Solar Greenhouse

Running Manual

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Energy
Environment
Solidarity

Solar Greenhouse Running Manual

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1. Contents

2. Introduction

Himalayan context: The monsoon rains being stopped by the Great Himalayas southern range, most of the places in western Himalayas are cold deserts of high altitude. The summer is hot (over 30°C) but short, and the temperature can be very cold in winter (-25 °C in Leh, Ladakh). The air humidity is very low and climate is very sunny.

In these areas agriculture is fully dependent on irrigation: water is issued from melting glaciers. Main crops are barley, wheat and alfalfa. Potatoes are also important in some places. Growing season, from April / May to September / October, depending on altitude, is often too short to grow vegetables outside.

Extending this growing period by the use of a greenhouse can be extremely profitable for vegetable production. Seedling productions in spring time, fruit production in autumn (tomato), leaf vegetable production in peak winter, are among the possibilities.

In many remote and isolated areas fresh vegetable shortage happens during winter. That situation can be improved by the development of efficient greenhouses in such areas, bringing many benefits for their users:

- Health improvement by a more balanced diet
- Income generation (fresh vegetables can be sold at a very high price in case of winter shortage)
- Improvement of women autonomy (most of the greenhouses are hold by women who are also selling vegetables)

The passive solar greenhouse designed by GERES is adapted to grow vegetables in Ladakh and similar climatic areas. The greenhouse is designed to pick up maximum solar radiation, to store heat and release it at night.

This manual should help farmers and development organisations to use this tool at best:

- In first part it gives basic knowledge about plants and their relation with their environment,
- Then greenhouse is described and its functioning explained.
- Different uses of the greenhouse, their strategy, advantages and difficulties are then presented in a very practical way.
- Basic agricultural practices in greenhouse are described with very practical information and advice.
- Last part gives information about each crop that can be grown in greenhouse.

This manual is based on experimentation and studies led in Leh, Ladakh (3500m altitude). Using strategy and growing periods must be adapted for uses in different climates and altitudes.

Picture 1: high altitude Himalayan landscape

3. Vegetable growing in greenhouse: agronomic basis

3.1. The plant and its environment

3.1.1. Introduction

To grow vegetables the farmers has to provide a suitable environment to the plant. In this first part the relations between the plant and the soil, the water, the atmosphere, the light and the other plants are described. This knowledge will help to understand the reasons of the practices recommended in the following parts of this manual.

3.1.2. Plant and soil

The soil has many roles concerning plants:

- It is a support for root system;
- It stocks nutrients;
- It stores water;
- It stores air (oxygen for root respiration)

Therefore a good soil has specific physical and chemical qualities:

- Soil particles form spherical aggregates so gaps between aggregates facilitate water and air storage and root penetration (fig. 1);
- A good soil is also rich in Nitrogen (N), Phosphorus (P) and Potassium (K) which are the main nutritive elements for plants. They are released by organic matter decomposition or can be brought by fertilizers;
- The soil should be able to store N,P,K elements to release them little by little. Humus (from organic matter) and clay help to store theses elements.

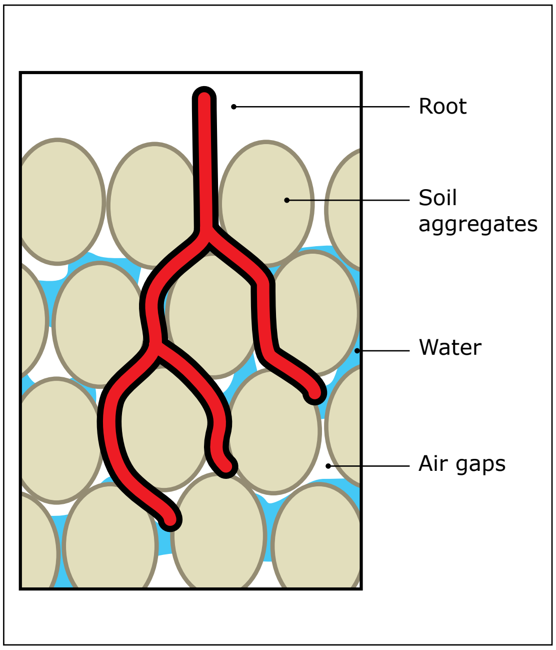


Figure 1: a good soil structure

Several practices help to improve soil qualities (fertility)

- Soil work (preparing a sowing place, §6.2.2; Hoeing, §6.2.7.2)
- Compost amendment (§ 6.4.1) ;
- Using fertilisers (§6.4).

3.1.3. Plant and water

Water plays 3 different roles:

- It transports nutrients from the soil to the plant;
- It gives the plant its rigidity by inflating cells;
- It transports elements inside the plant.

A water shortage can kill the plant, but over watering can have the same effect. Good practices for watering are explained in page 19.
The freezing damages on vegetables are due to ice forming inside the cells and breaking them. It can kill the plant if all cells are damaged, or it can damage only a part of the leaves.

3.1.4. Plant and atmosphere

The atmosphere is necessary to the plant for:

- Breathing
- Photosynthesis
- Evaporation

Breathing: It concerns all parts of the plant, including roots. Carbon dioxide is released and oxygen absorbed. When over watering, soil air gaps are filled with water so roots cannot breathe and plant risks dying.

Photosynthesis: Carbon dioxide is absorbed and oxygen released (by leaves). This process, powered by light, allows building organic matter from light energy, atmospheric carbon dioxide and soil elements (N, P, K).
During the day photosynthesis is more important than breathing. By sunny days in a closed greenhouse carbon dioxide shortage can happen, especially in high altitude where air pressure is low. A good ventilation and composting inside greenhouse (compost releases high quantities of carbon dioxide) will solve this problem.

Evaporation: Water evaporates through leaves into the atmosphere. This creates a depression inside the plant that drives water from the soil into the plant roots with its carriage of nutrients. So evaporation is the pump for water circulation inside the plant. It depends mainly on relative air humidity. If relative humidity is too high, evaporation is low so growth is slow. If relative humidity is too low, the plant protects itself from drying by limiting evaporation, and then growth becomes slow. Relative humidity is favourable to growth when between 45% and 75%. It can be controlled by watering (when too dry) or ventilation (when too humid).

3.1.5. Plant and light

The light has following roles for the plants:

- It powers photosynthesis and therefore growth;
- Light rhythm can have an effect on plant development (for example varieties of onions need long days and short nights to form a bulb). Therefore for some species the cultivated variety must be adapted to the season and latitude.

A light shortage produces yellow leaves, long stems and weakness of the plant.

3.1.6. Competition for resources

Soil, water, atmosphere and light are plant resources (figure 2).
These resources must be used at best in the greenhouse. Too many plants grown in a small place can lead to heavy competition and therefore low production.
Competition for resources must be optimised, for that purpose:

- Respect distances for planting adapted to each crop;
- Allow the roots to explore the maximum volume by letting the plant grow to full size before harvesting;
- Weeding prevents competition between crop and weeds.

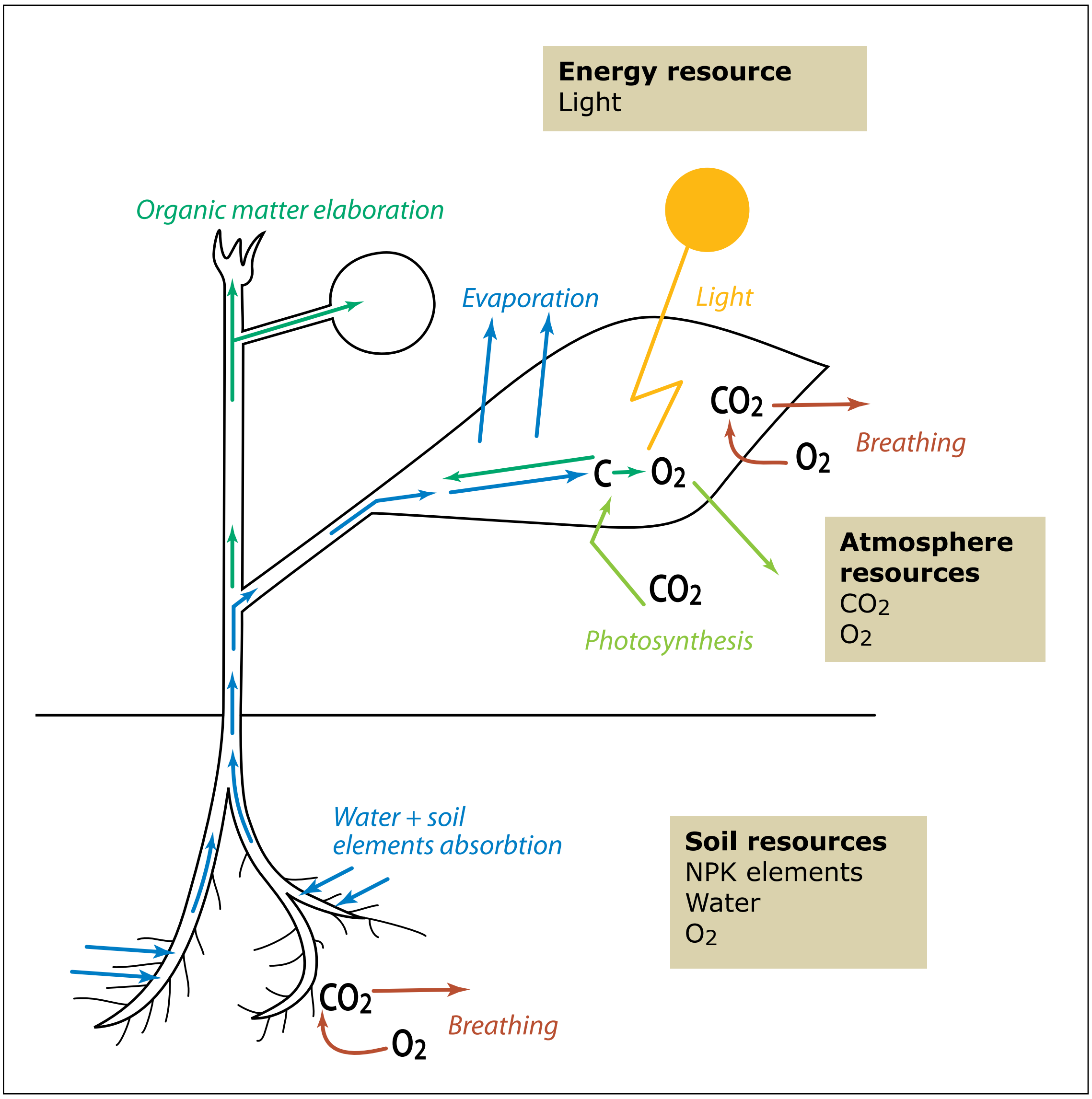


Figure 2: the plant in relation with its environment and resources

3.2. Plant development

All plant cycles aim at producing seeds. During this development the plant has to reach different stages. Conditions (temperature, light rhythm, soil) to reach each stage depend on species and varieties. Harvest occurs on various stages depending on variety and production purpose (leaf, bulb, root and fruit). The more the harvest stage is advanced in the development cycle, the more difficult it will be to succeed because the plant will have to reach many stages, each one requiring specific conditions. The yield will depend on the success in reaching each stage.

From what precedes it is clear that producing leaf vegetables is easier than producing root vegetables which is easier than producing fruit vegetables. That’s why leaf vegetables can be grown in relative extreme condition (spinach in winter for example), and fruit vegetables only at certain precise period of the year (tomato for example). General information on specific needs for each crop are available in chapter 7, but success can be insured only if the farmer knows well the varieties he has access to.

The role of the greenhouse is to modify the climatic parameters (air and soil temperatures, humidity) to provide a favourable environment to the crops. Of course the climate inside a greenhouse changes with seasons and locations. So it is necessary for the farmer to know very well this tool to be able to choose the right variety to grow at the right period with the right growing practices. This manual can give practical information and general knowledge, but success will come only with experience.

Stage	Conditions (* to adapt to the variety)	
Germination	• Good quality seeds • Soil Temperature* • Soil Humidity • Sowing depth*	
Vegetative growth	• Mineral availability in soil* • Air temperature and humidity* • Soil temperature* • Watering (quantity and frequency)* • Density*	Leaf vegetables Harvest
Bulb/root formation	• Adaptation to the growing period • Mineral availability in soil* • Air temperature* • Soil temperature* • Watering (quantity and frequency)*	Bulb and root vegetables Harvest
Flowering	• Adaptation to the growing period • Day length* • Air temperature* • Mineral availability in soil* • Watering (quantity and frequency)*	Conditions to be avoided for leaf, bulb and root vegetables
Flower fertilization	• Air temperature (avoid overheating), air humidity, insects…	
Fruit formation	• Air temperature (avoid overheating), Mineral availability in soil*, watering (avoid shortage)	
Fruit growing	• Mineral availability in soil* • Watering*, air and soil temperature	
Fruit Maturation	• Air temperature	Fruits vegetables Harvest

4. The Greenhouse

4.1. Description

This type of greenhouse has been designed to grow vegetables in high altitudes areas. It is briefly described below. For more details see the construction manual (A manual of solar greenhouse construction in Ladakh, Himalayan Range, V. Stauffer, GERES).

4.1.1. Description

The greenhouse (pictures 2 and 3 and figure 3) is composed of:

- Three double walls (East, West, North) that are insulated
- A roof with northward slope equipped with ventilation openings
- East and west openings (door and window for cross ventilation)
- Polyethylene sheet with two southward angles, doubled at night by an insulating curtain

4.1.2. Functioning:

The solar radiation enter inside the greenhouse through the polyethylene and heat inner walls, soil, vegetables and air. The polyethylene slopes are designed to transmit maximum solar energy (the lower part Ha a suitable orientation to catch the morning and evening sun, the higher part is oriented for middle day sun). During the night, walls and soil release by infra red radiation and convection the heat stored during the day. These radiation heat the vegetable leaves so that even if the air temperature inside the greenhouse is far below 0°C (-7°C have been recorded) the leaves do not freeze.

The northern and eastern walls are black painted to absorb and store solar radiations during the day and the evening. The west wall is white painted to reflect the morning light on the vegetables. The roof reduces the polyethylene surface, therefore heat losses and decreases the volume of greenhouse. Its slope is designed to avoid shadows inside the greenhouse during autumn, winter and spring.

An operable ventilation system avoids over heating during sunny days and regulates relative humidity inside greenhouse (figure 3). Warm air naturally rises and exits by roof ventilator at the top; it is replaced by cooler air allowed entering by opened door and window at the bottom. Cooling efficiency can be improved if necessary by lifting the polythene on its southern side to allow more air to enter (picture 4).

Picture 2: a greenhouse under construction (notice: roof, double walls, ventilation openings, angles)

Picture 3: inside view of a greenhouse (notice: ventilation system)

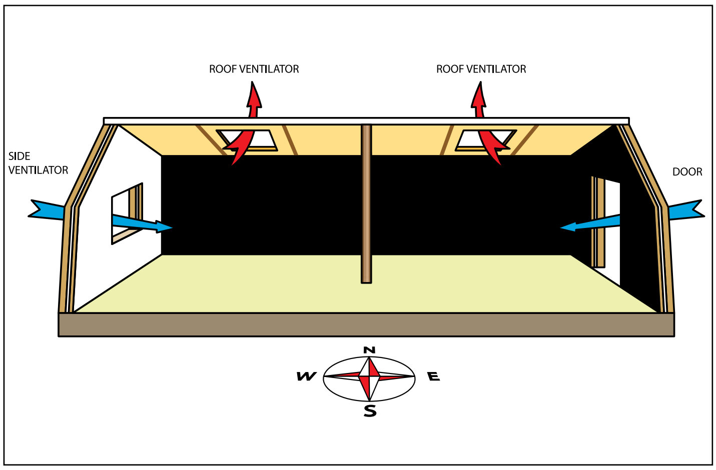


Figure 3: view of air circulation in a greenhouse

4.1.3. Zoning in a Greenhouse

The greenhouse growing surface is shaded by the East and West walls, especially during spring and summer (figure 4, zone 3 and 4). The north side is always shadowed by the roof during summer (zone 2). And there is a temperature gradient during night: Places near the south side, next to the polyethylene (zone 5) are much colder than places near the walls. The farmer has to take this zoning into account when deciding soil occupation.

