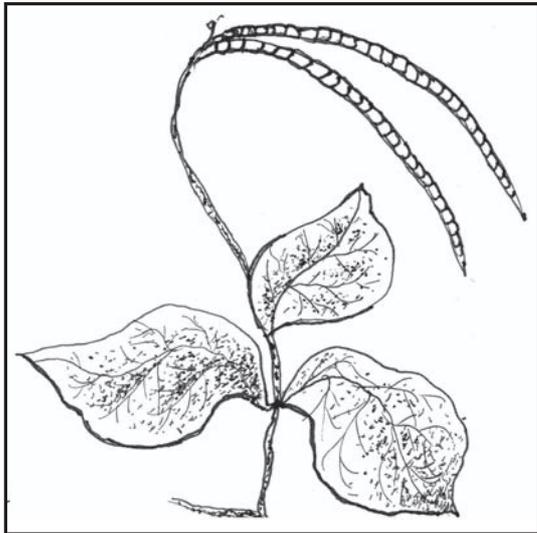


Rotations in Vegetable Production.



I. What is Crop Rotation?

Growing the same crops in the same site year after year will encourage a build up of pest and diseases and weeds in the soil and will reduce soil fertility. Therefore crops should be moved on a yearly basis in a rotation.

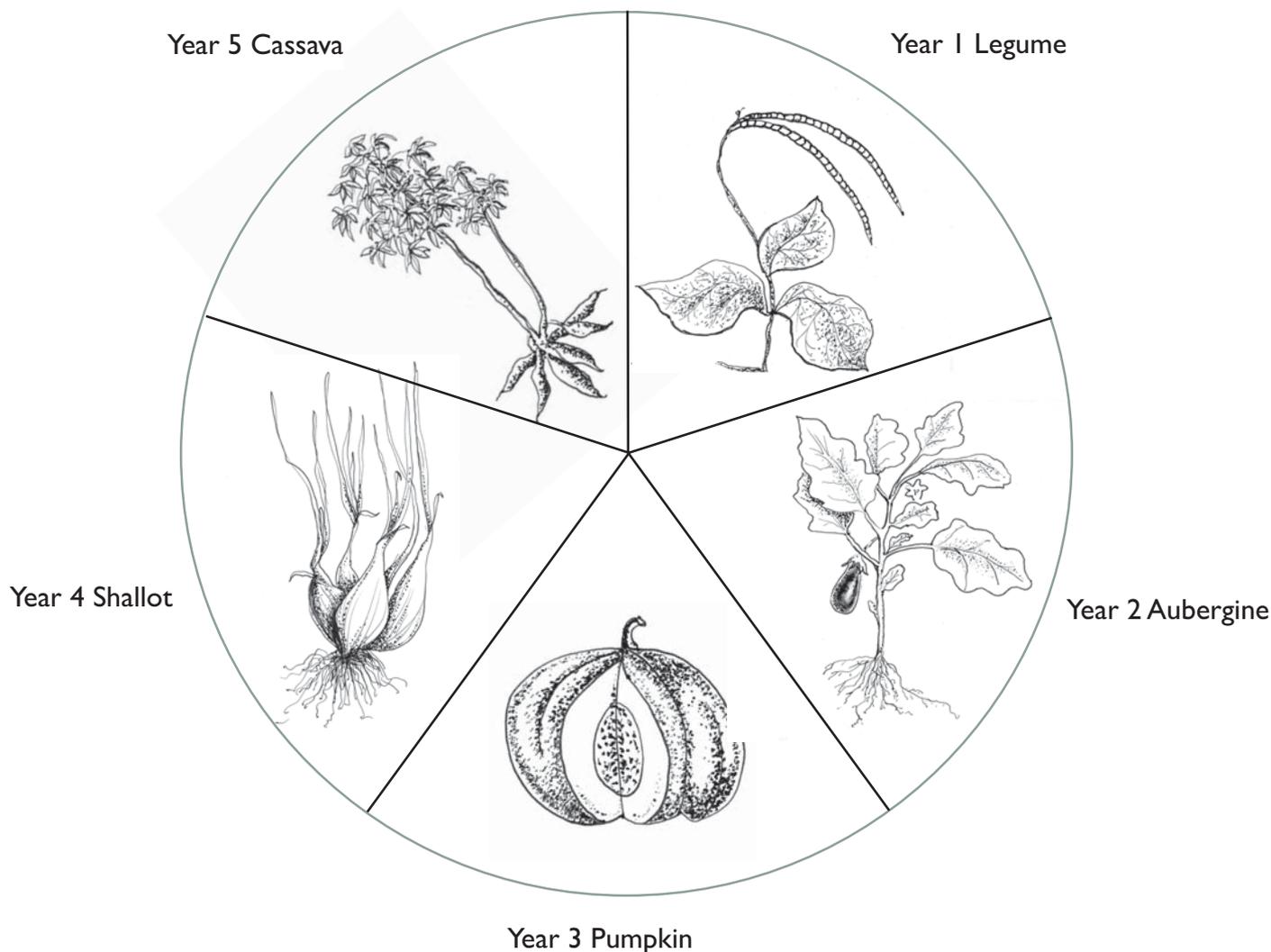
Diversity is key. It is important to encourage a range of soil fauna and beneficial organisms that will create a healthy soil and crops.

A rotation is a planned sequence of crops grown in different areas to avoid growing the same crop continuously in the same place. For vegetables a rotation of at least 4 years is usually recommended.

A typical rotation will include a fertility-building green manure (legume) that is grown to enrich the soil.

Intercropping (growing mixtures of crops) is often an important feature of low input systems and can be incorporated into rotations. This is discussed in more detail in section six.

The diagram below gives an example of a rotation.



2. Why are Crop Rotations Important?

There are three key reasons for planning a crop rotation:

1. Maintain soil fertility

Different crops have different requirements for soil nutrients so varying the crop every year prevents the soil fertility from becoming depleted. Green manure crops are also grown to restore the fertility of the soil and add organic matter to improve soil structure.

2. Avoid problems with pests, diseases and weeds.

Different pests and diseases prefer different crops, so a rotation prevents the build up of certain pests and diseases. The different cultivation techniques needed for different crop types can also prevent any one particular weed building up.

3. Diversity reduces the impact of crop failure

There is always the risk that a crop will fail. If a wide range of crops is grown, then the failure of one crop will have a much smaller impact than if only a few crops are grown.

3. Basic Principles of Rotation

Rotations must be planned to suit the local growing conditions and the demands of the local market. For example, it is important to plan your rotation with the pattern of rainfall.

Many locations in the tropics will have rainy and dry seasons. The timing of growing crops to fit with these seasons depends on the type of crop grown and whether water is available from another source. It is generally easier to grow crops during the wet season as they will not require extra water, but the rains can bring other problems such as:

- washing nutrients out of the soil
- forming a crust on the surface of the soil
- damaging seedlings (this can be avoided by building temporary palm shelters)
- increasing fungal diseases

There is not one set way of planning a rotation, but some general principles should be followed:

Grow green manures to build soil fertility.

A rotation has break periods when fertility-building leguminous plants (bean family) are grown to replenish the nitrogen in the soil. No income is made directly from growing them, but they are essential for making sure that all the other crops grow well¹.

Grow crops with different demands for nutrients.

Plants that have a high demand for nutrients should be grown soon after the soil fertility-building phase when the soil has high fertility. Plants can follow these that have less demand for nutrients when soil fertility is depleted. Lastly, legumes such as beans can be grown as a cash crop as these fix their own nitrogen.

