Agrodok 10

Soya and other leguminous crops

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Foreword

This Agrodok is based on a previous shorter edition, Soya. The text has been extended to include more practical information on growing and processing soya and other legumes into nutritious food products. We have included other legumes so that the information in the book will be useful in more areas.

Soya is a legume with many good qualities, and it can be used to improve farming systems. It can also be processed into products which contribute to the daily diet and to family income. In this new edition we devote extra attention to this crop. There are also many areas however where soya cannot be cultivated, but other legumes do grow well and have many of the same good qualities.

This Agrodok is intended to help farmers and extension workers to make choices that will work well under local conditions.

Contents

1 Introduction

Many farmers face urgent problems of making sure there is enough food for their families for the whole year and earning sufficient income. Population growth and the increasing size of cities and towns mean that the amount of land available to grow food for each family is decreasing. Yields are not always high and the prices of agricultural products are generally declining. The amount of money available to buy food if it cannot be grown, to provide housing, travel and medical costs is also decreasing. The costs of agriculture are rising; artificial fertilizers and other chemicals are becoming more expensive, while farmers are not able to increase the prices of their products. There is a shortage of food both in terms of quantity, but also quality: the amount of nutrients in food that children need to grow and adults to stay strong and healthy is often too low.

By growing legumes farmers can do something about these problems.

Legumes take up nitrogen from the air and pass it on to the soil, thereby improving soil fertility. The yields of crops grown on the same land after the legume crop will increase. In addition legumes are nutritious, and may provide income opportunities. Products made from soya and other legumes can be eaten or sold.

This Agrodok is intended for farmers who want to know more about legumes and for extension workers who want to assist the farmers. The answers to the following questions can be found in this book:

- What are legumes?
- How can I cultivate them?
- What products can be made from soya and other legumes?

2 The importance of legumes

Plants that belong to the legume family (*Leguminosae*) have pods in which beans grow. Legumes possess an important characteristic, which is their ability to bsorb nitrogen from the air. Many crops that are unable to do this are dependent on the nitrogen that is present in the soil. Most soils in tropical areas do not contain sufficient nitrogen, an important nutrient. For this reason growing legumes (in addition to other staple crops such as potatoes, maize and rice) is a good way for farmers in tropical areas to enrich the soil. The legume crops also provide extra food for the daily diet of both humans and animals.

The nitrogen that the legume crop absorbs from the air is used for its own growth and is stored in the root nodules. When the crop is harvested the roots are left in the ground, where they decompose, releasing the nitrogen into the soil. This nitrogen can then be used by the next crop that is planted in the same field. The pods contain beans that are easy to prepare. Legumes must never be eaten raw. Nevertheless they have so many advantages that it is worthwhile growing and processing them. Soya beans are a legume that is very rich in nutrients and there are a number of products that can only be made from soya. Soya beans and soya products can also be sold and can therefore be a source of extra income. This Agrodok about legumes focuses on soya for these reasons.

2.1 Legumes

Legume crops provide dried beans for human consumption and are grown all over the world (see table 1). Some beans are a good source of oil (groundnuts and soya beans), others are good for cooking, either as whole beans or pulses or as split beans or peas. Some beans are ground into flour which is used to prepare a number of foods. After the beans have been harvested the crop remains make a good source of animal feed. They can also be dug into the soil so that they improve the

fertility of the soil. Some legume crops can be grown in combination with a grain crop, which helps to increase yields and soil fertility. Cowpeas are often grown together with millet or maize (Agrodok 2: Soil Fertility Management).

There are other legume crops that are especially suitable for green manure. The crop is sown and when it is fully grown it is ploughed under without being harvested. However, because these crops do not have direct economic returns it is more difficult to motivate farmers to use these. Finally there are legumes that make good ground cover. These are sown between the rows of a crop that does not cover the soil, such as maize (Agrodok 2: Soil Fertility Management).