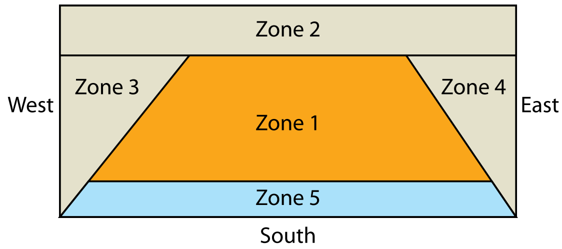


Figure 4: climate zoning of a greenhouse

Table 1

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Solar radiation	High amount of solar radiation	Very shadowed in summer	Shadowed in the evening	Shadowed in the morning	Highest amount of solar radiation
Temperature	Quite warm	Quite warm at night	Cold at night	Warm at night	Very warm during day Very cold at night
Best use	Suitable for most crops Good for seedlings	Good place to grow during peak winter	Good place to grow resistant and permanent plants	Best place to grow vegetables that are less cold resistant	For cold adapted varieties
Example of adapted crops	Tomato, cabbage, cauliflower seedlings	Swiss chard, turnip	Mint, parsley	Tomato for late harvest	Spinach

4.2. For a best performance

4.2.1. Limits

The passive solar greenhouse is a simple tool, quite efficient, but it doesn't provide an environment exactly adapted to the vegetable needs. It has no active heating system, and as insulation is poor (heat losses through polythene), temperature are often too cold at night during winter.

- If the weather is cold and cloudy during more than 3 or 4 consecutive days, the walls are cooling and do not radiate enough during the night to prevent leaf from freezing.
- In very a cold weather the ventilation is not possible because of temperature reasons, so the relative humidity remains very high inside the greenhouse, which is not favourable to growth.

Openable surfaces are very little compared to the greenhouse size, the natural air circulation for cooling doesn't cross properly the greenhouse and there is no active cooling system, in sunny days overheating is frequent, even during winter time.

- Despite the ventilation system there are still risks of overheating during very sunny days.
- On very sunny days temperature is very high inside greenhouse, ventilation is maximum, so relative humidity is very low. It is necessary then to water very often, especially seedlings. It is necessary to be very watchful in this case to avoid plant drying.
- Thermal amplitude can be very high, especially in autumn and spring: there is often over 40°C difference between night and day, which is quite unfavourable for most of the plants at any stage.

4.2.2. How to get the maximum efficiency

A simple equipment can help to get the maximum efficiency from the greenhouse. Improvement will have to reduce thermal amplitude

4.2.2.1. Cooling system:

- During summer, it is recommended to improve the ventilation by enlarging the surface that can be opened, especially in the lower part of greenhouse for air entrance. For example by lifting polythene on its south face (picture 4). These openings must be tightly shut in case of strong wind.
- An active cooling system can be installed (fan / water circulation)

Picture 4: south face of polythene lifted to improve cooling

4.2.2.2. Insulation at night:

During the night heat losses can be reduced by adding a curtain, doubling the polyethylene sheet: this stops heat losses by radiation through polyethylene and reduces heat losses by convection and conduction because of the presence of a layer of still air against polyethylene.

Picture 5: Inside view of a greenhouse (notice: curtain installed for night insulation, ventilation system)

Experimentation shows that 5°C can be saved by this equipment. (See picture 5).
A double polyethylene is also very efficient for insulation but as it stops too much light during the day time it is only recommended for very high altitudes (above 4000 m)

4.2.2.3. Heating capacities:

It can be increased in a passive way by adding more thermal mass inside the greenhouse: partition wall, water tanks.
Active heating systems can also be adopted (geothermal heating).

5. Different uses and Strategy

The use of the greenhouse and the strategy adopted by the farmer depends on the climate and on the economic environment. This chapter is based on Leh (Ladakh, India) environment located at 3500m altitude and where markets are not supplied by road during winter.
Possibilities will be different in other environments (see Table strategy, technical data sheet 1, Appendix)

5.1. Using greenhouse to extend summer season

The summer season is quite short in high altitude areas. By the use of a greenhouse, it can be interesting to extend the growing season to allow long development cycle vegetables to finish their cycle (Eg: tomato, eggplant...).

1. Vegetables can be grown in greenhouse, without polyethylene during summer, then covered (last week of September)
2. Vegetables can be grown during summer, with the polyethylene on greenhouse

5.1.1. What vegetables are concerned

1. For 1st method: Late turnip (sown in august), late cabbage, celery (sowing July, August)
2. For 2nd method: Hot climate fruit vegetables: tomato (late varieties, planting in June/July), brinjal, capsicum, chillies, and cucurbits.

5.1.2. Difficulties

1. Choosing the date to cover greenhouse with polyethylene in Autumn: to avoid over heating and prevent damages from coldness. It can be done when outside night temperatures are about 0 to 5°C.
2. Avoiding over heating under polyethylene during summer, especially at flower stage where it can reduce flower fertility. Water needs are very high when polyethylene is on during summer, and all ventilation opened. In lower altitude areas (eg: Sham, below 3000m) ventilation has to be larger (eg: openings under the polyethylene on the south face)
3. Transplanting fully grown plants can damage them.

If the polyethylene is removed during summer, it can be damaged by manipulation. If not it is more exposed to destructive UV radiation. The best for its lifetime will be known only with experience. The decision remains the farmer's, according to his production objectives.

5.2. Using greenhouse for peak winter vegetable production

During winter in high altitude areas, growing outside is impossible because of very low temperatures. The few fresh vegetables found in the market are therefore very rare and expensive. Fresh vegetable prices are very high at this period. Using a greenhouse to produce fresh vegetables during the peak of the winter is economically very interesting.

5.2.1. What vegetables are concerned

- spinach
- beet leafs (from roots transplanted from outside)
- local varieties of Chinese cabbage
- some varieties of lettuces (Ex: Salad Bowl)
- some varieties of turnip

These can be sown from 15th September to 15th October to be harvested from December to March.

5.2.2. Difficulties

In autumn the sun is still warm and can damage young seedlings under the polyethylene. Spinach is very sensitive to that.
To prevent this,

- don't sow too early,
- water seedlings daily,
- open ventilation when temperature is high (above 25°C)

The vegetable growth is slower when the temperatures are low. So if sowing is too late, the cold period comes at a very early stage and the growth is slowed. It can postpone harvest to the end of winter.

During peak winter, the risk of freezing is very high, especially for fully grown vegetables, next to the polyethylene surface. Risk is increased if weather is cloudy during three consecutive days. An insulating system such as a curtain or a double polythene will reduce the risks of freezing damages at night.

Even in peak winter, over heating is to be avoided by opening ventilation.
When the weather is cold, the relative humid-

ity is very high in the greenhouse because it must stay closed. The evaporation is therefore low an growth is slowered

5.2.3. Conclusion

Using a greenhouse to produce vegetables in the peak of winter is certainly a little risky, but it can also be highly profitable. Sowing at the right time is essential.

Innovative techniques are still to be invented or experimented. Especially concerning:

- Different types of insulation at night, on soil, crops, greenhouse.
- Selection of the more productive varieties in winter (genetic improvement of local varieties)
- Growing on ridges side or top can help the soil warming during the day.

5.3. Using greenhouse for seedling production in spring

As the summer season is very short, producing seedlings inside a greenhouse to be transplanted outside as soon as possible (usually 15th to 20th of May) allows growth of vegetables that could not be grown outside in high altitude areas or allows to harvest earlier in the season. This is usually practised by farmers with traditional greenhouses. In some lower places (around 2000 m altitude), the precocity obtained by the greenhouse allows to grow two crops during the season

5.3.1. What vegetables are concerned

Cabbage, cauliflower, lettuce, onion, celery, tomato...

5.3.2. Difficulties

To produce strong and healthy seedlings (figure 5) that will support transplantation outside:

- Avoid dense sowing (final density 100 plants/m²).
- Use good quality seeds.
- Sow in a sunny place (avoid greenhouse sides shadowed by East, West, or North walls).
- Progressively acclimate seedlings to outside climate by opening greenhouse ventilation during night from one week before planting.

To sow at the right time:

- The soil has to be warm enough to allow germination (temperature depends on variety).
- The greenhouse climate has to be warm enough for a normal growth of the seedling.
- The outside climate has to be adapted to the specific needs of the crop at the time of planting (usually about 1month after sowing).

5.3.3. Conclusion

Producing good quality seedlings at the right period requires great care, specific skills and good experience.
Therefore seedlings can be sold to other farmers who have no greenhouses or less skills with good added value, if quality is recognised. Producing seedlings can become a speciality for some farmers and an interesting business.

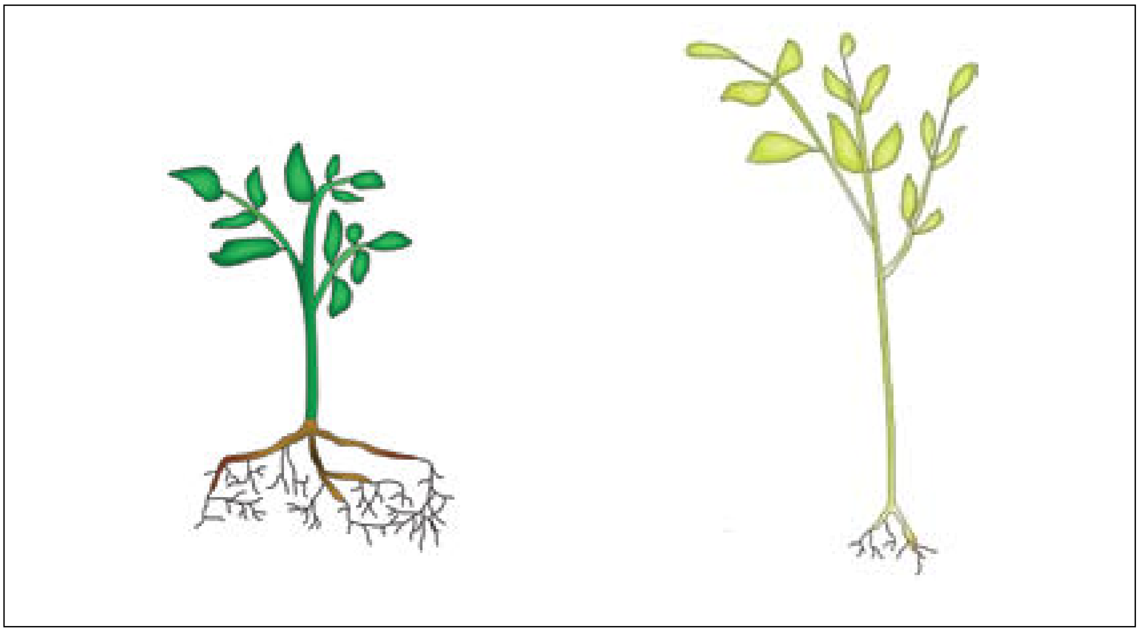


Figure 5: Left, good seedling plant; right, bad seedling plant

5.4. Examples of greenhouse use throughout the year

In the following example, two different uses are described. The first one called "polyvalent with 3 crops in a 3 years rotation" is a type of use which is very realistic, aimed at home consumption and marketing. It is sustainable.

The second example called "commercial use" is oriented on crops generating a very high income in a particular economic context. It is an example on one year and does not mention any rotation. Margin and pay back time are calculated for both examples.

Table 2

Polyvalent with 3 crops, in a 3 years rotation

Plot	Surface 16m²	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Expected harvest	Rs/unit	Value in Rs
Plot 1	4m²	Spinach													20 Kg	30	600
		Nursery													400 U	5	2000
		Tomato													60 Kg	20	1200
Plot 2	4m²	Lettuce													12 Kg	30	360
		Turnip													20 Kg	20	400
		Beans													20 Kg	20	400
Plot 3	4m²	Coriander													2000 U	2	4000
		Swiss chard													20 Kg	15	300
		Onion													20 Kg	20	400
Perma-nent	2m²	Parsley/Mint													500 U	2	1000
																Total	**10,660**

Commercial use, nursery and aromatics

	16m²	Spring nursery													1200 U	5	6000
		Summer nursery													1200 U	5	6000
		Flowers													800 U	10	8000
		Coriander													6000 U	2	12000
																Total	**32,000**

Charges

Maintenance		
Seeds, Inputs	500	
polythene	400	on 5 Years
Tools	100	
Building writing off	1800	on 10 Years
Total	2800	

Investment		**18000**
Margin	Polyvalent use	7860
	Commercial use	29200
Pay back	Polyvalent use	2,29 Years
	Commercial use	0,62 Years

6. Using Greenhouse: General Matters

6.1. Climate Control

The main function of a greenhouse is to provide a suitable climate for vegetable growing. The needs concerning climate depend on crop variety and stage. The climate is not fully controllable in this type of greenhouse. Most of vegetable can survive if the environment is slightly different than the optimum condition.

If the greenhouse temperature is uncomfortable for men, it is unfavourable for crops also.

However general rules can be underlined:

- Avoid temperature and humidity excesses by opening ventilation system (figure 3) during sunny days. This is necessary in summer but also in winter time if the weather is very sunny.
- Water in the morning to avoid cooling and excess of humidity during the night.
- Close the ventilation openings about one hour before sun set to warm the greenhouse before the night
- Use an insulation system (picture 5).

During winter, the temperature inside a greenhouse should not rise over 25°C and should remain as warm as possible during the night.

If the air inner temperature inside a greenhouse reaches –4°C as minimum during the night, after a cloudy day, there is high risk of vegetables freezing: during winter, use always an insulating curtain at night, or/and put blankets (or any insulating material) over the crops.

6.2. Agricultural practices (Basis)

The main agricultural practices for growing vegetables are described step by step from soil preparation to harvest. The unexperimented farmers will find basic knowledge to grow vegetables. More experimented ones will find information to optimise their work.

6.2.1. Tools

Watering can, transplanting tools, hoer and other gardening tools are useful to grow in a greenhouse (picture 6). Thermometers (soil thermometer and air min/max Thermometer) can be also very useful.

Picture 6: useful tools for the greenhouse

6.2.2. Preparing a sowing place

The day before sowing level and water

1. Trace the sowing bed (any size), add compost according to the requirements (see § 6.4.1), turn soil and remove stones, weeds and roots (figure 6).

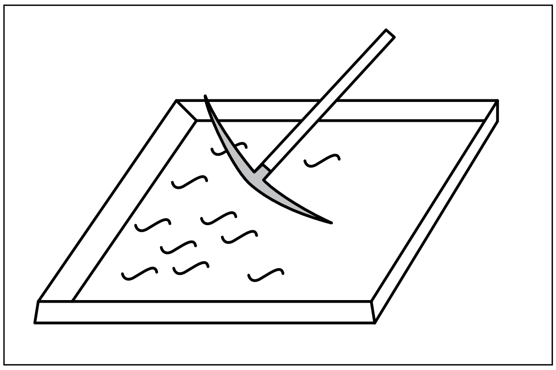


Figure 6

2. Fill the bed with water and level the sowing place using water surface as indicator. A bed badly levelled can have negative consequences on germination and seedling growth because the lower part of the bed risks being over watered and the higher part being too dry (figure 7).