¹ I see Green Manure booklet for further details (www.gardenorganic.org.uk/pdfs/international_programme/GreenMan.pdf)

Also different plants take up nutrients from different soil depths so growing a mixture of shallow and deep rooting crops allows different parts of the soil profile to be exploited. Information on depth of rooting of various crops is given in section five.

Leave a gap of at least three years between growing plants in the same family

Plants in the same family suffer from the same problems with pests, weeds and diseases, so growing a different family each year reduces the chance of them building up. *Solanaceae* (tomatoes, peppers, aubergines, irish or round potatoes) and brassicas (cabbages, cauliflower, pak choi, mustard) are the most susceptible to pests and diseases so it is **very** important that there is a gap of at least 3 years between growing these crops. For short term crops e.g salad, brassicas and spring onions, you can sow successional crops in the same year provided you still leave a 3 to 4 year gap.

Avoid leaving bare soil for long periods of time

When the soil is left bare, nutrients can easily be washed out, especially during the heavy rains in the wet season. If no crop is growing during this period, it is well worth sowing a short-term cover crop such as velvet bean as this prevents large amounts of fertility being lost from the soil.

Allow some flexibility in the system

Don't be too rigid with your rotation plan. If plants are showing signs of nutrient stress you may need to grow a fertility building crop earlier than planned. If a field in a rotation has a long standing weed problem, it may be necessary to change the plan to avoid growing weed susceptible crops there.

3.1 Economic Factors in Planning a Rotation

Are there markets for the crops?

If you are planning to sell the crop then do not start growing it unless you know you have a market for it. First check who is going to buy it from you when it is ready. Then find out when they need it and work backwards from there to when to sow and transplant it.

If many people grow a popular crop in one area, there is often a glut when everybody's crop is ready at the same time. This can drive the price down very low. This is particularly true of perishable crops such as tomatoes. Planning your rotation so that your crop is ready at a slightly different time to other people can lead to higher prices. For example, different varieties of a crop are ready at different times. However, growing at the extreme ends of seasons is often associated with higher risks.

Growing a proportion of crops that can be stored such as squashes, pumpkins and onions can spread the income so that there are fewer fluctuations in price.

Is labour available to deal with the busiest times?

The busiest times for growing crops are:

- Transplanting
- Early growth period – the crop will need most weeding during the wet season or most watering during the dry season
- Harvesting

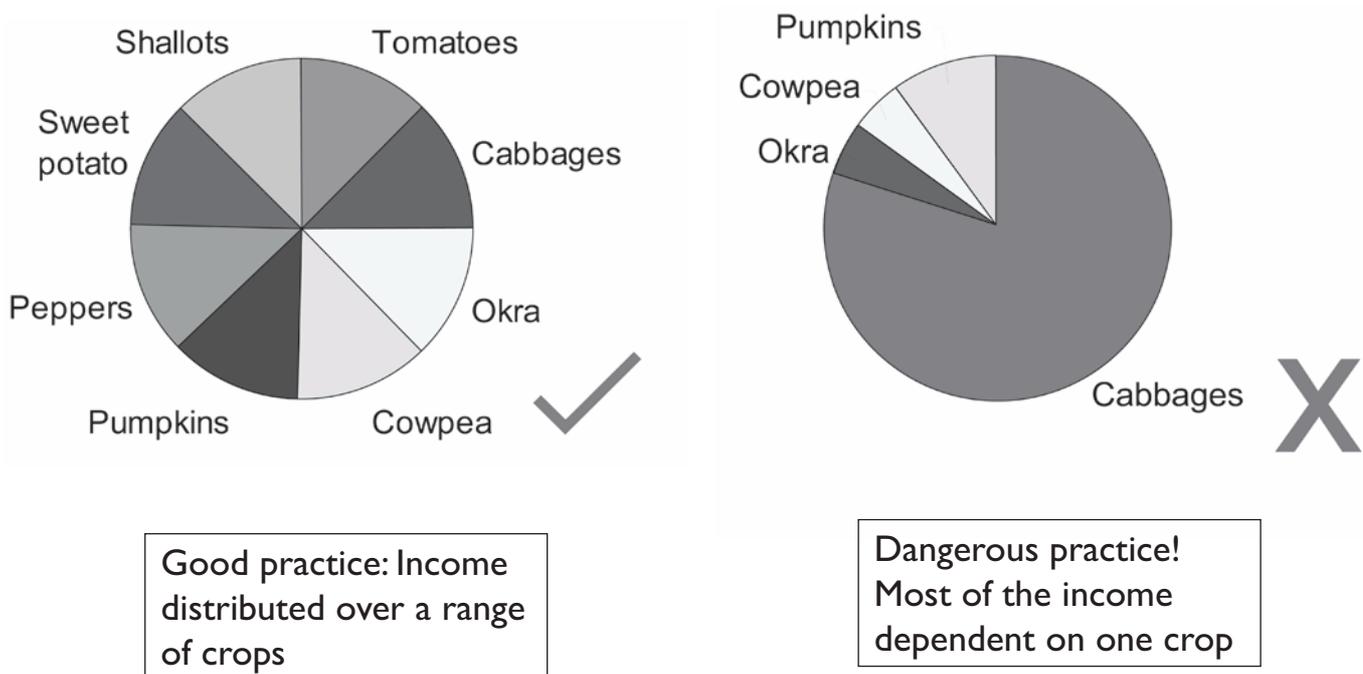
Ideally a rotation should be planned so that not all peak demands in labour happen at once, otherwise it can be difficult to keep on top of the workload. However, this is not always possible and if a number of peaks in labour demand happen at once, then extra labour may be needed. It is important to arrange this early.

The period after planting is particularly important for weed control, before the plants have covered the ground. Achieving good weed control during this period can mean the difference between a good yield and a disastrous crop.

Does the income from the farm come from a range of crops?

Some crops will be more profitable to grow than others. If one crop is particularly profitable, it can be tempting to grow a large area of it, but this is a very risky strategy because failure of this crop will result in a large reduction in the total income from the farm. It is wise to ensure that the total income from the farm comes from a range of crops.

Figure 1 Distribution of income throughout the rotation



4. Building and Maintaining Soil Fertility in the Rotation

Whenever a crop is grown, any parts that are harvested remove nutrients from the soil. Root crops in particular remove large amounts of nutrients from the soil, as a large bulk of material is harvested and taken away from the field. These have to be replaced or the fertility of the soil will decrease over time. Nutrients from the soil can be replaced by growing fertility-building legumes and by adding compost and manures.

Many soils in the tropics are low in nutrients as the more soluble nutrients such as nitrogen are washed out with the rains. Phosphate is very commonly lacking as it becomes locked up in a form that the plants can't use. The following section shows how to maintain soil fertility in the rotation.

4.1 Growing Green Manures to Replace Soil Nitrogen

A rotation will have a 'fertility-building phase' when no cash crops are grown and a green manure crop is grown to improve soil fertility and structure. Full details of green manure crops are detailed in the booklet (Green Manures / Cover crops) but some key points are listed here. Most green manures are leguminous (bean family) plants that form an association with bacteria in the soil (*Rhizobium*) that then fix nitrogen from the air. This is turned into nitrogen compounds that the plants can use. The plants are dug or ploughed into the soil which builds up soil fertility. A good green manure crop can add considerable amounts of nitrogen to the soil. They can be grown for any period from a few months to 4 – 5 years before being incorporated into the soil. It is important to prevent the green manure from flowering extensively; otherwise it becomes tough and woody, making it difficult to incorporate. Also if it is left to go to seed it may become a weed nuisance in later crops.