Uses of legume crops

crop
- combine with other crops to improve soil fertility
- green manure
- ground cover

crop remains
- animal feed
- worked into the soil to improve soil fertility

beans
- important source of vegetable oil
- cooked or eaten as pulses and split peas
- ground into flour for cooking

Table 1: Worldwide production of legumes as dried beans: peas, lima beans, cowpea, chickpea etc.
(ACIAR Proceedings no.18, 1986)

Continent/country	Production (1000 ton)	Yield (kg/ha)
Africa	7 026	646
Ivory Coast	8	672
Tanzania	362	539
Zaire	127	634
Zimbabwe	51	734
America	6 847	644
Argentina	273	1 020
Mexico	1 331	648
Paraguay	39	713
Asia	24 551	688
China	5 640	1 276
India	12 985	544
Indonesia	354	829
Europe	5 294	1 632
World	55 200	807

2.2 Soya

Table 2 below indicates that soya is grown in many areas of the world: in North and South America and in Europe agricultural production is mechanized, in Asia production is small scale and largely done by hand. Soya has only recently been introduced in Africa, while it has been grown and processed for many centuries throughout Asia.

In Bolivia in South America, soya is grown for oil which is processed industrially. Bolivian soya oil was first sold on the world market in 1985, and since then production has increased considerably. The total area in Bolivia planted with soya increased from 60,000 hectares to 330,000 hectares in the summer of 1994 – 1995.

Table 2: Worldwide cultivation of soya by region in 1996 (Meneses et al., 1996)		
Region (country)	Hectares (1000 ha)	Yield (kg/ hectare)
Worldwide	57 778	1 920
Africa (Nigeria)	401	1 270
Asia (China, India)	15 439	1 340
Europe (Italy)	547	2 840
North America	23 837	2 170
South America	16 787	2 140

3 Cultivation requirements for legumes

This chapter is about how to grow soya and other legume crops. To grow legumes successfully farmers need to know about the following:

- climate requirements
- soil type and soil fertility requirements
- when to sow
- suitable varieties
- how to combine legume crops with other activities on the farm

Practical examples show how legumes can be integrated into local farming systems and under which conditions legumes grow well in different areas of the world.

3.1 Suitable areas

Legumes and soya can be grown under a wide range of agroclimatic conditions. We list the main ones here to give the reader an idea of the variety of conditions under which legumes do well.

Upland river terraces and hills where shifting cultivation takes place

Shifting cultivation is a system in which farmers cut down an area of trees, burn the remaining vegetation and use the land they have cleared for agriculture. The ash from the burned material contains a lot of nutrients, so the soil is fertile and in the first season crops with high nutrient requirements can be grown. In the following seasons other crops are grown.

In traditional shifting cultivation systems a piece of land was usually used for three or four years, after which the soil was exhausted and

Fig. 1:
Example of shifting cultivation where not all trees have been felled.

weeds would start to take over. The land would then be left fallow for a period of 10 to 15 years, giving the soil time to recover after which the cycle would start again. This system is now under pressure however as the fallow period becomes shorter, and the soil and vegetation have less and less time to regain fertility. In many places land is cultivated after each rainy season; weeds become more and more difficult to control and soil fertility is decreasing. The lack of nitrogen in the soil is a big problem. Legumes can help to restore nitrogen deficiencies and stop weeds taking over. For example, *Mucuna utilis* can help to suppress Imperata, a stubborn grassy weed which prevents farmers from cultivating land.

Lowland along rivers and coastal areas where rice is often grown

The soils in these areas are surrounded by rivers. Coastal areas where mangroves used to grow are often not suitable for legumes as they are too acid once they have dried out after the rice harvest. Other soils in these areas which are not subjected to salt water are less acid and more suitable for agriculture. If these areas are submerged under water during the rainy season, rice is the only crop that can be grown. If the water recedes after the rice harvest, legumes can be grown as a second crop, making use of the moisture that remains in the soil. If it is possible to irrigate, the land can also be used in the dry season.

Highland areas

Many legume food crops are grown at altitudes above 1000 metres. Highland areas are characterized by low temperatures, dryness and a relatively short growing season. The fields are often small, which makes

it difficult to use machines. Farmers work the land by hand or using animal traction. Legumes are grown on their own or in combination with other crops such as maize. The yields are often low, but the beans are an important source of protein for many families. Legumes such as chickpeas, peas, broad beans and lentils are grown in areas where the soils are poor because they are resistant to drought, and the crop remains can be used as animal feed.