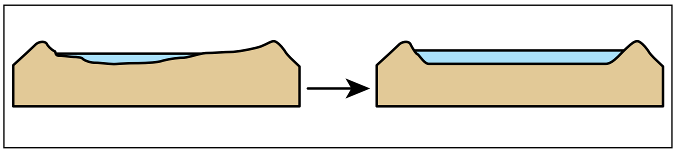


Figure 7

3. On the sowing day, the soil should be humid but not soaked. Hoe the bed surface. Trace the sowing lines, respecting depth and distances adapted to each crop (§ 7 Information on crops).

6.2.3. Direct sowing and thinning

There are two methods to reach the density adapted to the crop:

- Direct sowing then thinning
- Sowing then transplanting

The first method is adapted to all vegetables grown in winter, specially root and leaf vegetables.
Sowing: A frequent mistake is to sow too densely. High density leads to heavy competition just after germination, spoils seeds and increases time spent for thinning. About one seed every inch is usually enough (figure 8).
Big seeds can be sown manually one by one, smaller seeds can be scattered on the line either by hand, either using a piece of paper. Very small seeds can be mixed with sand before sowing: it helps to keep a low density.

After sowing seeds must be covered with soil by filling up the sowing lines and watered.

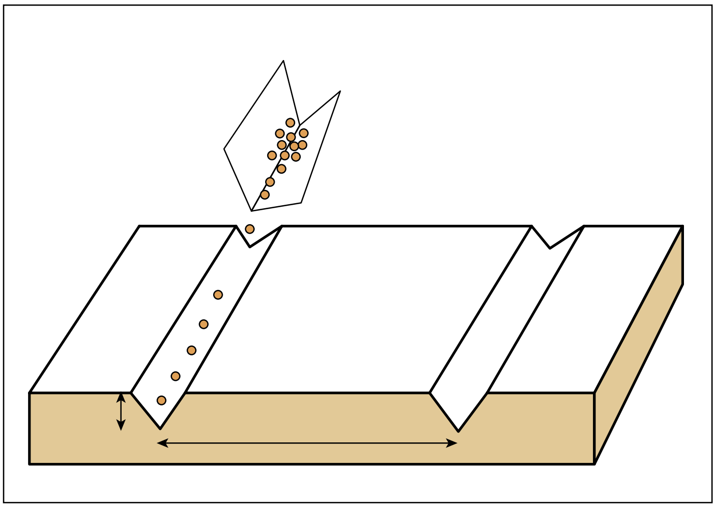


Figure 8

First thinning: After two or three weeks depending on temperature and variety, when plants present 3 leaves, a first thinning must be done. Leaving one plant every 3 inch, biggest plants are kept (figure 9).

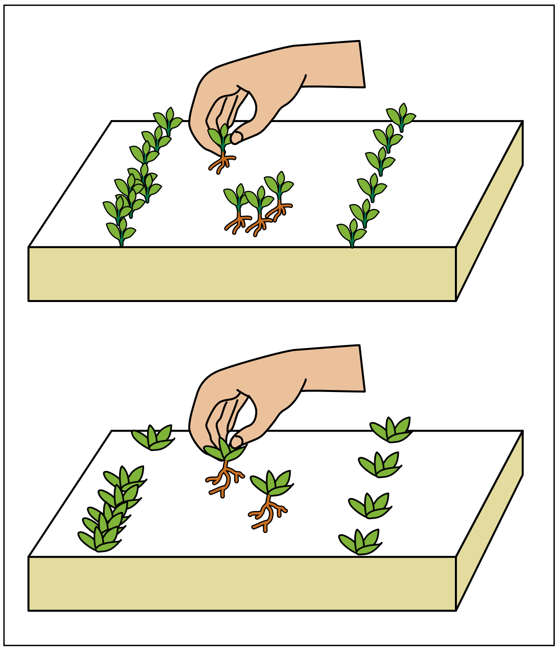


Figure 9

Second thinning: about 1 month after first thinning, when vegetation on the lines becomes thick, specific distance to the variety is reached by thinning. For leaf vegetables, this second thinning can be a first harvest.

6.2.4. Nursery production and transplanting

If some species can not be transplanted (carrots, turnip, radish, spinach...) other species can be sown in a nursery then transplanted outside, in pots or in other places of the greenhouse. This process saves place and helps the formation of a strong root system. Sowing is done as for direct sowing (see previous page) and seedlings are transplanted when it is necessary. Time spent in a nursery depends on temperatures and varieties: it is generally about 1 month. To get good quality vegetable seedlings final density (after one month) must not exceed 100 plants /m².

If the weather is too cold for sowing in a greenhouse it can be done in a heated place in a container, after germination seedlings can be transplanted in little pots for better convenience and less stress at planting (picture 7, figure 11). All pots and containers are filled with a mix of garden soil and very matured compost. They have small holes in the bottom for drainage.

The climate inside greenhouses is confined, very different from external climate which is windy, colder and very dry. Transplantation from inside to outside without precautions can kill the plants. Before transplanting seedlings outside, they must be hardened. Little by little, from ten days before transplanting, they should be exposed to dryness, wind and cold weather. This can be done by progressively reducing watering and by opening ventilation during the night.

Example of seedlings hardening before transplantation:

- Onion plants are sown on 10th of April, to be transplanted outside on 20th May.
- From the sowing to the 10th of May, the greenhouse is ventilated from 10 AM to 2:30 PM
- And watered 5l/m² daily
- Then starts the hardening period:

Picture 7: using pots for seedling production

Table 3

	11th	12th	13th	14th	15th	16th	17th	18th	19th
Open ventilation	9:00 18:00	8:30 19:00	8:00 19:30	7:00 20:00	6:30 21:00	6:00 22:00	5:00 23:00	Not closed	Not closed
Water quantity	4l	3l	-	4 l	-	3l	-	2l	-

The use of hot beds:
Some species need warm conditions for germination (ex: tomato need a soil temperature of 20°C minimum to germinate and 15°C to grow properly). The heat released by fermentation of compost can be used to warm the bed. Dig a trench 50 cm deep and fill it as follow (figure 10 A), water abundantly.

After one week the surface soil will be warm enough for sowing or transplanting. Ten days before transplanting, cut the top layer around the plants, using a blade, forming 10x10x10 cm clods. Roots will grow more ramifications. Renew the operation three days before transplanting. Then it will be easy to remove each plant with its clod and transplant it without damaging the roots (figure10 B).

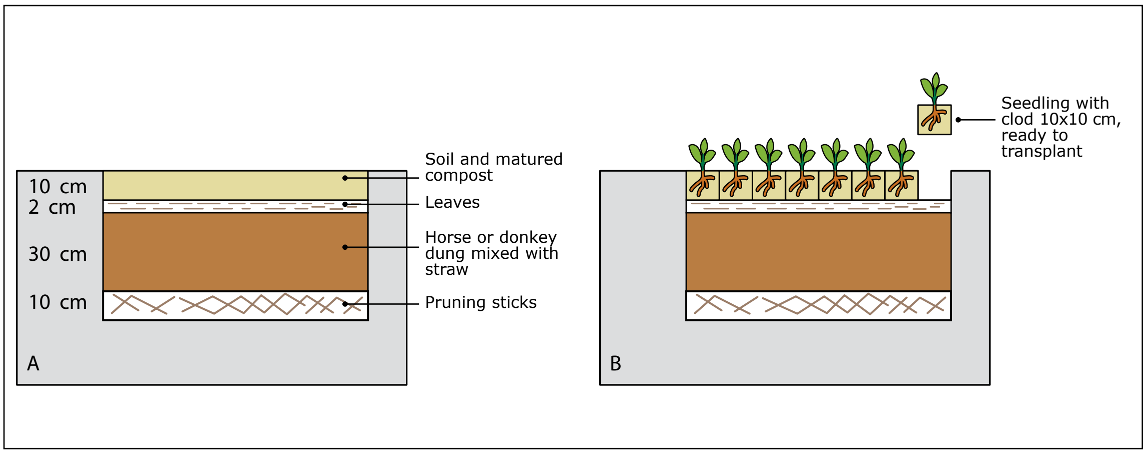


Figure 10: nursery production. Hot bed

Good quality seedling plants are:
Short
Thick
Strong
Dark coloured
With a thick root system

It is obtained by
Respecting distances between plants.
Providing good watering, light, and matured compost.
Opening the greenhouse progressively one week before transplanting and reducing watering at the same time to harden the seedlings.

Transplanting seedling outside is always a stress for the plant. Yield will depend on the quality of the seedling.

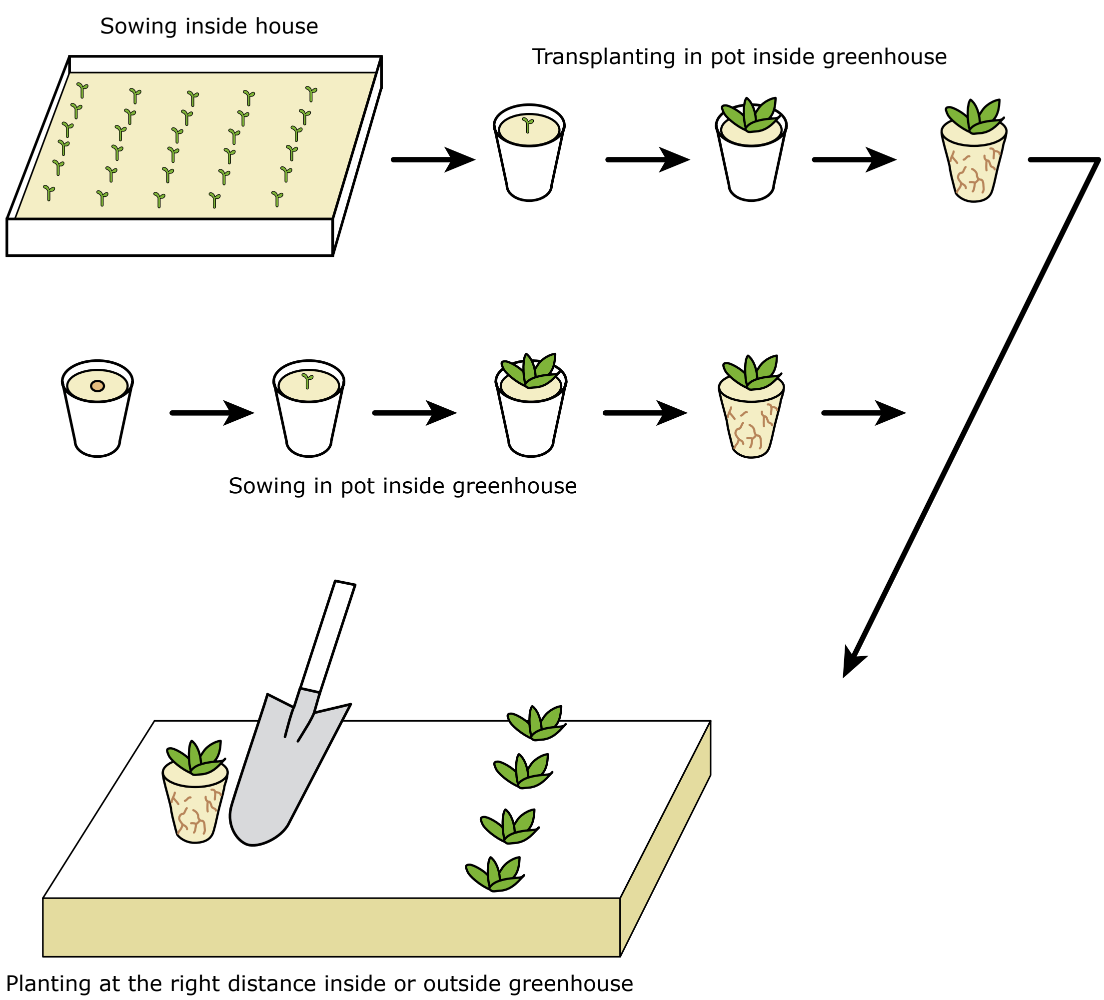


Figure 11: using pots and containers for nursery production

Both seedlings and planting place must be watered abundantly one day before planting and just after transplantation. After planting do not water on leaves, and provide shade for 1 day, with a paper for example (figure 12).

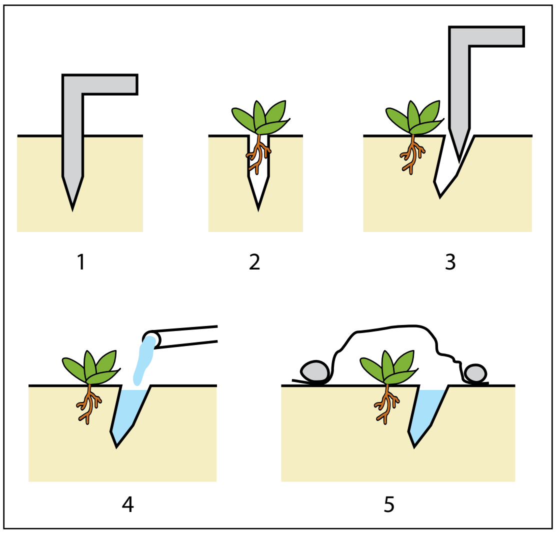


Figure 12: steps for transplanting seedlings outside (make hole, place seedling, water, cover with a paper)

The best soil occupation is obtained by a staggered arrangement which must be adopted for voluminous species (cabbage, cauliflower, tomato…) (figure 13)

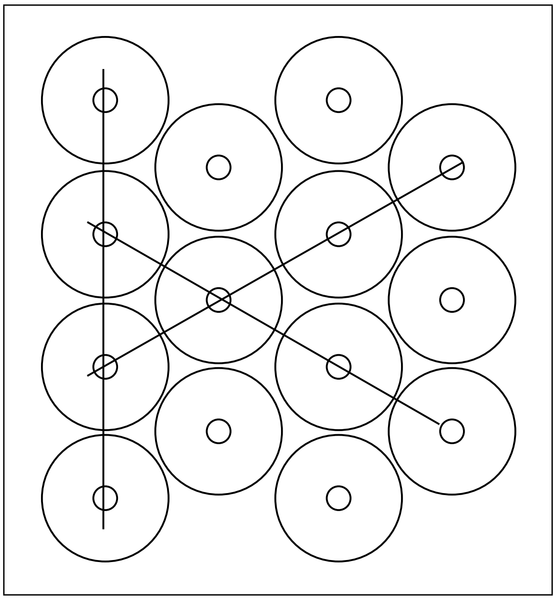


Figure 13: a staggered arrangement

6.2.5. Harvesting leaf vegetables

Many species and varieties of leaf vegetables (spinach, beet leaf, salad...) can be harvested by picking only big leaves. New leaves will grow for further harvests (figure 14).

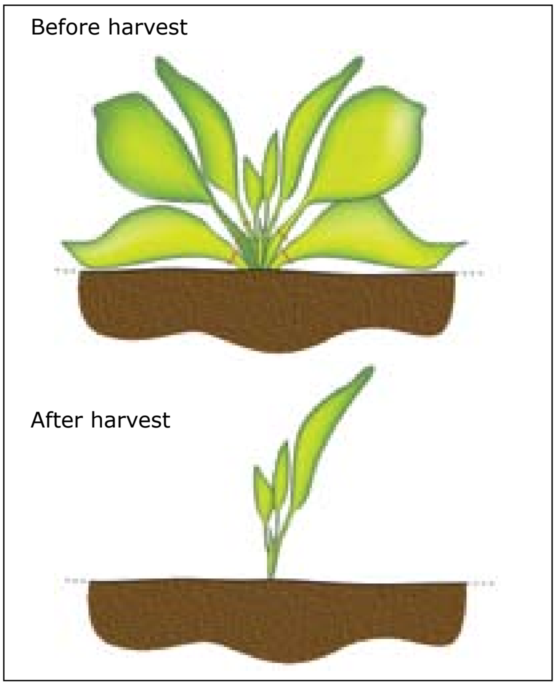


Figure 14: harvesting leaf vegetables by picking big leafs

6.2.6. Irrigation and water saving

The temperature of the water for irrigation must be similar to the soil one or little warmer. Cold water is not well absorbed by the roots. During winter black water tanks can be installed inside the greenhouse, exposed to solar radiation, to store and heat water for irrigation. They will also improve the thermal mass of the greenhouse.