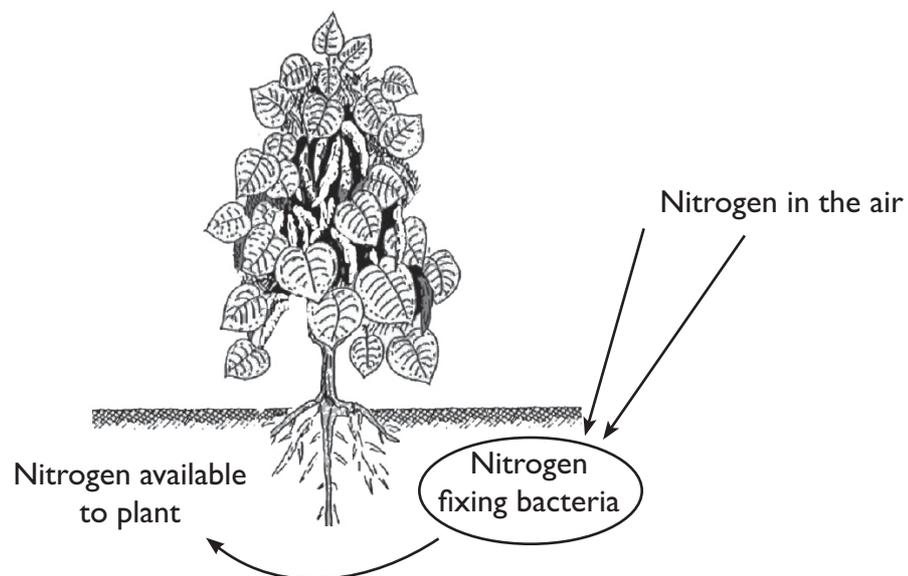


Figure 2 Nitrogen fixing crops

It is important to note that growing a legume where the beans are removed as a cash crop does little to improve the nutrient status of the soil. If a crop is allowed to produce seed, most of the nutrients are moved to the beans so these are removed when the beans are harvested. However, a bean crop does fix its own nitrogen so can be grown at the end of a rotation when soil fertility levels are low.

Short term legumes for fertility building.

A short-term green manure should be dug in just before it flowers, some examples are:

- Pigeon pea (*Cajanus cajan*).
- Jack bean (*Canavalia ensiformis*).
- Lablab (*Lablab purpureus*) is particularly suitable for the dry season.
- Velvet bean (*Mucuna pruriens*) forms a thick mat and can be used to protect the soil during the wet season.

Longer term legumes for fertility building

Longer term green manures should be mown or grazed, before they get to knee height, for example:

- Centro (*Centro pubescens*) does not become woody for 18 months so it can be used in longer-term fallows.
- Egyptian clover (*Trifolium alexandrinum*) regrows when it has been cut so can be used in longer term fallows.

Non legume cover crops with other useful functions

Although non-legume crops do not fix nitrogen, they can provide a number of other useful functions such as: soil cover, reduced leaching and improved soil structure. Good soil structure is essential for healthy crops and organic matter improves the health of the soil and reduces the amount of nutrient loss.

Mustards grow rapidly, provide good soil cover and prevent leaching. They are easy to establish and useful in a rotation of arable and root crops. However, since they are a brassica, they should not be grown in a rotation already containing other brassica vegetables such as cabbage and pak choi.

Buckwheat is rapidly growing, improves soil structure and can make phosphate more readily available.

Grass species are deep rooting and good for 'lifting nitrogen' out of lower profiles reducing leaching. The extensive root systems are good for building soil organic matter.

4.2 Replacing Nutrients through Additions of Compost and Manures

Growing green manures replaces nitrogen removed from harvested crops in the rotation, but other nutrients must also be replaced through applying compost or manure².

Many animal manures, especially poultry manure have high amounts of nitrogen in a form that is readily available to plants. These should not be applied before growing legumes, because they suppress the bacteria that fix nitrogen.

Composted plant waste is an excellent source of potassium and phosphate but most of the nitrogen is locked up in a form that will not benefit plants immediately.

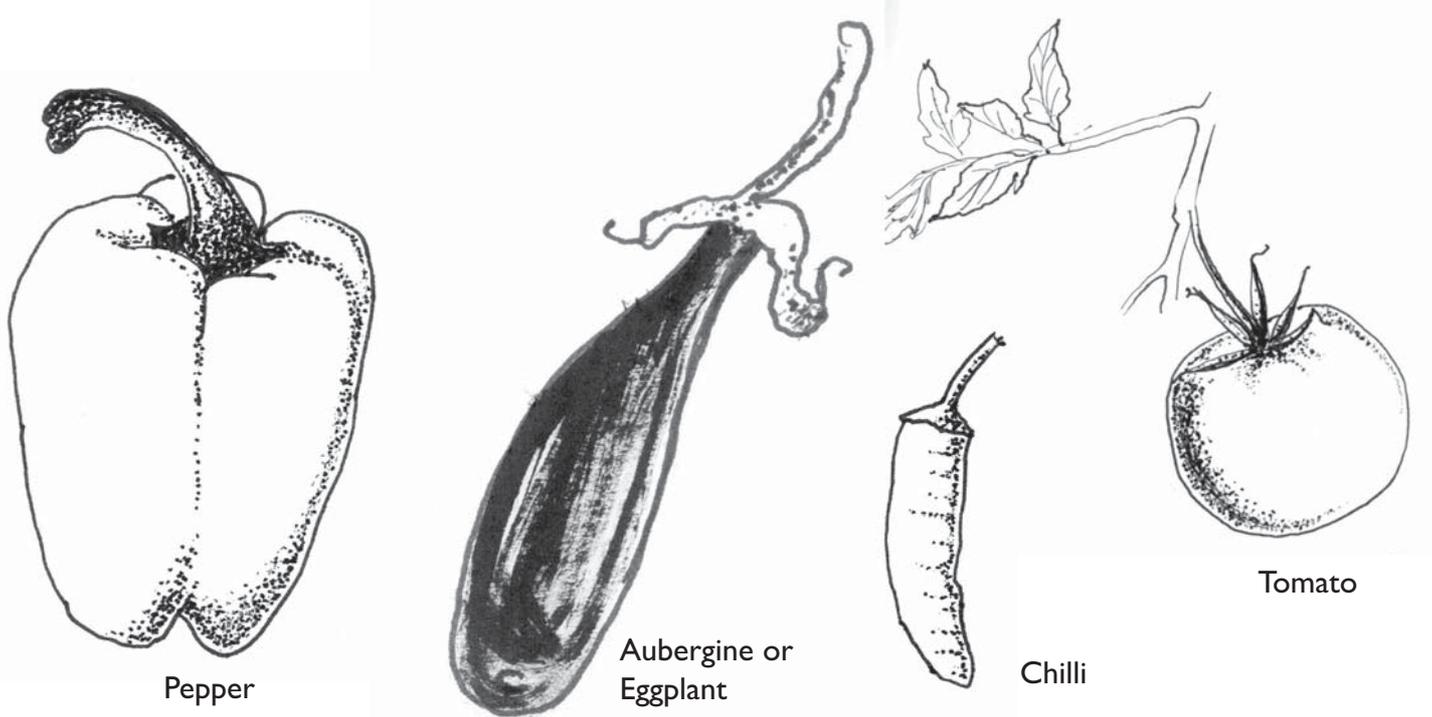
² More details on composting are in our booklet 'Composting in the Tropics'. (www.gardenorganic.org.uk/pdfs/international_programme/Compost102.pdf)

5. Arranging the Rotation by Plant Family

Plants from the same family should not be grown too often in the same place. Below is a list of the main families of vegetable crops and their requirements. Pests and diseases that can survive in the soil between crops are also mentioned as these affect when to grow certain crops in the rotation. Different plants take up nutrients from different soil depths, so it is good to have plants that root at different depths within the rotation.