Picture 8: Watering with watering can

Before and during germination it is very important to maintain bed surface humidity by watering often but in low quantity. A bad repartition of water on a sowing place that is not well levelled can affect germination and seedling growth.
A watering can must be used (picture 8): flooding can damage vegetables (especially for young plants) and it wastes water. (figure 15).

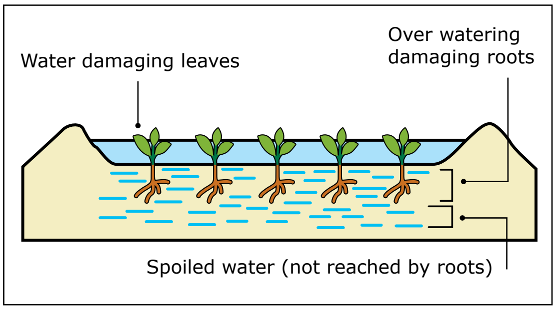


Figure 15: Bad effects of watering by flooding beds

Effects on leafs: Flooding reduces photosynthesis by bringing mud on leaves. It can also transmit plant diseases, reduces or stops the normal gas exchanges. Water current can physically damage the plant, bury leaves in mud, bring root into open air...

Effects on roots: Over watering reduces the air quantity in the soil (by filling air gaps with water), that stops root breathing. It is very favourable to soil born diseases.

Effects on water and soil management: Water quantity exceeds the water storage capacity of the soil so the water it infiltrates below the roots rech, is spoiled and it brings also many mineral in the deep soil, reducing surface soil fertility.

6.2.7. Water Saving

6.2.7.1. Definition and principles
Water saving is
1. to bring the right amount of water, at the right frequency
2. to reduce or stop losses by evaporation from soil

The soil has a limited water storage capacity that depends on its nature: Sandy soils have very low storage capacity. Heavy soils can store more water. Compost amendment can increase this water storage capacity.

Watering ideally brings the soil at its full capacity on the depth of the crop roots: this determines the quantity of water to bring.

Then plants pump in this reserve until it is too dry for them. At that time next watering should be brought: this determines watering frequency. It depends on the vegetable stage and on the climate (temperature, humidity, light).

Quantity and frequency have to be adapted to the nature of the soil, to the weather and to the stage of the plant. Exact calculation requiring special skills and tools, and can not be treated in this manual. However these can be approached by experimented farmers who know well their climate, soil and crop varieties.

Example:
The figure 16 compares the watering of a bed of same soil required by a grown crop and a young crop. These could be beds of 1,5 m², of heavy soil (good water storage capacity), at the end of winter (evaporation is not too high). The crop could be spinach, 4 months old on left side, 1 month old on right side.

1. On day 1, the soil is brought to its full capacity on root depth. This requires large amount of water on left side because roots are deep, so the volume of soil to "fill" is large: 2 full buckets are necessary. On right side roots are small so a limited amount of water is sufficient to fill the little volume that they can reach: only half bucket is brought.

2. Then evaporation and plant consumption "pump" into the soil reserve

3. On day 3, for young crop (left side) reserve is empty because it was small. It has to be filled again: half bucket is brought. For old crop reserve is not empty because a large quantity is stored.

4. Then evaporation and plant consumption "pump" into the soil reserve

5. On day 5, both reserves are empty and have to be filled again. On the right side, the total amount of water is 4 buckets in 5 days, left side only 1,5 bucket is required: grown crops consume more water than small crops (there is more evaporation through leaves) but frequency is higher for small crops (every 2 days) because soil reserve is smaller due to short roots.

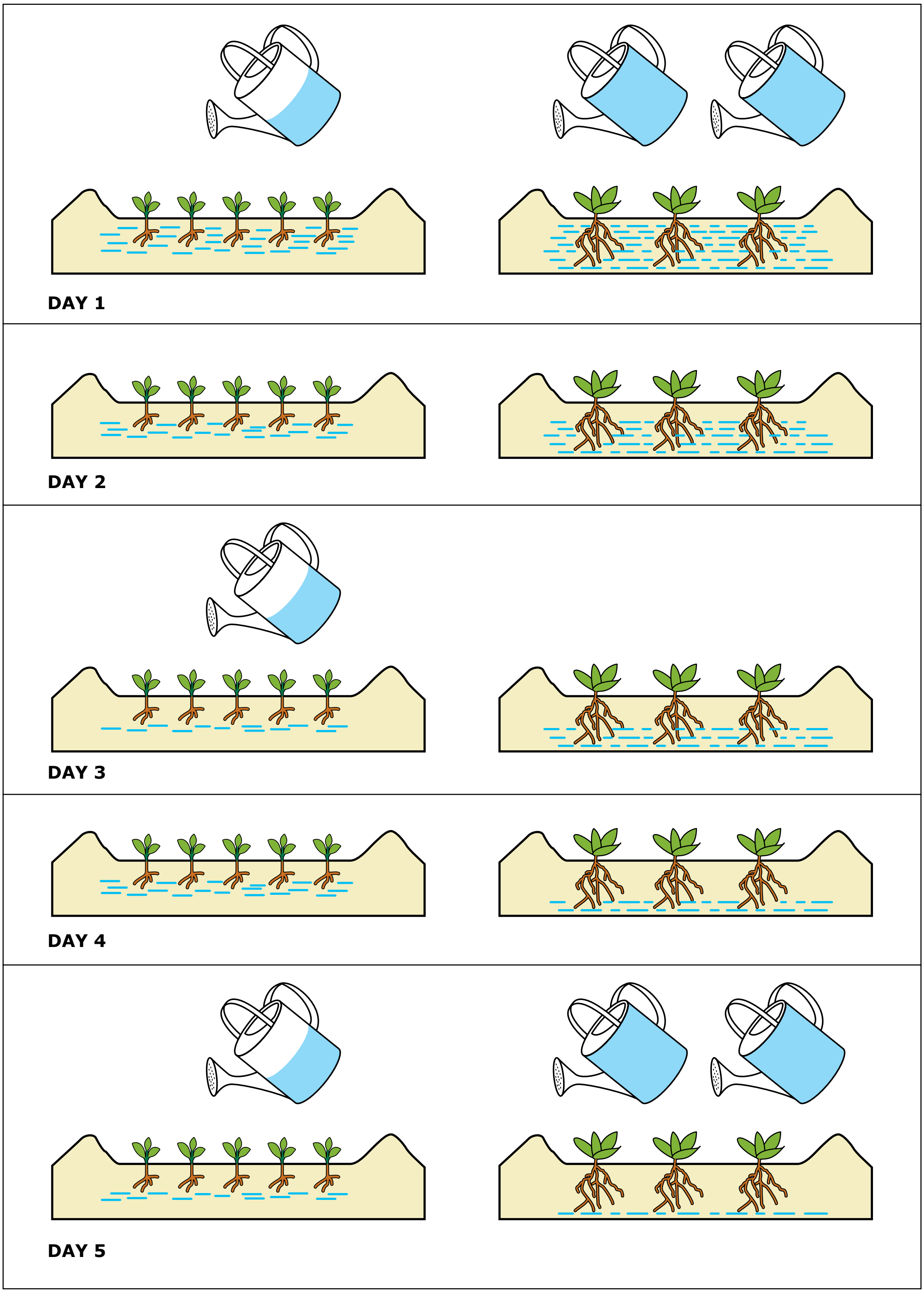


Figure 16: Adapting water quantity and frequency to plant size.

6.2.7.2. Hoeing

Hoeing is a surface work, that breaks and aerates the top soil layer. But it must not disturb the crop roots. Hoeing one day after watering is saving water by reducing evaporation from the soil (picture 9).

Picture 9: Hoeing is water saving.

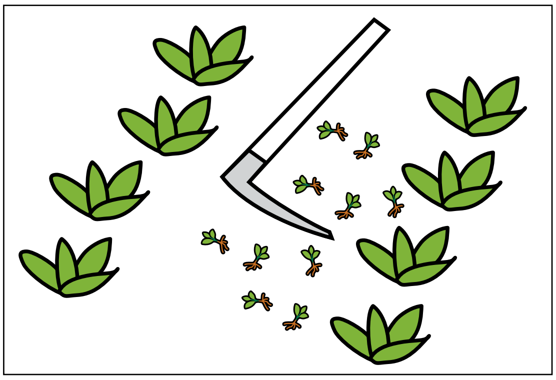


Figure 17: hoeing regulates weeds.

- Hoeing traps air in the top soil layer, it creates an insulating layer that retains moisture below.
- Hoeing improves soil fertility by easing organic matter mineralization.
- Hoeing helps to regulate weeds (figure 17)

6.2.7.3. Mulching

Definition:

Mulching reduces evaporation by covering the soil under a crop with a suitable material. It has also many side effects on soil temperature, life in the soil, mineralisation of organic matters, according to the materials.

Mulching helps to preserve the soil structure.

Materials

- Plastic mulching: black polythene cover heats the soil and helps to control weeds.
- Straw
- Pine bark
- Flat stones (recommended for strawberries)
- Leaves
- Half matured compost: It Increases the soil life.

Drop irrigation is a good complement to the use of plastic mulching, but its use requires heavy investments and specific skill that can not be detailed in this manual.

6.3. Pest control

The environment created by a cultivated greenhouse can be favourable not only to crops but also to pests that are damaging crops. These pests can be weeds entering into competition with crops, insects feeding on these crops or vegetable diseases.

6.3.1. Weeds

The weeds entering into competition with crops should be manually removed. A transplanting tool can be used to remove roots. Hoeing regularly between lines helps to maintain the place clean from weeds. Always remove weeds before they can produce seeds. If a place is much infested with weed seeds the most efficient is to practice false sowing:

1. Prepare bed as if for sowing
2. Water
3. Wait until most weeds have germinated
4. Destroy weeds by hoeing

If necessary this process can be done two or three time before sowing, to reduce seed stock in the soil.

6.3.2. Insects

In the nature insect populations are in balance, because they all have predators and parasites. The populations are regulated. In a greenhouse environment only few vegetable species are growing and that doesn't allow this natural regulation. Sometimes a pest proliferation can happen, and affects seriously yields and product quality.

6.3.2.1. Prevention

The basis of organic growing is to create an environment favourable to insect parasites and predators to help the natural regulation. For that it is advisable to:

- Improve biodiversity by growing many different species and by letting few weeds grow in places where they don't enter in competition with crops
- Let a few vegetables (turnip, lettuce) flower, and grow flowers inside the greenhouses (many insect parasites need flowers).
- Make compost inside greenhouse (many insects develop on compost, it improves biodiversity)

- Ventilate greenhouse, avoid overheating
- Avoid spraying insecticides if not absolutely necessary because it would kill some useful insects.
- Grow Crops in association: some plants have a repulsive effect on some insects, especially aromatic plants (see §6.7 crop associations)
- Practice crop rotation (§ 6.6)

6.3.2.2. In case of pest invasion
Before engaging any action the insect must be identified, then specific action can be engaged. If specific insecticides are available in the market, they can be sprayed. Avoid the use of insecticides that would kill all insects including predators and parasites which are farmer helpers. If these are not available spray only on places were it is absolutely necessary.

Aphids
Main risk for greenhouse is aphids. These can be regulated by few solutions
- Put a handful of wood ashes on aphid colonies
- Spray milk + smashed garlic + water
- Boil 150 g soap, into 1l of water until complete dissolution. After cooling add 1 volume of oil (peanut oil) for 10 volumes of mixture, mix well. This can be stored in a bottle and sprayed when necessary after dilution (1 volume for 10 volumes of water).

Always use a specific sprayer for chemical pesticides. Never apply them by other means (watering can, sweeper...). Be aware that these are toxic products. Respect indicated quantities and dilution.

6.3.3. Diseases
Plant diseases are caused by fungus and bacteria. They often occur when immature compost or dung is used as fertiliser or excessive quantity of chemical fertiliser is brought.
To prevent these diseases:

- Use only very matured compost as organic fertiliser (cf §6.4.1)
- Practice crop rotation (see § 6.6).
- Use watering can, do not water by flooding
- Avoid excess of humidity by opening ventilation and by watering only in the morning
- Use disease free seeds

Disinfecting soil
For seedlings production only. If some young plants die just after germination because of soil born diseases, it can be necessary to disinfect the soil used for nursery production.
The soil can be disinfected by heating it: prepare it as a very fine sowing bed, perfectly levelled, water abundantly and apply a transparent polythene on it during one full week of sunny weather (figure 18), or put some wet soil in a metal container (or metal sheet) with fire under it (figure 19).

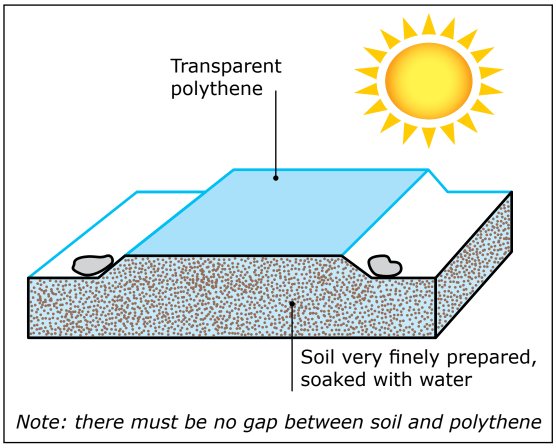


Figure 18: disinfecting soil by solar heating

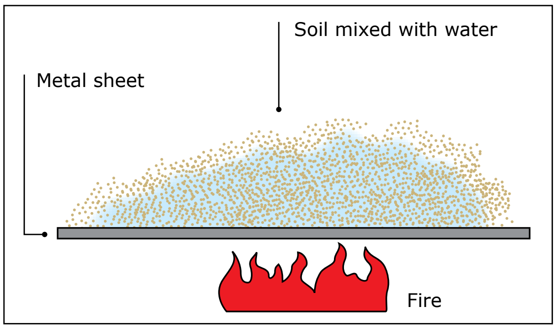


Figure 19: disinfecting soil using fire

Chemical treatments
Charcoal powder mixed with seeds helps to prevent diseases on seedlings. Seeds can also be bought in the market with fungicide treatment already done.

Other fungicides (copper or sulphur based) for agricultural use are usually available in the market. They can be sprayed on leaves, mixed with soil or mixed with seeds according to indications and purpose. Preventive treatments can be done.

6.4. Fertility management
As greenhouses are permanently in use, each harvest exporting minerals from soil, it is necessary to maintain fertility to prevent the soil from becoming very poor.

Minerals are nutritive elements for plants. Among them Nitrogen (N), Phosphorus (P) and Potassium (K) are the most important. These minerals are soluble in water. In the nature they are released by the decomposition of organic matters (dead plants, animal dung, leaves.) This decomposition process involves many microorganisms and insects. To release soluble minerals from organic matter these organisms require minerals to develop themselves. Therefore the decomposition process consumes minerals at its beginning and enters into competition with the plant nutritive needs at this moment. That is why it is not recommended to bring as fertiliser organic matter that is not already decomposed (as dung for example).

The objective of the farmer is to provide nutritive elements to the crop, to fulfil their needs. These needs are different from one crop to an other and vary also with stage (Table 4 gives needs in compost for different crops).

The highest needs are at the following stages:
- for leaf vegetables during vegetative growth (ex. after first harvest),
- for root vegetables at the beginning of root formation,
- for fruit vegetables at the beginning of fruit growing.

To reach these objectives different sources of nutritive elements are available:
- compost that is a stable organic matter after decomposition
- fertilisers: chemicals (Urea, Nitrates), ashes, that provide minerals

The compost is brought during soil preparation, as an amendment. Fertilisers can be used as a complements to bring during the periods of high needs. Compost and mineral fertilisers are complement because compost helps to store minerals that are soluble in water.

6.4.1. Compost

6.4.1.1. Definition
Composting is a natural process of decomposition of raw organic matters, monitored by farmer to produce a matured amendment. Compost releases soluble minerals to the soil , and contains humus which can store minerals and release them little by little. Presence of compost in the soil also improves soil structure (for root development) and water storage capacity. Compost amendment is the only way to improve soil fertility.
Technical data sheet 2 (§8.2) gives more details about compost (principles, how to make compost...)

6.4.1.2. Compost Use
The compost must be sieved before use.
Usually matured compost is incorporated in the first 5 cm layer of soil, according to the needs of the cultivated species, before sowing or before plantation. Compost need for most common vegetables are shown in table 4. Half matured compost and raw compost (that has not been sieved), covered with straw is also an excellent mulching material.

Table 4: Compost needs

Low needs	Medium needs	High needs
No compost supply	Less than 10 liters / m²= 3 kg / m2	10 to 20 liters / m² = 3 to 6 kg / m2
Garlic Onion Turnip Radish	Beet* Beet leaf Carrot* Coriander* Bean* Lettuce* Peas	Eggplant Celery* Cabbage* Cauliflower* Spinach* Chilly / Capsicum Tomato Cucurbits

* Need very matured compost

For the best use of compost, crop rotation must be practiced:
1. bring compost (15 to 20 litres/m²), to grow vegetables with high needs
2. on the same place, vegetable with medium needs,
3. on the same place, vegetable with low needs.

In this way, second and third crops will use the compost left by first crop.

6.4.2. Fertilisers
Fertilisers, like chemical fertilisers, wood ashes, chicken manure, can be used in low quantities as a complement when needs are high (at fruit formation stage for example). Among chemical fertilisers, complex fertilisers (N,P,K) should be preferred to others.

Excessive use of fertilisers can have damaging effect on soil and crop qualities and can lead to pollution.

6.5. Crop varieties, importance of seed quality

6.5.1. Commercial seed
For each cultivated species different varieties have been selected by seed companies. Each variety is adapted to special conditions or special uses. The selected varieties are fixed homogeneous and give good yields when grown in proper conditions.

Example:
Lettuce is one species. From this species different varieties have been selected, some are

forming heads (ex: "Iceberg"), others grow again after cutting (ex: "salad bowl"). Some are cold resistant ("winter marvel") others are more adapted to summer (they spend more time to reach flowering stage). Some varieties have soft leaves, other have crispy leaves, some are red coloured, others completely green.

It is not possible to make a list of all varieties for all species. Availability of commercialised varieties are not the same in all countries, their name can change. Usually seed companies edit catalogues where their varieties are described.

The choice of the variety is a very important step. It must be adapted to the growing period, to the greenhouse environment and also to the market demand. Success can depend on this choice. Only with experience the farmer will know the varieties he has access to.

The buyer should be watchful concerning indications on seed packaging:

- Package quality: should be closed, air tight.
- Best before date: should not be passed
- Germination rate: should be over 80%
- Genetic purity: should be over 95%

Buying good quality seeds is an investment that must be done because uncertain quality can lead to very poor yields despite all investments in time and money brought to the crop. If care is brought at the sowing time and to the nursery, a very little quantity of seeds is necessary.

Example:
10 g of tomato seeds can produce enough plants to fill a greenhouse (50 m2).
10 g of lettuce seeds can produce enough plants to fill a greenhouse.

Hybrids (F1), are much more expensive than fixed varieties, but are also much more productive and often resistant to some diseases. Seeds issued from hybrids must not be sown.

6.5.2. Local Varieties

Local varieties have a very high genetic diversity; these are more like diversified populations than homogeneous varieties. They are usually less productive than commercial varieties, but more resistant, easier to grow, and more adapted to local conditions.

Genetic diversity of "local" vegetable can be interesting if some selection is done to improve them. This can be easily done for some species for which present low risk of cross fertilisation between varieties (table 2). In this case plants kept for seed production should be selected for their qualities (yield, product qualities, precocity, and time before flowering...)

6.5.3. Producing seeds

Restrictions to own seed production:
Vegetables of Cruciferae family (cabbage, turnip, cauliflower, radish...) should not be reproduced by farmers because of easy crossing between very different varieties.

Carrots, celery can be multiplied, but there are risks of crossing between varieties, as for spinach, Swiss chard, beet and cucurbits.

Once harvested and dried, seeds must be stored in a dry place, packaged in paper envelopes or in a metal box. Their life time depends on species (see § Information on crops, Page 28). Hybrids (F1) usually found in market are more productive than fixed varieties but can not be reproduced by farmers.

6.6. Crop rotation

Crop rotation has been mentioned before as a necessity to reduce risks of diseases and damages due to insects and as a necessity to

Table 5: How to produce seeds

Vegetables	Organ to select	Process
Beans, peas	early formed pods	• let to dry completely on the plant • harvested and stored in a fresh and dry place
Eggplant, capsicum	seeds from early formed fruits that are very matured	• Let seeds dry during one or two weeks • store in a fresh and dry place
Tomato	seeds from early formed fruits that are very matured	• Put seeds with pulp into a bowl of spring water • After few days a fermentation happens. It purifies seeds: bad ones come to the surface, good ones sink to the bottom • Wash them in clean water • let them dry on an absorbent paper before storing them
Lettuce	large size plants that are late to flower	• Harvest seeds when they have dried

manage soil fertility. For that the farmer has to take into account:

- The crop family (Table 2)
- The need for compost (Table 4)
- The growing season (§ Information on crops, Page 28)
- The type of vegetable (fruit, leaf, roots)

On the same place, crop families should alternate, type of vegetable should alternate, taking into account the growing season and compost needs. Crop schedule and land occupation setting is a complex but necessary task.

Crop rotation: Method & Example:

1 - Make a list of the vegetables you want to grow:

- Cabbage, Turnip, Cauliflower, Onion, Radish, Carrot, Celery, Bean, Spinach, Pea, Lettuce, Coriander, Beet leaf.

Table 6: Main vegetable families

Asteracea	*Apiacea*	*Liliacea*	*Fabacea*	*Chenopodiacea*	*Solanacea*	*Brassicacea*	*Cucurbitacea*
Lettuce Endive	Carrots Celery Celery Coriander	Onion Garlic	Bean Peas	Beet leaf Beet Swiss chard	Eggplant Tomato Potato Capsicum Chilli	Cauliflower Cabbage Radish Turnip Mustard Broccoli	Pumpkin Cucumber Watermelon Melon Courgette Bottle gourd

Table 7

Year	Groups of same need & family	Family	Compost needs	
1	Turnip, Radish	*Brassicacea*	Low	
2	spinach, beet leaf	*Chenopodiacea*	High	Bring compost 6 kg/m² (***)
3	Carrot, coriander, celery	*Apiacea*	Medium	
4	Onion	*Liliacea*	Low	
5	Cauliflower, cabbage	*Brassicacea*	High	Bring compost 6 Kg/m² (***)
6	Bean, Peas	*Fabacea*	Medium	
7	Lettuce	*Asteracea*	Medium	Bring compost 2 kg/m² (**)
8	Back to 1			

Notice that group 1 and 5 are same family.

Table 8

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Plot 1	Turnip Radish	Spinach Beet leaf (***)	Carrot Celery Coriander	Onion	Cauliflower Cabbage (***)	Beans Peas	Lettuce (**)
Plot 2	Spinach Beet leaf (***)	Carrot Celery Coriander	Onion	Cauliflower Cabbage (***)	Beans Peas	Lettuce (**)	Turnip Radish
Plot 3	Carrot Celery Coriander	Onion	Cauliflower Cabbage (***)	Beans Peas	Lettuce (**)	Turnip Radish	Spinach Beet leaf (***)
Plot 4	Onion	Cauliflower Cabbage (***)	Beans Peas	Lettuce (**)	Turnip Radish	Spinach Beet leaf (***)	Carrot Celery Coriander
Plot 5	Cauliflower Cabbage (***)	Beans Peas	Lettuce (**)	Turnip Radish	Spinach Beet leaf (***)	Carrot Celery Coriander	Onion
Plot 6	Beans Peas	Lettuce (**)	Turnip Radish	Spinach Beet leaf (***)	Carrot Celery Coriander	Onion	Cauliflower Cabbage (***)
Plot 7	Lettuce (**)	Turnip Radish	Spinach Beet leaf (***)	Carrot Celery Coriander	Onion	Cauliflower Cabbage (***)	Beans Peas

2 - Put them in groups of same family and same compost needs.
3 - Order these groups in a logical succession for compost needs, avoiding same family to come back before 3 years. Notice that 1st position comes back after last position in a cycle way.
4 - Divide the land in same number of plots as group number (7 plots in Table 8) and affect 1 group to each plot.

6.7. Crop association

Definition:
Vegetables of different species are grown together. (ex: to alternate one line of radishes and one line of onions, picture 10).
Growing different vegetables in association can be profitable because some vegetables have positive effects on others. It can also help to the best use of the land. Long cycle vegetables can be combined with short cycle vegetables for better soil occupation.
Some vegetables can have protective effects on others concerning insects or diseases prevention. (ex: carrots + onion, coriander + carrot, cabbage + tomato).

It is necessary to respect planting distances for crops grown in association or competition will reduce to nothing all benefits of this method. The right distance between lines of two different vegetables is the sum of the specific distances divided by two.

Example:
- Distance between lines for carrot is 40 cm,
- For onion it is 30 cm,
- So distance between onion line and carrot line should be 35 cm.

Some associations can have also negative effect. Table 9 shows positive and negative associations.

Picture 10: crop association (onion and radish)

Table 9: Vegetable Associations

Crops	Bean	Cabbage	Carrot	Cauliflower	Celery	Cucumber	Eggplant	Garlic	Lettuce	Melon	Onion	Peas	Potato	Pumpkin	Radish	Spinach	Strawberry	Turnip	Tomato
Bean	P	P	P	P	P	P	P	**N**	P	P	**N**	P	P		P	P	P		P
Cabbage	P				P	P			P			P	P		**N**		**N**		P
Carrot	P								P		P	P			P				
Cauliflower	P				P	P						P	P				**N**		P
Celery	P	P		P		P						P							P
Cucumber	P	P		P	P				P			P	**N**						**N**
Eggplant	P												**N**						
Garlic	**N**											**N**							
Lettuce	P	P	P			P				P	P	P			P		P	P	
Melon	P								P										
Onion	**N**		P						P			**N**					P		P
Peas	P	P	P	P	P	P		**N**	P		**N**		P		P			P	
Potato	P	P		P		**N**	**N**					P		P					P
Pumpkin													P						
Radish	P	**N**	P						P			P				P			P
Spinach	P														P		P		
Strawberry	P	**N**		**N**					P		P					P			
Turnip									P			P							
Tomato	P	P		P	P	**N**					P		P		P				

P: association is positive **N**: association has negative effect

7. Information on crops

The following part will give some information necessary to grow each vegetable. These might have to be adapted to the growing seasons and to the specificity of the varieties.

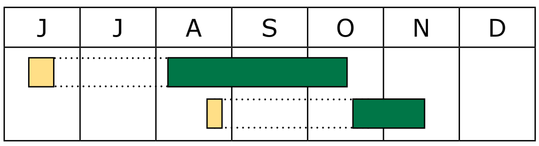
7.1. Bean

Latin Name: *Phaseolus Vulgaris*
L. Family: *Fabaceae*
Seed lifetime: 3 years
Germination in: 5 to 8 days
Compost needs: 3 Kg/m2, matured

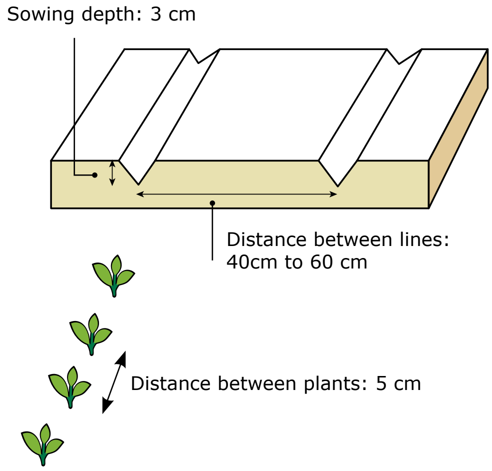
Temperature requirements
Soil for germination: 20 to 25°C
For vegetative growth: 15 to 25°C
Extremes: 10°C / 30°C

Special conditions: beans are very sensitive to any shortage of water and to overheating, especially when flowering. That is why a very good soil structure is very important to grow beans. The soil must not make a hard crust in surface during germination.

Growing periods inside greenhouse (for dwarf, mange-tout types)



Plantation: direct sowing



Special practices: When 2 leaves are well developed, bring some soil around the stems. Climbing types need stakes, dwarf type do not need. Harvest regularly.

Varieties: For some varieties the whole pod is consumed unmatured (before grain formation), as vegetable, for others the seed only can be consumed when dried (grains). For the Mange-tout types the whole pod can be consumed at a later stage (when grains are formed). Dwarf varieties are earlier (60 to 80 days) than climbing types (90 to 110) days for green beans.

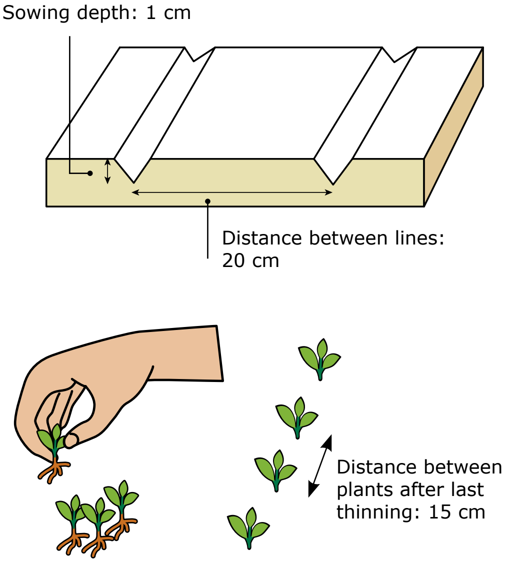
7.2. Beet leaf

Latin Name: *Beta vulgaris*
Other names: Palak(Hindi), Mongol (Ladakhi)
Family: *chenopodiaceae*
Seed lifetime: 6 years
Germination in: 10 days
Compost needs: 3 Kg/m2

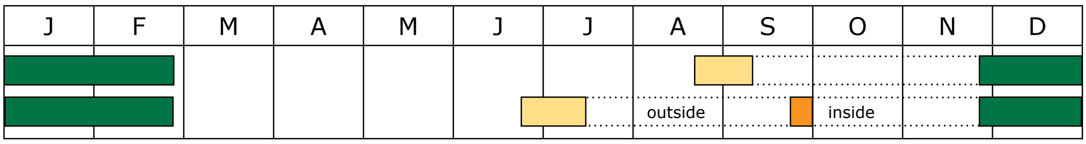
Temperature requirements
Soil for germination: 5 to 25 °C
For vegetative growth: 10 to 25°C
Extremes: -3°C

Special condition for flowering: warm temperatures after a cold period.
Special practices: Harvesting by cutting well developed leaves.
Roots can be transplanted from outside into the greenhouse in autumn.