5.1 *Solanaceae* (Tomato family)

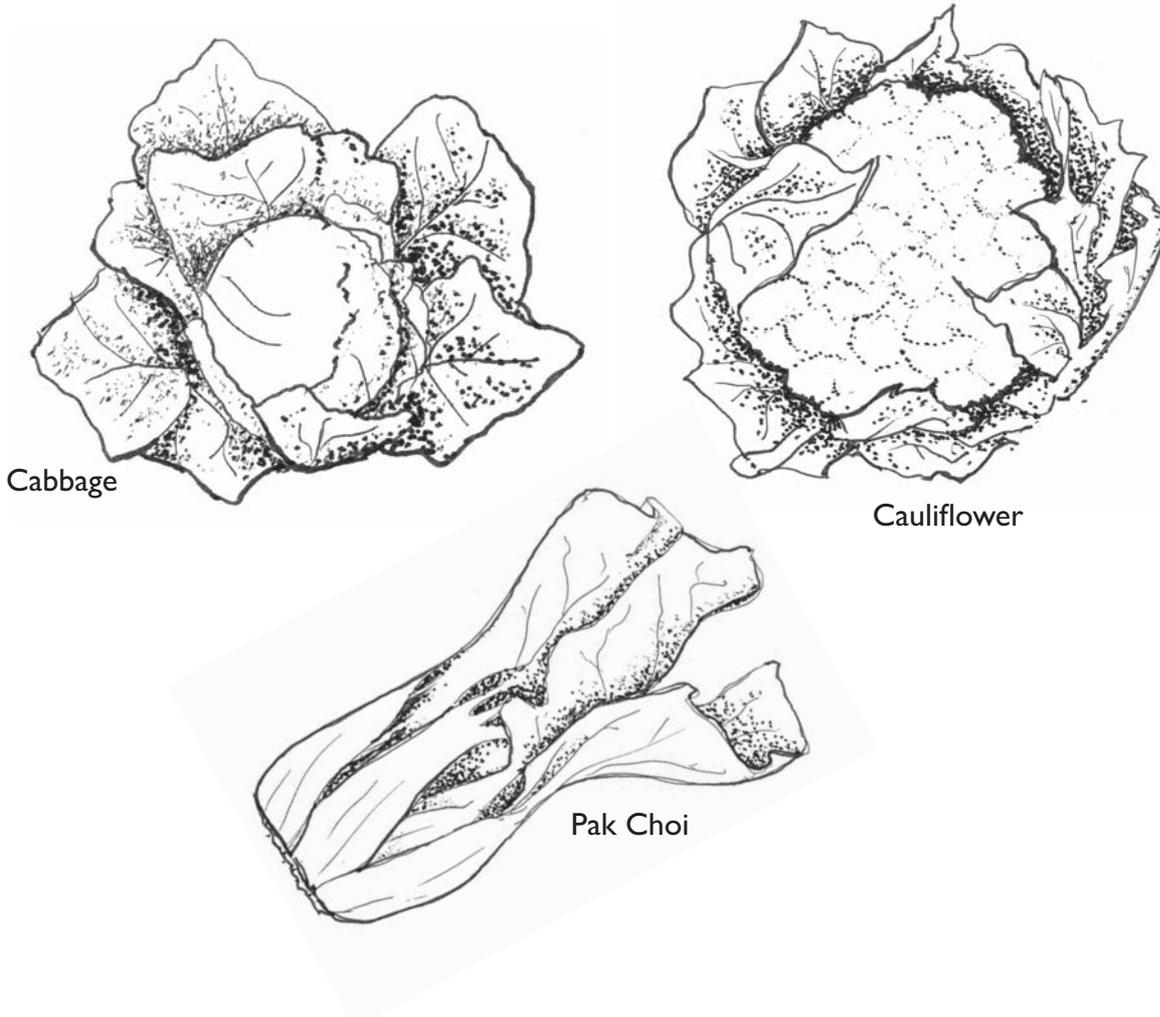
Solanaceae cover a wide range of crops that are popular to grow in the tropics. Once the plants are established, weed control is fairly easy. Regular watering after transplanting is more essential than with some crops so they are generally easier to grow in the rainy season, unless there is a reliable water supply. They also have the advantage that seed can be saved from open pollinated varieties.



Main crops	Rooting depth	Nutrient requirements	Soil borne pest and disease problems
Peppers	Medium	Need high levels of nitrogen and potassium for fruit formation and should be grown after a fertility building crop or applying compost. Animal manures, especially poultry are high in nitrogen. Levels of potassium can be boosted by adding well-rotted compost or small amounts of woodash.	These are one of the most disease susceptible groups of crops in the tropics so should not be grown in the same place for at least 4 years ie 3 years between crops. Continuously growing these plants in the same place often results in a build up of root knot nematodes (<i>Meloidogyne</i> spp.) - microscopic worms that infect the roots. Fungal diseases that live in the soil can also build up such as Fusarium (<i>Fusarium oxysporum</i>) or bacterial wilts (<i>Ralstonia solanacearum</i>).
Aubergines/ Eggplant	Medium		
Tomatoes	Deep		
Potatoes (Irish potatoes in cooler highlands only)	Medium		
Chilli pepper	Medium		

5.2 Brassicae or Cruciferae (Cabbage family)

These are a more recently introduced 'exotic' crop to many regions. Again weed control is fairly easy once they are established. Crops such as pak choi and cabbage have cultivars that can be grown in either the dry or the rainy season, although they will require some additional water if grown in the dry season. Many brassicas do not flower readily in the tropics, so seed has to be imported.



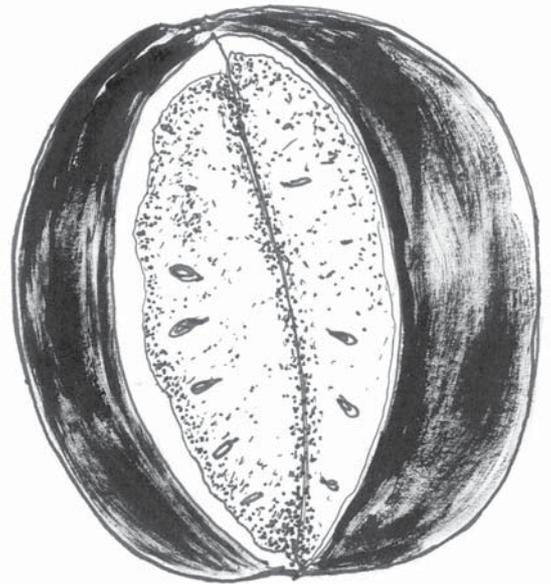
Main crops	Rooting depth	Nutrient requirements	Soil borne pest and disease problems
Cabbage (heat tolerant varieties)	Shallow	These need high levels of nitrogen and should be grown directly after a fertility-building crop. Levels of nitrogen can also be boosted by poultry manure. They grow best on heavier soils and need high levels of organic matter.	Brassicas are also very disease susceptible and should not be grown in the same place more than one year in five. The most serious soil borne disease is clubroot fungus (<i>Plasmodiophora brassicae</i>). This can remain in the soil for 20 years and once the land is infected, brassicas cannot be grown on this land for at least this length of time.
Pak Choi	Shallow		
Cauliflower (early heat tolerant varieties – grows better in cooler highlands)	Shallow		
Broccoli (early heat tolerant varieties – grows better in cooler highlands)	Shallow		
Mustard	Shallow		
Radish	Shallow		