Plantation: direct sowing and thinning



Growing periods inside greenhouse



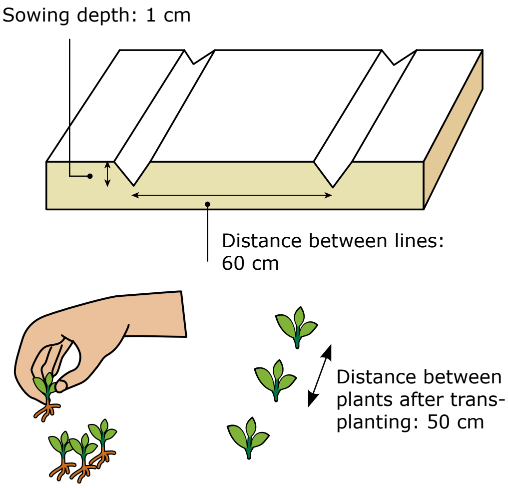
7.3. Cabbage

Latin Name: *Bassica oleracea L.*
Other names: Gobhi (Hindi), (Ladakhi)
Family: *Brassicaceae*
Seed lifetime: 5 years
Germination in: 7 to 10 days
Compost needs: 3 to 6 Kg/m2 , matured

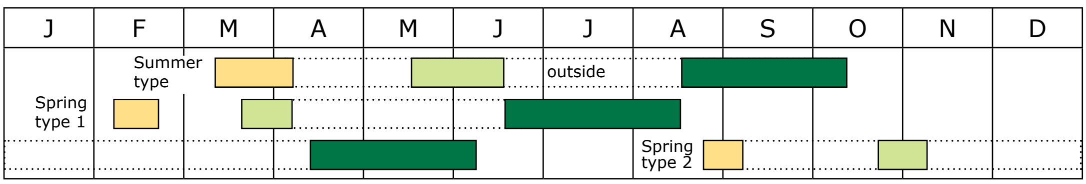
Temperature requirements
Soil for germination: 10 to 15°C
For vegetative growth: 10 to 15°C
Extremes: -3°C

Special condition for flowering: high temperatures after a cold period. Cabbage temperature requirements vary according to the variety (spring, summer or winter type).
Special practices: For summer types the greenhouse is only used to produce seedlings. Spring cabbage are sown in containers in a warm place (15°C) or in hot beds, they are transplanted when 2 leaves are developed (10 X 10 cm). They can be planted when 5 leaves at 50 X 40 cm, inside the greenhouse. In lower altitudes spring cabbages can be sown in autumn to harvest in early spring (next table type 2).

Plantation: sowing in nursery, transplant



Growing periods inside greenhouse



7.4. Carrot

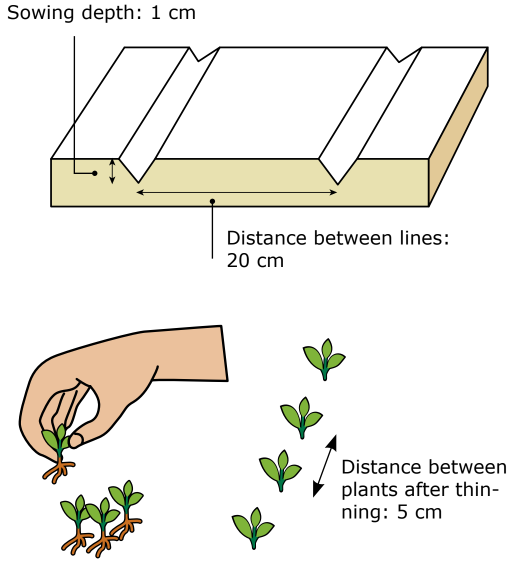
Latin Name: *Daucus carota L.*
Family: *Apiaceae*
Seed lifetime: 4 to 5 years
Germination in: 10 to 20 days
Compost needs: 3 Kg/m2 , matured

Temperature requirements
Soil for germination: 10 to 20°C
For vegetative growth: 9 to 18°C
Extremes: -3°C / 28°C

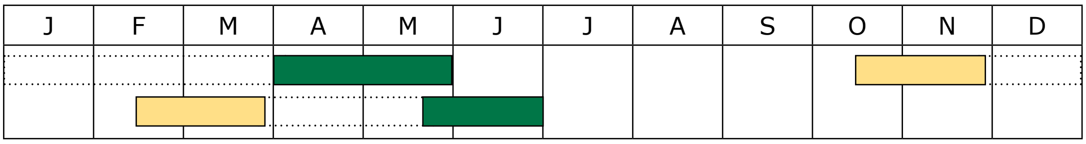
Special practices. Mix carrot seeds with sand before sowing to avoid very high density. Sowing bed must be very finely prepared.

Varieties. Prefer early types. Carrots can not be grown during winter in very high altitudes.

Plantation: direct sowing



Growing periods inside greenhouse



7.5. Cauliflower

Latin Name: *Brassica oleracera L.*
Other names: Phul Gobhi (Hindi, Ladakhi)
Family: *Brassicaceae*
Seed lifetime: 5 years
Germination in: 7 to 10 days
Compost needs: 3 to 6 Kg/m2 , matured

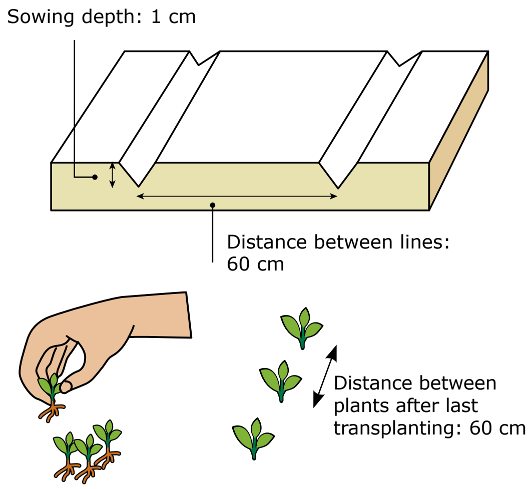
Temperature requirements
Soil for germination: 10 to 25°C
For vegetative growth: 18 to 22°C
Extremes: 5 to 25°C

Special condition for
- curd induction: temperature over 15°C
- curd formation: 5 to 25°C

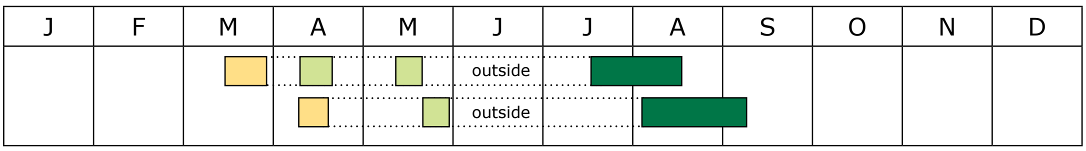
Temperature conditions are very important for cauliflower curd formation. Requirement vary with variety. Upper indications are for summer type varieties.

Special practices: first transplant at 3-4 leafs (10x10cm distance in greenhouse). After one month transplant outside at 60x60 cm. When transplanting select seedlings with one and only one bud.
Varieties: In high altitudes, due to a very short growing season, only early varieties and mid season varieties can be grown.

Plantation: sowing in nursery, transplant



Growing periods inside greenhouse



7.6. Cucumber

Latin Name: *Cucumis sativus L.*
Family: *Cucurbitaceae*
Seed lifetime: 5 years
Germination in: 6 days
Compost needs: 3 to 6 Kg/m2

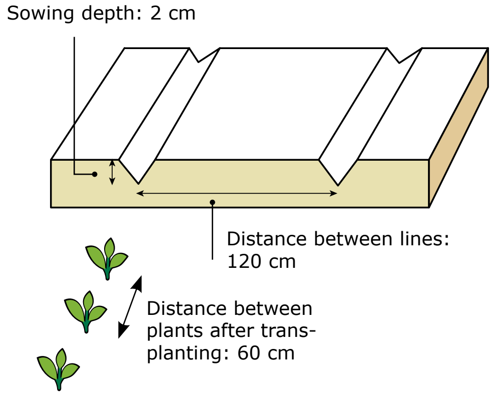
Temperature requirements
Soil for germination: 16 to 20°C
For vegetative growth: 20 to 28°C
Extremes: 8°C / 35°C

Cucumbers are adapted to tropical condition: warm temperatures but also high humidity are required. (Relative humidity from 65 to 85%).

Varieties: The use of hybrid varieties is recommended. They are much more productive than fixed varieties, resistant to diseases, and more adapted to greenhouse condition.

Special practices: Sow in a warm place (in pots, 13 cm diameter). Cut the main stem after the third leaf to get an earlier production. Transplant into the greenhouse. To save place in the greenhouse cucumbers can be attached to a mesh structure, 1,5 m high.

Plantation: Sowing in pots and transplanting



Growing periods inside greenhouse

J	F	M	A	M	J	J	A	S	O	N	D
				in a warm place	in GH						

7.7. Garlic

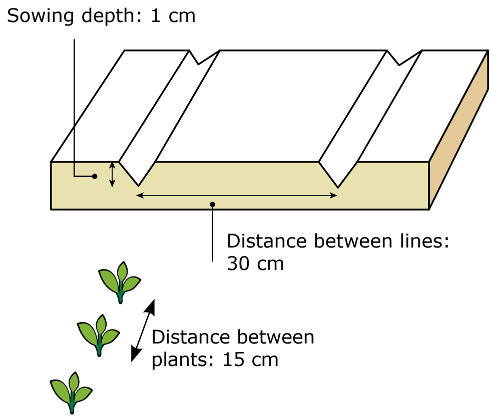
Latin Name: *Allium Sativum*
Family: *liliaceae*
Garlic produces no seeds,
only cloves are planted.
Germination 10 days.
Compost needs: no compost

Temperature requirements
Soil for germination: 17 to 18°C
For vegetative growth: 0 to 16°C
Extremes: -10°C / 20°C

Special condition for germination: cloves must be old enough to be able to germinate, they must be revived by coldness (7°C) during 8 to 16 weeks before sowing, depending on variety.
Special condition for bulb formation: high soil temperature (18 to 20°C) and long day.
Special condition for flowering: low temperature (<18°C) and long days

Special practices: Avoid humidity. Select big cloves for sowing. If flowering cut the flower stems. If the leaves are still green bend them on the floor one week before harvesting and stop watering.
Varieties: They have different needs concerning temperatures to revive cloves before sowing and concerning condition for bulb formation. Experimentation will help to choice a variety well adapted to the climate and day length.

Plantation: Direct sowing



Growing periods inside greenhouse

J	F	M	A	M	J	J	A	S	O	N	D

7.8. Lettuce

Latin Name: *Lactuca sativa*
Other names: Salad (Hindi), Ldums (Ladakhi)
Family: *asteraceae*

Seed lifetime: 4 to 5 years
Germination in: 4 to 6 days
Compost needs: 3 Kg/m2 , matured

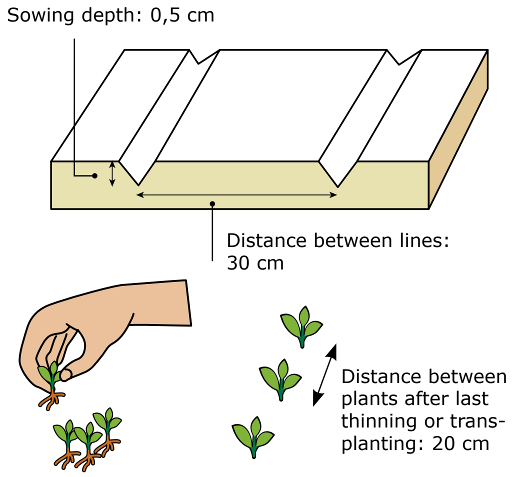
Temperature requirements
Soil for germination: 0 to 25°C, best 18 to 20°C. Use seeds from the year before
For vegetative growth: 7 to 20°C
Extremes: -5°C / 30°C

Special condition for flowering: warm temperature, water shortages

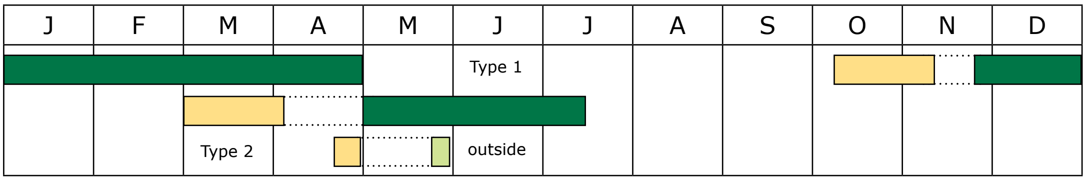
Special practices: For local varieties and cutting type lettuce (Salad bowl, Chinese yellow, Slobolt) distances can be reduced to 20 cm between lines and 15 cm between plants.

For these varieties harvesting by cutting big leafs Type 1. For varieties forming heads (great Lakes, Iceberg, Boston), head is cut once formed Type 2.

Plantation: Direct sowing / thinning / transplanting



Growing periods inside greenhouse



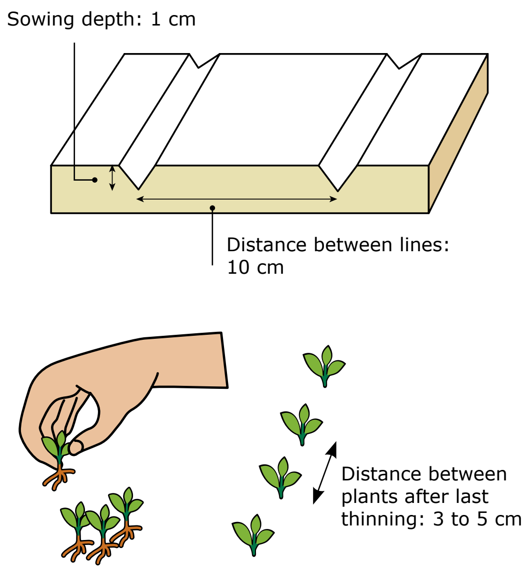
7.9. Radish

Latin Name: *Raphanus sativus L.*
Family: *Brassicaceae*
Seed lifetime: 4 years
Germination in: 2 to 5 days
Compost needs: no compost

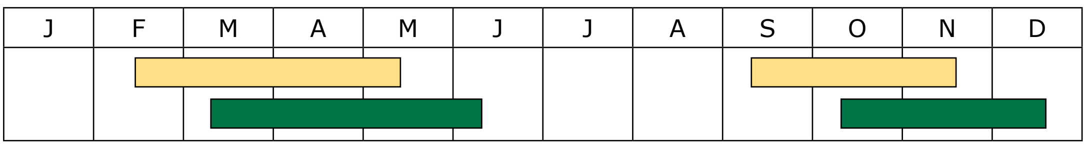
Temperature requirements
Soil for germination: 10 to 15°C
For vegetative growth: 14 to 18°C
Extremes: 6°C / 28°C

Varieties: small varieties are very quick 25 to 35 days. They can be easily sown between line of bigger vegetables to optimise soil occupation at the beginning of the cycle (carrots, lettuce, spinach). Round types must be sown in surface (2 mm deep). Bigger varieties are much longer to grow and must be grown at bigger distance (6 cm x 25 cm).