5.3 Cucurbits (Cucumber family)

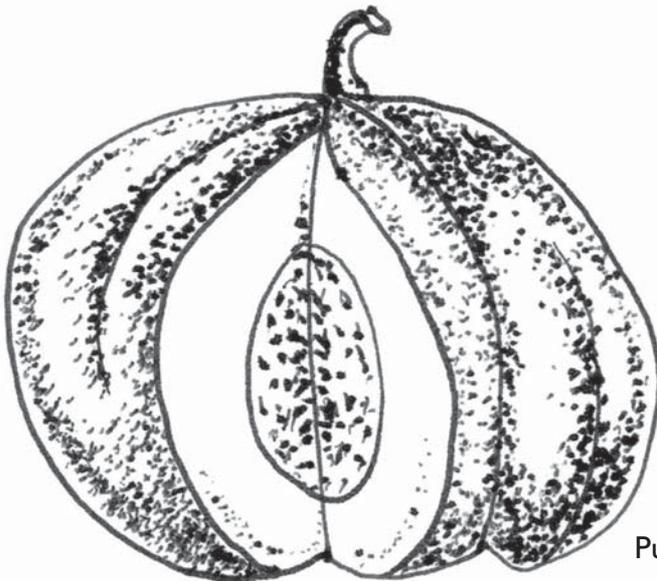
Cucurbits are generally easy to grow and with their rapid ground cover, require very little weed control. They have varying degrees of heat tolerance. Seed saving from open pollinated varieties is easy.



Pumpkin Plant



Watermelon

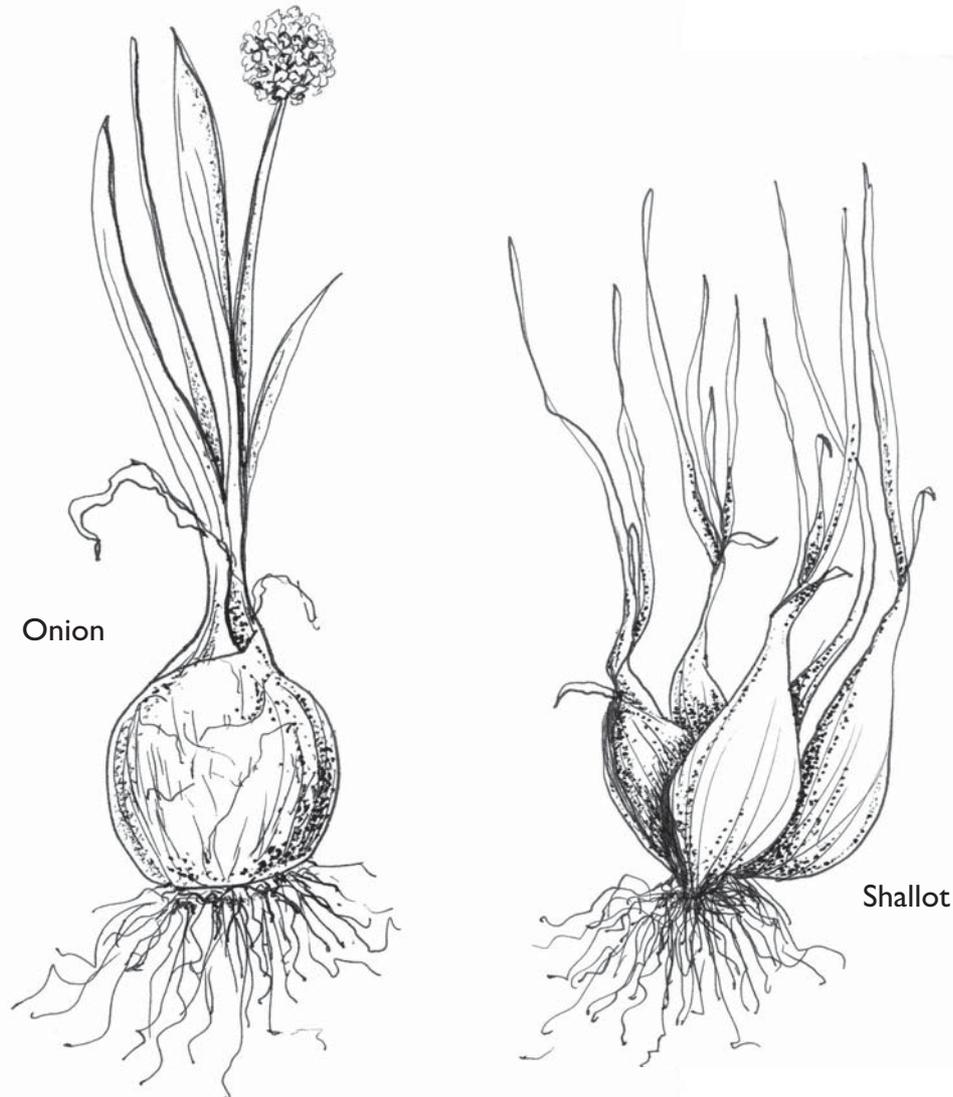


Pumpkin

Main crops	Rooting depth	Nutrient requirements	Soil borne pest and disease problems
Cucumber	Medium	These will generally grow with more moderate levels of nutrients so are a good second crop after fertility building (although cucumbers may need slightly higher levels). They need well drained soils with high organic matter content.	Soil diseases are less of a problem in cucurbits, although fusarium wilts (<i>Fusarium oxysporum</i>) can persist in the soil for many years. These are specific to each species.
Squash	Deep		
Courgette	Medium		
Pumpkin	Deep		
Melon	Medium - deep		

5.4 Alliums or Liliaceae (Onion family)

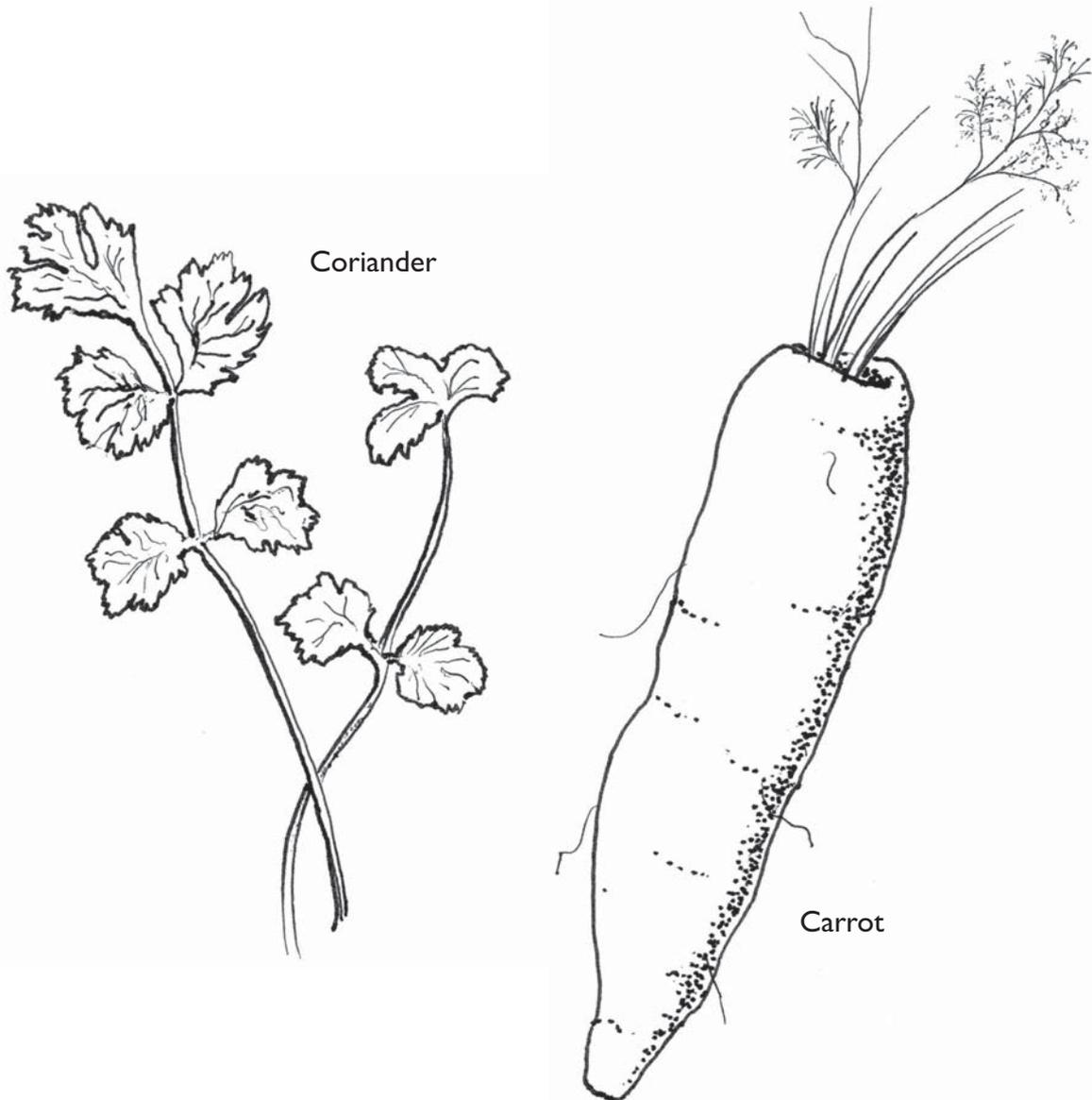
Most *alliums* require a good deal of hand labour for weeding and if the soil has always been weedy in the past, it is better to find something else to grow. In an onion crop, if labour is short, it is more essential to keep the early period (when the leaves are still growing) weed free, than trying to weed the crop later.



Main crops	Rooting depth	Nutrient requirements	Soil borne pest and disease problems
Onion (short day varieties essential at tropical latitudes, grows better in cooler highlands)	Shallow	These need more moderate levels of nutrients and too much manure can cause thick or double necks. They are best grown as a second or third crop in the rotation. Good drainage is essential.	Soil borne diseases are also less of a problem in alliums in the lowland tropics where the soil temperature remains above 20°C. At higher altitudes, where soil temperatures are consistently lower than 20°C, white rot (<i>Sclerotium cepivorum</i>) may become a problem. Once introduced, it can remain in the soil for at least 20 years. Onions and garlic are particularly susceptible, but growing alliums after brassicas can suppress white rot.
Shallot	Shallow		
Chive	Shallow		
Garlic	Shallow		

5.5 *Apiaceae* or *Umbeliferae* (Carrot family)

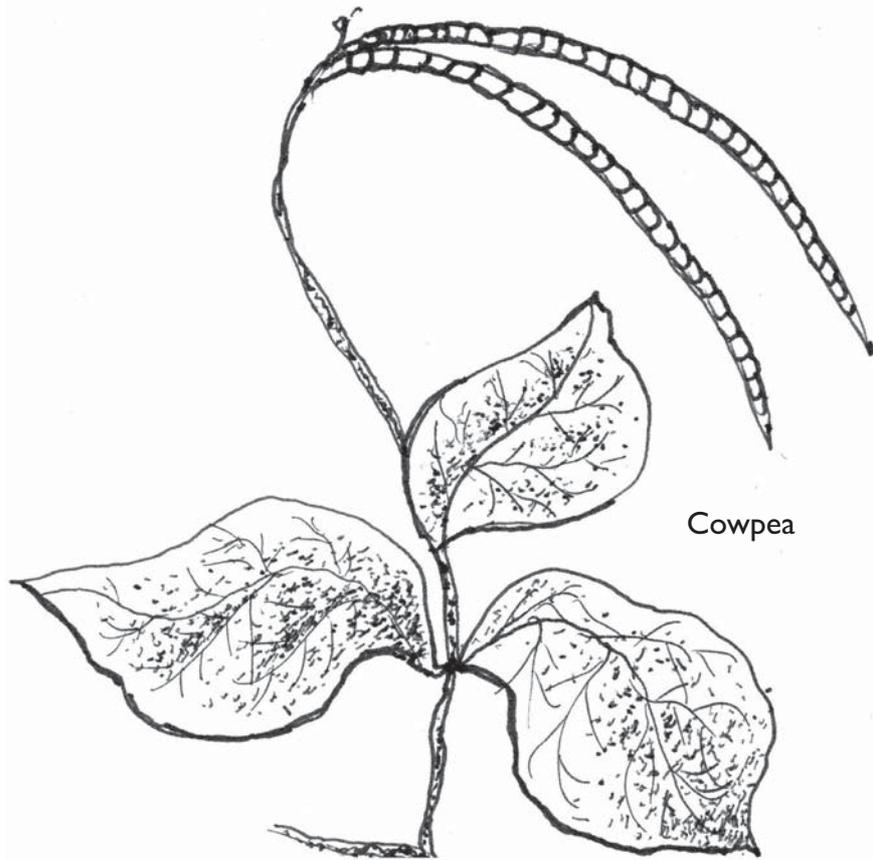
As most of these crops are sown directly into the soil and have fine feathery leaves, a large amount of hand labour for weeding is required, especially in the early stage of the crop.