Plantation: direct sowing / thinning



Growing periods inside greenhouse



7.10. Marrow

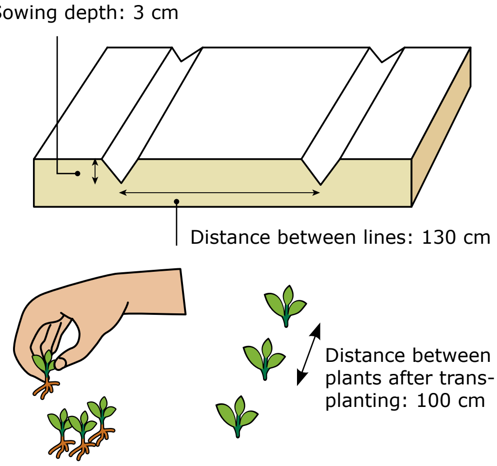
Latin Name: *Cucurbita Sp.*
Family: *Cucurbitaceae*
Other names: squash, courgette, pumpkin, cucurbit
Seed lifetime: 5 years
Germination in: 6 to 10 days
Compost needs: 3 to 6 Kg/m2 , Matured

Special condition for fruit formation: female flowers need to be fertilised to develop a fruit. Female and male flowers appear on the same plant, but males happen about 10 days after females. To ensure a good fertilisation at the beginning of the production it is advised to sow 10% of the plants 10 days before the others. These will produce male flowers in time to fertilise the first female flowers of the following 90%. Insects help fertilisation.

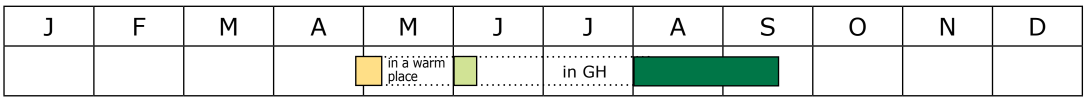
Temperature requirements
Soil for germination: 25°C
For vegetative growth: 16 to 25°C
Extremes: 5°C / 30°C

Special practices: Needs in water and organic matters (compost) are very high. Sow in pots 10 to 13 cm diameter in a heated place. Transplant in greenhouse when 4 leaves are developed.
Varieties: Many species and varieties of different shape and colour. Courgette (*Cucurbita pepo*) are harvested at a young stage. Pumpkin (*Cucurbita maxima*) harvested well matured can be preserved in a cellar.

Plantation: Sowing in pots and transplanting



Growing periods inside greenhouse



7.11. Swiss Chard

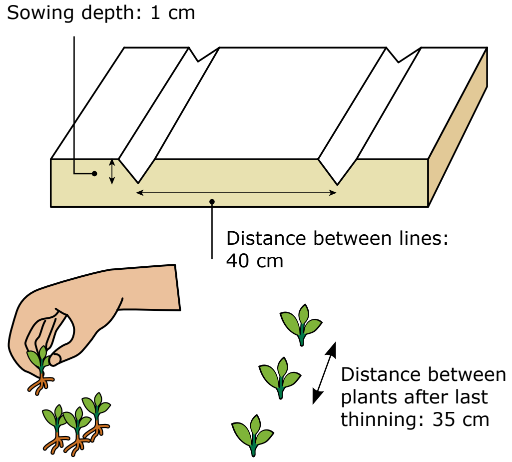
Latin Name: *Beta Vulgaris L.*
Family: *Chenopodiaceae*
Other names: Mongol (Ladakhi)
Seed lifetime: 5 years
Germination in: 10 to 12 days
Compost needs: 3 to 6 Kg/m2

Temperature requirements
Soil for germination: 5° to 25°C
For vegetative growth: 10 to 20°C
Extremes: -3°C / +28°C

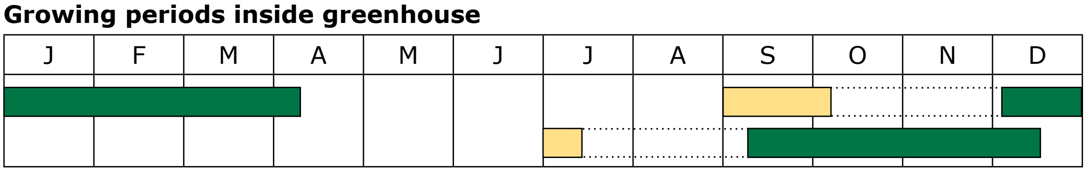
Special condition for flowering: warm temperature after a cold period.

Special practices: Harvest by cutting well developed leaves. When the plant flowers the leaves are no more edible.
Varieties: The Swiss Chard is an improved variety of the cutting type beet leaf (Mongol). It is a bigger plant and has very large stems that can be consumed as vegetables.

Plantation: sowing in nursery, transplant



Growing periods inside greenhouse



7.12. Peas

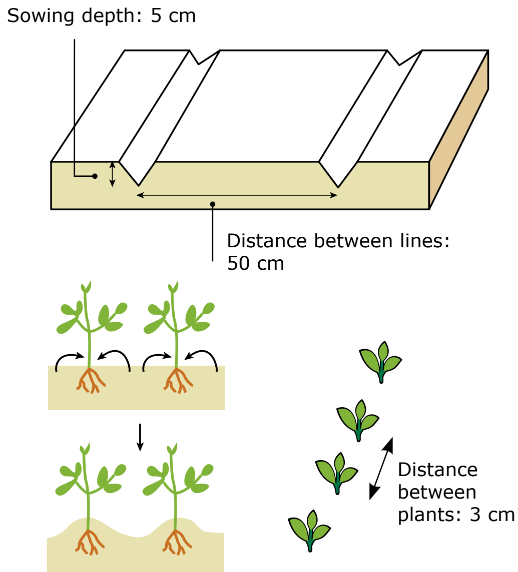
Latin Name: *Pisum sativum L.*
Family: *Fabaceae*
Seed lifetime: 3 years
Germination in: 7 to 15 days
Compost needs: 2 to 3 Kg/m2 , matured

Temperature requirements
Soil for germination: 10 to 15°C
For vegetative growth: 15 to 20°C
Extremes: -1°C /+35°C

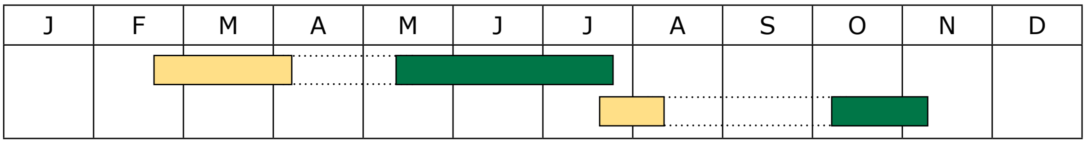
Peas are very sensitive to temperature conditions especially when flowering. Overheating or too cold conditions can lead to very poor yields.

Special practices. Climbing varieties (100 to 200 cm high) must be attached to stakes or mesh. When the plants are 15 cm high, bring some soil around the stem (next picture).
Varieties: high varieties are more productive, but dwarf ones are earlier. Wrinkled grain varieties are less resistant to coldness than round grain varieties but can resist better to overheating and their taste is sweeter.

Plantation: direct sowing



Growing periods inside greenhouse



7.13. Spinach

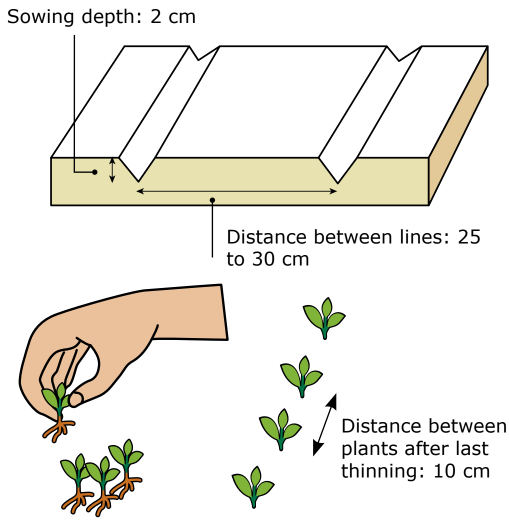
Latin Name: *Spinacia oleracera L.*
Other names: Vilayati palak (Hindi), palak (Ladakhi)
Family: *chenopodiaceae*
Seed lifetime: 4 years
Germination in: 6 to 10 days
Compost needs: 3 to 6 Kg/m2 , Matured

Temperature requirements
Soil for germination: 5 to 25°C
For vegetative growth: 10 to 25°C
Extremes: -7°C

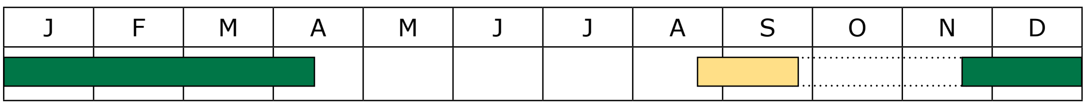
Special condition for flowering: long days and warm temperature after a cold period.

Special practices: Harvest by cutting well developed leaves. When the plant flowers the leaves are no more edible.
Varieties: Local varieties flower very early, as soon as days get longer and temperature higher. Some selected species do not flower so easily and can be harvested during a longer period. Some varieties can even be grown in summer time.

Plantation: direct sowing / thinning



Growing periods inside greenhouse



7.14. Tomato

Latin Name: *Lycopersicon esculentum P. Mill*
Family: *solanaceae*
Seed lifetime: 4 years
Germination in: 6 days
Compost needs: 3 to 6 Kg/m2 , half matured or matured

Temperature requirements
Soil for germination: 20 to 25°C
For vegetative growth: 16 to 18°C at night, 22 to 25°C during day time (if sunny weather)
Extremes: 12°C / 30°C

Special condition: when the weather is not sunny, tomatoes need lower temperatures to grow properly.

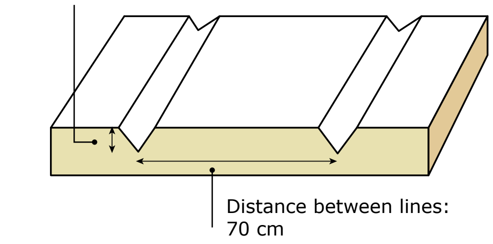
Special practices: Sow in a container distance 3 cm x 3 cm, in a warm and sunny place (heated room in the house), transplant in pots or greenhouse (hot bed) distance 10 x 10 cm when two leaves are developed. Plant when 5 leaves are developed.

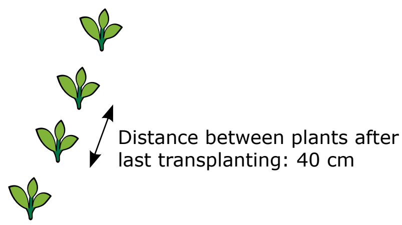
Varieties: Some varieties have a vegetative growth stopping after a time and the plant takes a bush shape.
For others (climbing varieties), vegetative growth does not stop. They have a longer harvest period and are therefore recommended for late production in greenhouses. They must be pruned (see next picture) and attached to a stake at the plantation.

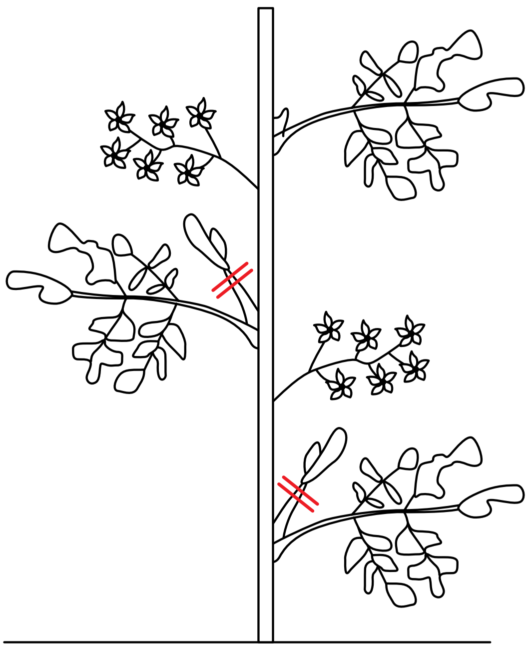
Hybrids (F1) are much more productive than fixed varieties.

Early varieties must be preferred in cold climates.

Plantation: sowing in nursery / transplanting





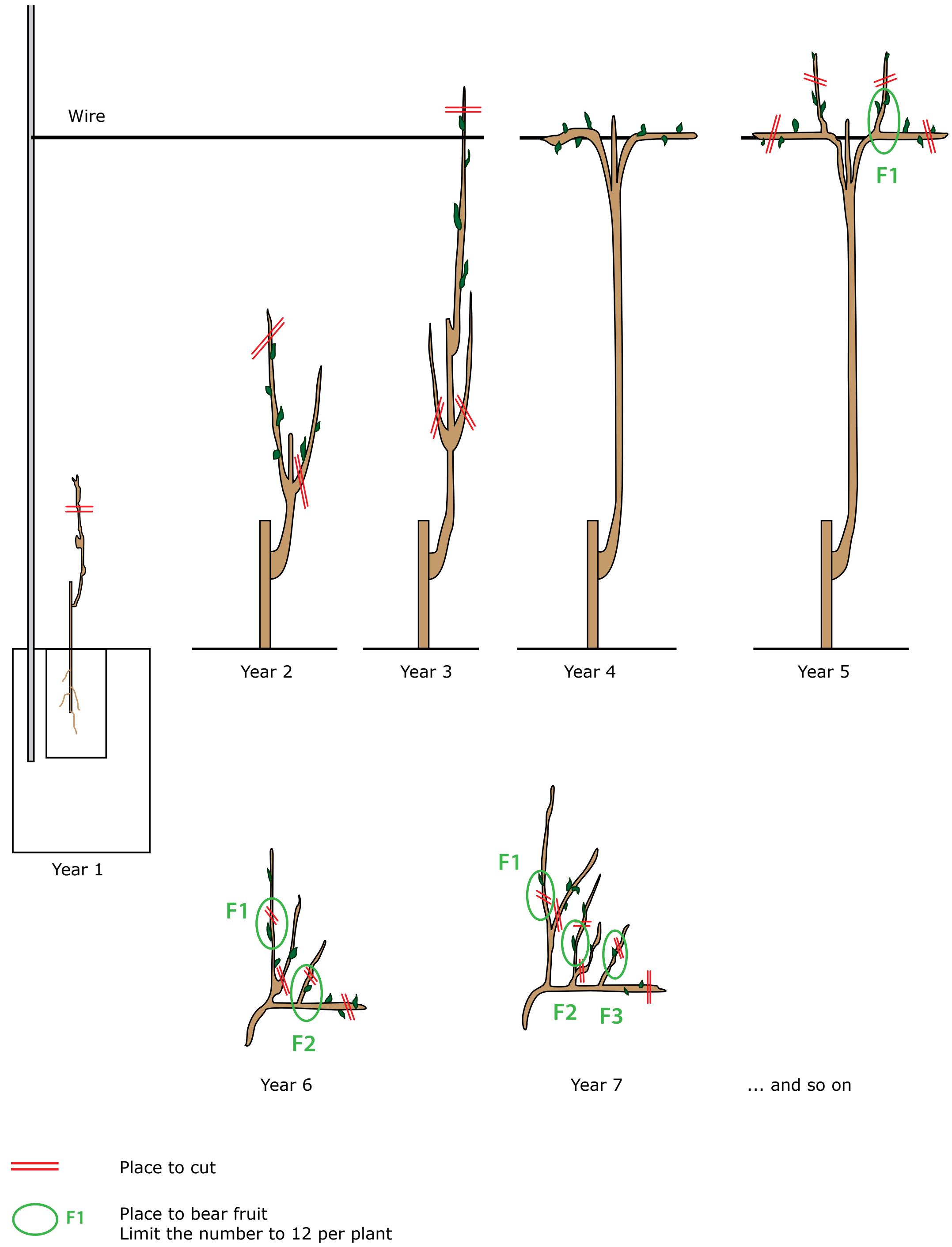


Growing periods inside greenhouse

J	F	M	A	M	J	J	A	S	O	N	D

7.15. Grapevine

Many greenhouse owners are growing a vine against the north wall of the greenhouse. To produce a good quantity of fruits it has to be pruned properly at the end of each winter. Years 1 to 4 pruning is to give its shape to the vine, then it is to induce fruit production. The plant is attached to a taut steel wire 50 to 100 cm high. Reproduction is done by a cutting.