Main crops	Rooting depth	Nutrient requirements	Soil borne pest and disease problems
Carrots (cool uplands only – will not germinate or form good quality roots in hot soils)	Medium	Carrots grow better with lower levels of nutrients – applying manure will cause them to fork. They are best grown as a second or third crop in the rotation.	Sclerotinia, violet root rot and cavity spot are all diseases that can affect carrots but are not a problem if not grown too often in the rotation. If there are already root knot nematodes in the soil, carrot roots will be disfigured and unmarketable.
Celery (leaves as a seasoning)	Medium		
Parsley	Medium		
Coriander	Medium		
Fennel	Medium		

5.6 Legumes (Bean family)

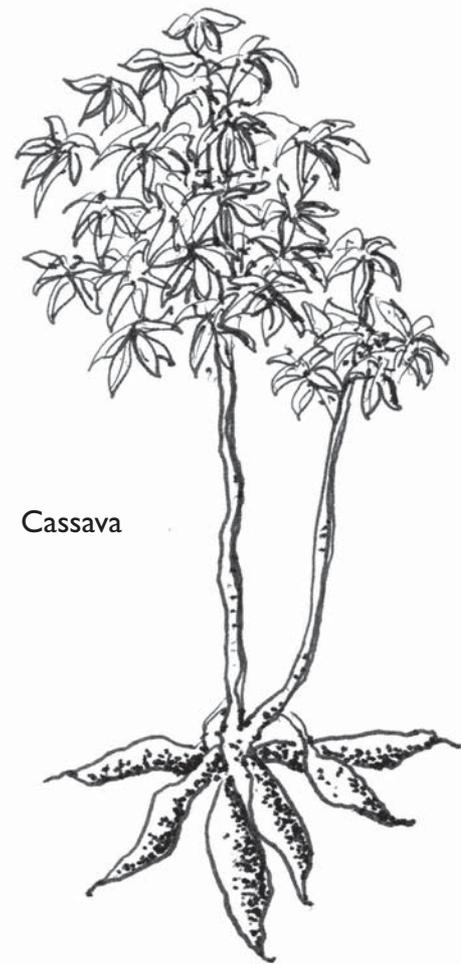
There are wide range of legumes available for growing in the tropics, both adapted to the wet season and the dry season (eg cowpea). Labour demand can be high for varieties that need tying up and for harvesting. Seed can be readily saved from open pollinated varieties.



Main crops	Rooting depth	Nutrient requirements	Soil borne pest and disease problems
Cowpea (Yard long bean, asparagus bean)	Medium	Legumes fix their own nitrogen so it is not necessary to add animal manures as this will just suppress the bacteria that fix nitrogen. The plants still require adequate potassium and phosphate which can be added through composted plant material or small amounts of wood ash. Contrary to popular belief, growing a bean as a cash crop does not increase the fertility of the soil as nearly all the nitrogen fixed is in the beans that are removed when the crop is harvested. It can be thought of as a 'nitrogen neutral' crop that fixes the nitrogen it needs. They are therefore are a good crop to have at the end of a rotation when soil fertility is not so high.	Most legumes are susceptible to attack by root knot nematodes. Many are also susceptible to a root rot fungus, <i>Fusarium oxysporum</i>
Pigeon pea	Medium		
Mung bean	Medium		
Chick pea	Medium		
Groundnut	Medium		
Lentil	Medium		
Many others			

5.7 Other leafy crops

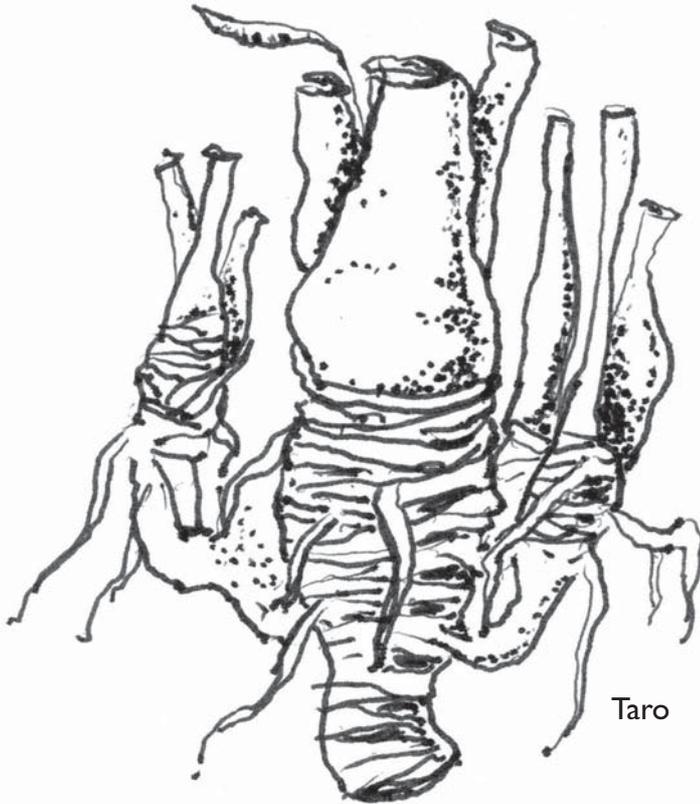
There are a wide range of locally adapted leafy crops that come from different plant families listed below. Many are harvested from other crops to provide a dual function.



Crops and family	Rooting depth	Nutrient requirements	Soil borne pest and disease problems
Spinach – (<i>Chenopodaceae</i> – cool season and other local types)	Medium	Exact nutrient requirements differ for each plant type but most require moderate levels of nutrients and can be placed as a second or third crop in the rotation.	
Calaloo (from Tannia) (<i>Araceae</i>)	Medium		Sclerotium root rot (<i>Sclerotium rolfsii</i>)
Cassava leaves (<i>Euphorbiaceae</i>)	Deep		Sclerotium root rot (<i>Sclerotium rolfsii</i>)
Pumpkin leaves (<i>Cucurbitaceae</i>)	Deep		Soil diseases are less of a problem in cucurbits, although fusarium wilts (<i>Fusarium oxysporum</i>) can persist in the soil for many years
Cocoyam leaves (<i>Araceae</i>)	Deep		Sclerotium root rot (<i>Sclerotium rolfsii</i>)
Corchorus (<i>Tiliaceae</i>)	Medium		Sclerotium root rot (<i>Sclerotium rolfsii</i>)

5.8 Root and tuber crops

There are a wide range of root and tuber crops that are well adapted to growing in the lowland humid tropics. These come from a range of families listed below:



Crops and family	Rooting depth	Nutrient requirements	Soil borne pest and disease problems
Yams – <i>Dioscoreaceae</i> family	Medium	Most of these require moderate levels of nutrients – too much nitrogen will usually encourage excessive leaf growth at the expense of root growth. These crops remove a reasonably large amount of potash from the soil when harvested. A free draining soil with good levels of organic matter is normally required. The exception is cocoyam which is more often grown in soils with high moisture levels close to rivers or streams.	Tuber rot (<i>Sclerotium rolfsii</i>) and root knot nematode
Cocoyams (eddoes or dasheen) – <i>Araceae</i>	Deep		Tuber rot (<i>Sclerotium rolfsii</i>) and root knot nematode
Sweet potato – <i>Convolvulaceae</i>	Medium		Sclerotial wilt (<i>Sclerotium rolfsii</i>) and root knot nematode
Tannia – <i>Araceae</i>	Medium		Sclerotium root rot (<i>Sclerotium rolfsii</i>)
Cassava – <i>Euphorbiaceae</i>	Deep		Sclerotium root rot (<i>Sclerotium rolfsii</i>)

5.9 Grasses and Cereals (*Poaceae* family)

There are a huge range of cereals that can be included as part of a vegetable rotation, and this topic will only be discussed briefly here. In low input systems they tend to be put to a wider range of uses than just harvesting the grains. Straw is used as a building material or fed to animals or sometimes the whole crop may be harvested as an animal feed or dried as silage. Most cereals will yield poorly if placed at the end of a rotation when soil fertility is low, so the placement in the rotation is often dependent on how important the yield of the cereal is relative to other crops.



Crops	Rooting depth	Nutrient requirements	Soil borne pest and disease problems
Maize	Medium	Requires reasonable level of water and nutrients	Suffer from some soil borne disease problems such as sclerotinia and some species of root knot nematode.
Sorghum	Deep	Will yield in drier climate on poorer soils than maize	
Millet	Deep	Most drought tolerant of cereals	

6. Intercropping and Rotations

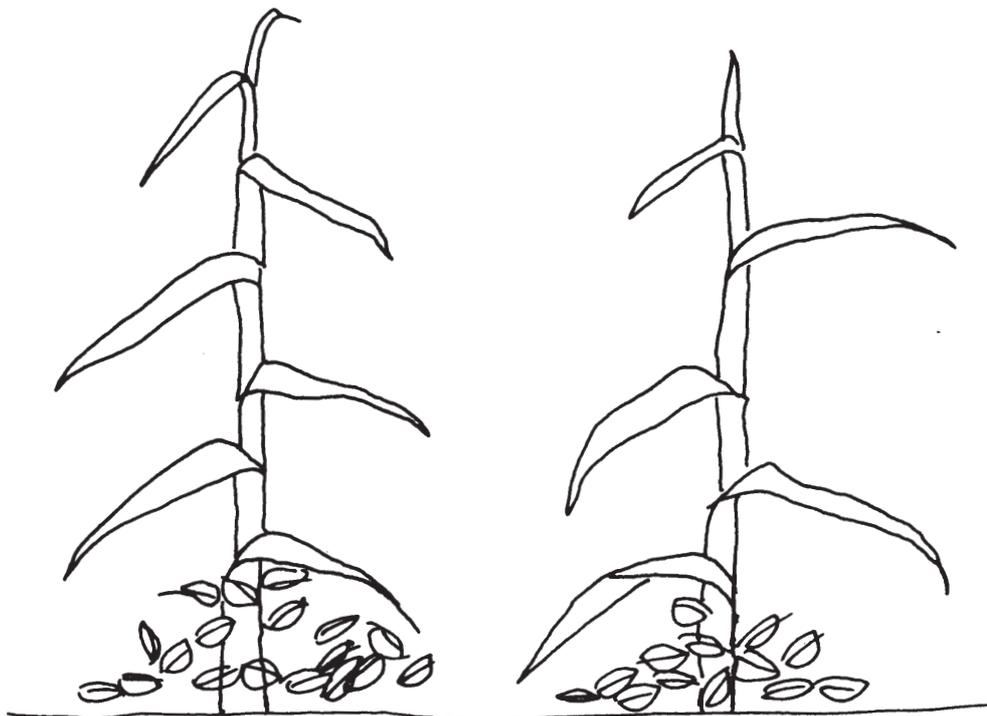
Intercropping is growing more than one crop in the same place at the same time. This technique can be incorporated into rotations and can have a number of benefits including:

- more efficient use of resources such as water, nutrients, light and land area
- lower incidence of pests, weeds and diseases than when a single crop is grown alone.

Small-scale, non-mechanised production is very suitable for intercropping.

Typical examples of intercropping include beans and cereals, but vegetables also work well in intercropping systems. Growing mixtures of tall plants such as corn and ground creeping plants such as pumpkins compliment each other well providing advantages for weed control and land use. A typical example grown in Mexico is a mixture of corn, beans and pumpkins. In this mixture, the corn is the most important crop and produces very good yields in the intercrop system. The beans and the squash do not yield as well as when they are planted alone, but they can be seen as an added bonus. Overall, much more is produced from the land than if the crops were grown alone.

Relay cropping is when the next crop is sown before the current crop has been harvested. This allows the next crop to be established more rapidly without a break. This is very commonly used for green manures that can be undersown in the vegetable crop. For example, a maize crop may be drilled in rows, then a green manure such as lucerne can be broadcast between the rows once the maize plants are a few centimetres high. The lucerne will grow only slowly when the maize crop is still in the ground, but once the maize has been harvested, it will establish much more rapidly than if it was sown afterwards.

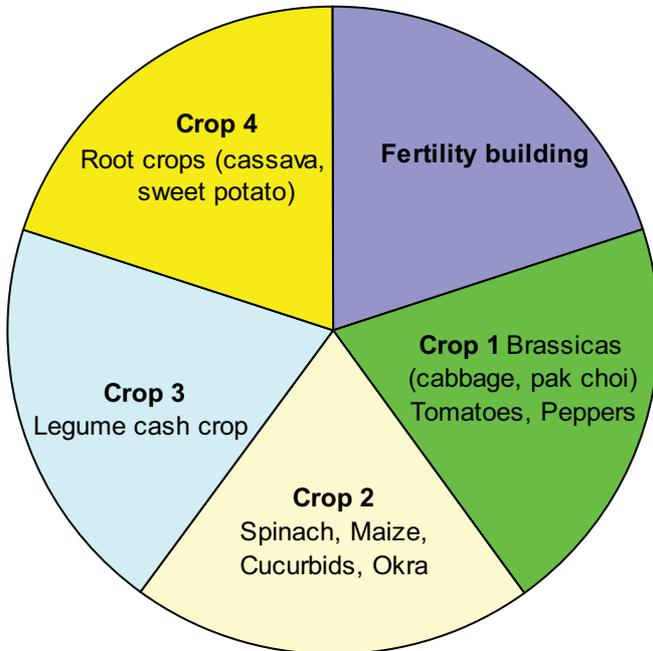


A green manure (for example a bean) sown beneath maize

7. Crop Sequences in a Rotation

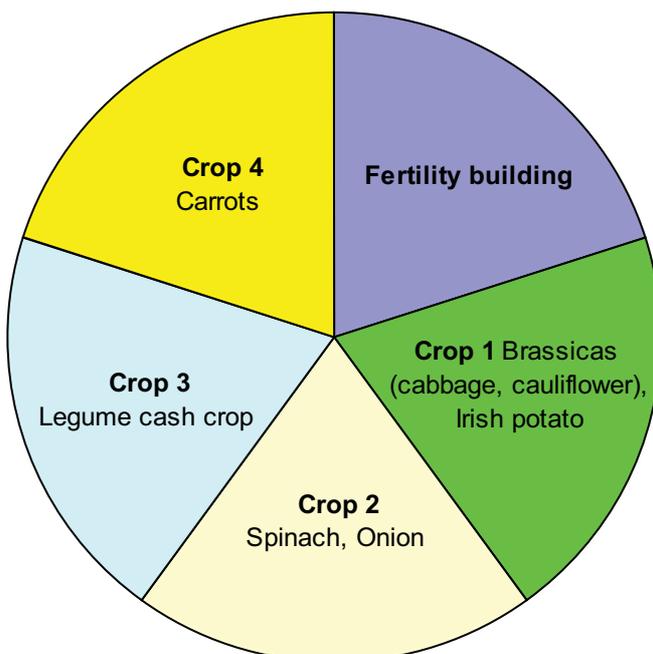
A general framework for planning a rotation is set out below. This can form a loose basis for planning – in practice, a rotation is always flexible to fit in with local conditions and the market.

Example of a rotation in a lowland area



Intercropping can be incorporated into this rotation. For example in crop 2 pumpkins can be grown between the maize and in crop 3 the legume cash crop could also be undersown in the maize as a relay crop to establish it more quickly.

Example of a rotation in a cooler upland area



Designed and set by Dave Webb
Thanks to Shiela McQuattie for providing the illustrations

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The International Programme of Garden Organic provides an enquiry service that answers specific questions on any aspect of organic agriculture or agroforestry. This service is provided free of charge to farmers, NGO's, government extension staff and other organisations working in Africa, Asia and Latin America.

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