7.16. Turnip

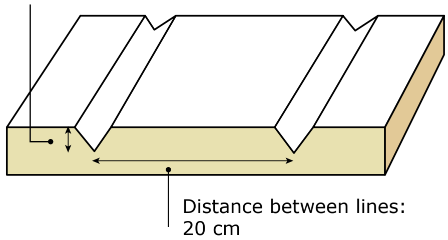
Latin Name: *Brassica rapa*
Family: *Brassicaceae*
Seed lifetime: 4 years
Germination in: 4 to 7 days
Compost needs: no compost

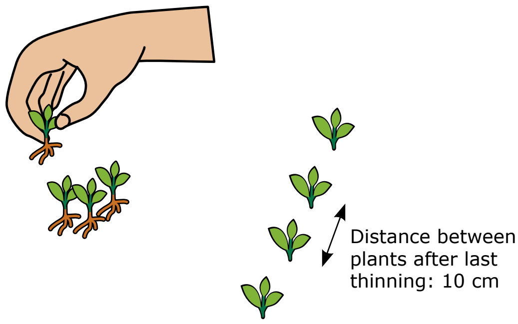
Temperature requirements
Soil for germination: 10 to 18°C
For vegetative growth: 8 to 20°C
Extremes: 1°C / 25°C

Special condition for flowering: high temperatures after a cold period. It is therefore difficult to grow in a greenhouse in spring time. It tends to flower very early and does not form a root to harvest.

Varieties: Some early varieties have been selected to grow under greenhouse. They can be grown in spring time. Others are more adapted to autumn.
Special practices: Avoiding overheating during the day and coldness at night is the key to prevent early flowering. It is also necessary to grow an early variety adapted to the greenhouse condition.

Plantation: direct sowing / thinning





Growing periods inside greenhouse

J	F	M	A	M	J	J	A	S	O	N	D
	Early types					Autumn type					

8. Appendix

8.1. Technical data sheet 1:

Uses of the greenhouse, a strategy depending on climatic and economic environment

Altitude (in Indian Western Himalayas conditions)
Very high: 3700 m and higher
High: 3200 – 3700 m
Medium: 2500 – 3200 m
The schedule in lower or higher altitude is advanced or postponed by two weeks

Table 10

Objective	**Summer season extension**			**Winter production**	
Crop Type	Temperate crops		Tropical crops	Cold adapted crops	Temperate crops
Specific Objective	Produce vegetables later than the normal period.	Produce vegetables later than the normal period. Increase production period of already grown vegetable by on root preservation	Produce vegetable that could not be grown outside at this altitude.	Produce vegetable when it is impossible to grow outside because of coldness.	Produce vegetable when it is impossible to grow outside because of coldness.
Strategy	Sowing in uncovered greenhouse	Transplanting root vegetable from outside to covered greenhouse	Sowing in a hot place, transplanting in a covered greenhouse	Under covered greenhouse	Under covered greenhouse
Concerned Vegetables	Lettuce Turnip (late varieties) Carrots Radish Cabbage (late varieties)	Beet leaf Swiss Chard Cabbage	Tomato Eggplant Capsicum Chillies Cucurbits	Spinach Local leaf vegetable (Idums, salad, mongol..) Cutting type lettuce	Cabbage Turnip Carrots Celery (local variety)
Period	Sowing: 15th July-7th August Earlier for very high altitude Later for low altitude	Transplanting end of September Earlier for very high altitude Later for low altitude	Sowing: 15th to 30th may Transplanting: 15th to 30th June,	Sowing or transplanting from outside (mongol): September (end) to mid October Earlier for very high altitude	Sowing: September (end) to mid October Later for medium to low altitude
Suitable environment	Altitudes: - very high - high - medium	Altitudes: - very high - high - medium	Altitudes: - high - medium Notice: On market, possible competition with low altitude production	Altitudes: - very high - high - medium	Altitudes: - high - medium

Objective	Spring production		Seeding production	
Crop Type	Temperate vegetables	Tropical vegetables	Temperate vegetables	Tropical vegetables
Specific Objective	Produce vegetables earlier than the normal period (harvest in June/ July)	Produce vegetables earlier than the normal period (harvest in June/ July)	In high altitudes allow to grow vegetables that could not be grown because of short summer season. In lower altitudes, allow to harvest earlier	Produce vegetables that could not be grown at this altitude.
Strategy	Sowing and growing under covered greenhouse	Sowing and growing under covered greenhouse	Sowing under a covered greenhouse then transplanting to outside	Sowing under a covered greenhouse then transplanting to outside
Concerned Vegetables	Cabbage Cauliflower Lettuce Turnip Radish Carrot Celery Swiss Chard (all early varieties)	Tomato Eggplant Capsicum Chillies Cucurbits	Cabbage Cauliflower Lettuce Celery	Tomato Capsicum Chillies
Period	Sowing period: 1st to 15th March Earlier for lower altitudes	Sowing period: beginning of February	Sowing period: April (10h to 20th) Transplanting outside after 1 month. Later for higher altitudes earlier for lower altitudes	Sowing period: 20th to 30th March (on hot place) transplant outside after one month
Suitable environment	Altitudes: high medium Notice: Soil occupation at the same time as seedling production.	Altitude: medium Notice: Soil occupation at the same time as seedling production.	Altitudes: very high high medium	Altitudes: medium Notice: competition possible with low altitude production

8.2. Technical data sheet 2: Compost

8.2.1. Definition and principles

Composting is the natural decomposition of raw organic matters into an amendment that contains nutritive elements for crops and humus for soil fertility.

Matured compost:
- improves soil structure that leads to best roots development, best water storage, erosion resistance, and fertility optimised,
- releases nutritive elements during years,
- activates life soil.

Producing and using compost is the only way to improve soil fertility.

The specific steps of composting (figure 20) are:
- fermentation: stage of intense decomposition,
- cooling: decomposition is going on, but slower,
- maturation: stage of humus production.

To make compost the farmer has to rear micro-organisms that decompose organic matters. So he must ensure them the suitable life conditions:
- food
- air (oxygen)
- water
- moderate temperature

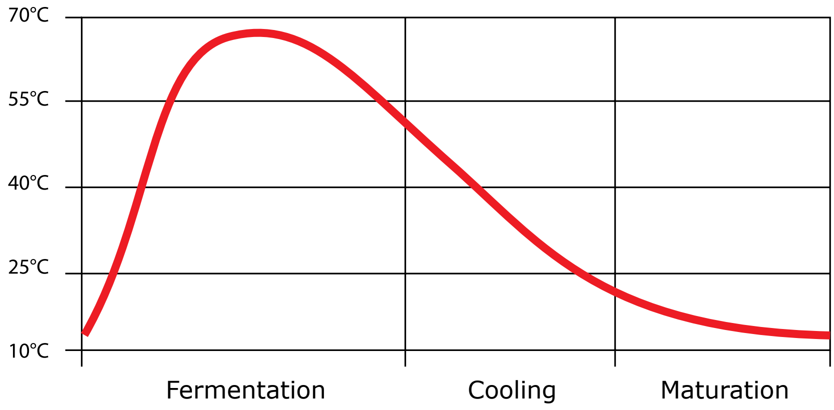


Figure 20:: temperature evolution during composting

Table 11: Composting principles

Micro-organism needs	To make compost
Balanced "food"	Organic matters have different composition. Some are rich in Carbon (C) other are rich in Nitrogen (N). They should be mixed in balanced proportion.
Water	Compost should always be wet
Air	Compost should be aerated, by frequent turnings and by putting a pruned sticks layer at the bottom.
Suitable climate	In very cold climate, an energy efficient design is required to heat the matter

8.2.2. Trench construction

The compost process takes place in a trench that provides aerated and warm conditions. This trench is 6′ long, 4′ wide and 3′ deep (see design) so its volume is 2m² (figure21).

The structure is designed following a passive solar concept:

- it is built along an east-west axis (+/- 25°) to collect the maximum amount of solar radiation
- the pit is dug to reduce the heat loss
- a double transparent polythene cover transmits the solar radiation to warm the matter with greenhouse effect.

The walls, constructed by a 18″ stone masonry, are neither cemented nor plastered to allow good air circulation. Banked earth are added on the north, east and west sides above the ground to reduce the heat loss through the external walls.
The bottom of the trench is filled by a 4″ layer of pruned sticks (6 to 8″ long, less than 1/2″ thick) so that air can be exchanged with the ground.

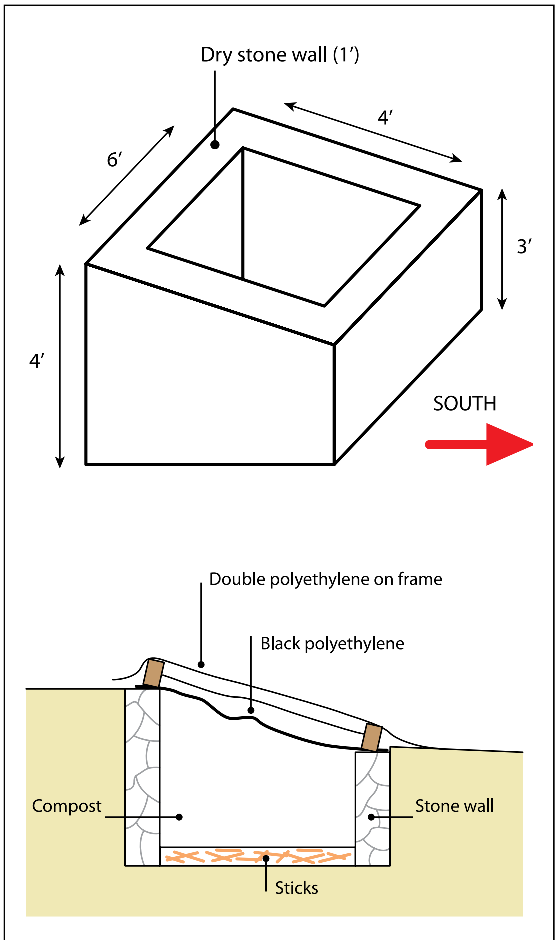


Figure 21: Compost trench designed for cold climates.
Walls are not cemented to allow good air circulation.

Two transparent polythene sheets are fixed on both sides of a wooden frame (3″x 2″x 2″) to cover the pit (see design). Theses two sheets should be tied and not in contact each other so that the air gap acts as insulator. The polythene angle is 20° to collect a larger amount of solar radiation and to drain out the rainwater.

Having two trenches can be very useful because it allows to have ready compost permanently (one ferments while the other matures).

8.2.3. Compost production

Raw organic matters
To make compost, materials must be mixed according to their opposite properties:

- matters rich in Carbon, that are also generally "dried" and structured,
- with matters rich in Nitrogen, also "wet" and settled.

Materials must be stored in a dry place until compost is started.

In Trans Himalayan areas, commonly available materials for composting are:

Ingredients	Carbon	Nitrogen
Dried tree leaves (poplar, willow)	+++	
Agriculture wastes	++	+
Grass, weeds (avoid grass with seeds)	++	+
Sawdust & chicken drops (litter)	+++	++
Horse and donkey dung	++	++
Kitchen waste	+	++
Cow dung	+	+++
Human excrement		++++
Chicken excrement		++++

Some examples of well balanced mixtures:
Material rich in Carbon must represent at least 70% of global volume.

Example 1:

- Leaves 50%
- Horse dung 40%
- Kitchen waste or cow dung 10%

Example 2:

- Leaves 80%
- Grass 5%
- Chicken excrements or cow dung 15%

To start the composting
Different steps:

1. Mix ingredients (picture 10)
2. Add water so that it is wet, but not soaked
3. Fill compost trench above the layer of sticks up to the top
4. Cover with a 2'' mud layer and black polythene
5. Close the trench with the double polythene on a frame

Compost evolution
Two or three days after having filled the trench, fermentation starts and the compost temperature increases. If the matter is well aerated, temperature rises up to 50°C – 70°C. This stage is very important because high temperature can kill the germs that might be in the compost if infected excrement or infected plants have been included. This temperature can kill also weed seeds.

During first 2 months, each compost turning activates the fermentation. If the weather is very cold, the fermentation can be slower to start and can be helped by watering with fertilisers (Nitrates, urea), but in low quantities (200 g for a trench). Wood ashes and old compost can also help to initiate the fermentation.

When fermentation processed has finished, cooling phase starts. The compost progressively reaches the ambient temperature. Then maturation takes 5 to 7 months, with insects and worms appearing inside the compost.
During this process, the original materials progressively change their colour, shape and smell until the compost becomes matured with:

- light organic soil aspect
- dark brown colour
- humus smell
- only few original materials can be identified

All the process can take between 6 to 10 months to get matured compost.

Picture 10: preparation of mixture

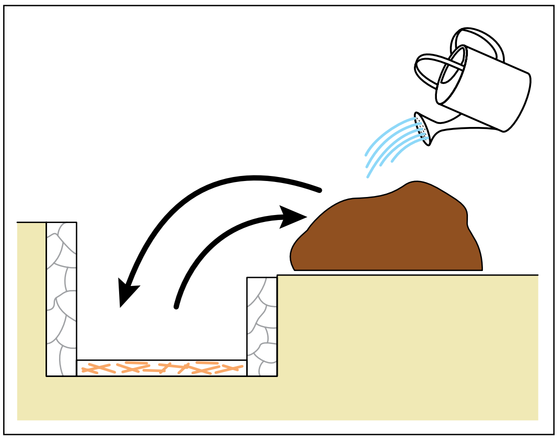


Figure 22: turning Compost

Turning compost (figure 22)
During the composting, the farmer must turn and stir the matter in order to:

- aerate homogeneously the matter
- get the same decomposition in all matter,
- check the process conditions (air, water...) and add water if necessary.

Turning frequency
During the first month, empty trench and fill it again every week, adjusting humidity level by adding water if necessary.
During next 5 months turn compost once a month, adjusting humidity when necessary.

To check compost humidity
Press hardly a handful of compost: just a drop of water should come out. If more, it is too wet, if nothing drops, it is too dry.

8.2.4. Compost Use

The compost must be sieved before use.
Usually matured compost is incorporated in the first 5 cm layer of soil, according to the needs of the cultivated species, before sowing or before plantation. Compost needs for most common vegetables are shown in table 12.

For the best use of compost, crop rotation must be practiced:

Season 1: bring compost (15 to 20 litres/ m^2), to grow vegetables with high needs

Season 2: on the same place, vegetable with medium needs,

Season 3: on the same place, vegetable with low needs.

In this way, the second and third crops will use the compost left by the first crop.
Half matured compost (after 4 months) and raw compost (that has not been sieved), covered with straw is also an excellent mulching material.

Table 12: Compost needs for different vegetables

Low needs No compost supply	Medium needs Less than 10 liters / m^2= 3 kg / m2	High needs 10 to 20 liters / m^2 = 3 to 6 kg / m2
Garlic Onion Turnip Radish	Beet* Beet leaf Carrot* Coriander* Bean* Lettuce* Peas	Eggplant Celery* Cabbage* Cauliflower* Spinach* Chilly / Capsicum Tomato Cucurbits

* Need very matured compost

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