Erosion is a common problem in these marginal areas. In some areas farmers work the land in such a way as to ensure that the ridges run horizontally as far as possible, following the contour lines. Rainwater is caught by the ridges and so seeps down slowly into the soil. If the ridges are made that follow the slope, rainwater runs off quickly, taking soil with it and causing erosion. If the rainfall is very heavy the soil cannot always absorb the water quickly enough. The water will then flow over the ridges, breaking them and causing serious erosion. In areas where this is a problem it is better to build the ridges diagonally over the slopes, so that some of the water is caught and can seep into the soil, and the rest can run off.

In the Bolivian highlands, where the amount of rainfall varies a lot, traditional methods are used to try and predict how much rain is likely to fall. If a lot of rain is expected the ridges are dug so that they run more in the direction of the slope; if less rain is expected the ridges are made so that they run more or less parallel with the contour lines.

3.2 Climate

Using local climate data and the data in Appendix 1 you can start to decide which legumes may be suitable to grow in your area. Some legumes grow better in cooler climates, where there are cold periods, others do better in a humid and warm climate, such as lowland areas in the tropics. Others are adapted to extremely arid and hot conditions.

Legumes for different climates

Food legumes as a group have a very wide range of adaptability with respect to latitude, temperature, day length and humidity. While some of them grow optimally at relatively low temperatures in long days, others flourish at high temperatures associated with a day length of 12 hours or more. This is perhaps one of the reasons that in almost every conceivable climate one food legume or other exists. Nevertheless, the fact remains that the adaptability of each species or cultivar individually is rather restricted (Sinha, 1977).

Cool climates with cold periods at high latitudes or in higher areas of the tropics

Beans grown in moderate climates come from western Asia and the Mediterranean, where they have been grown for thousands of years. These include lentils (*Lens culinaris*), peas (*Pisum sativa*), kidney beans (*Phaseolus sp.*) and chickpeas (*Cicer arietinum*). The cultivation of these crops spread over time to the Indian subcontinent and China. Peas and broad beans (*Vicia faba*) also spread northwards to the cooler areas of northern Europe, and later were also taken to North and South America, Australia and South Africa. They are also found in highland areas of African countries such as Ethiopia and Kenya.

Humid tropical climates

Soya (*Glycine max*) and pigeon peas (*Cajanus cajan*) are suitable for warm, humid climates.

Hot arid climates

Cowpea (*Vigna inguiculata*), green gram (*Vigna aureus*), black gram (*Vigna mungo*) and groundnut (*Arachis hypogaea*) can tolerate extreme dryness and high temperatures. Groundnuts, for example, are grown in semi-arid and low-humid tropical areas of Africa, Southeast Asia and Central America between 30° North and 30° South.

Climate requirements for soya

In Bolivia soya is grown in the subtropical areas between 15° and 20° South, at low altitudes (< 700 metres above sea level) where temperatures are quite high (22 – 32°C), relative humidity is high (> 65%), day length is short (12 – 13 hours) and annual rainfall is between 800 and 1300mm.

The minimum temperature at which soya develops is 10°C, the optimal temperature is 22°C and the maximum is about 40°C. The seeds germinate well at temperatures between 15°C and 40°C, the optimal temperature being about 30°C.

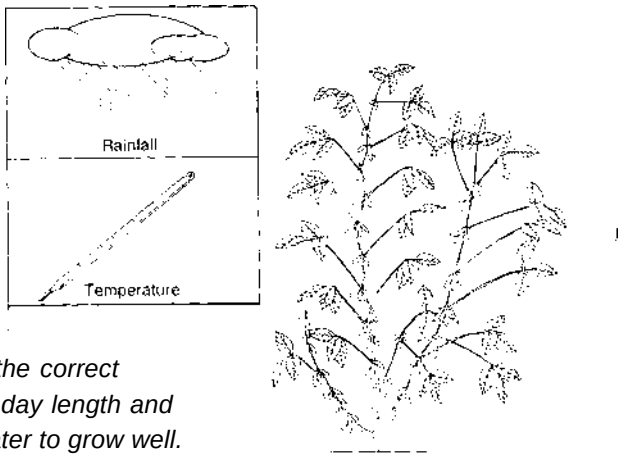


Fig. 2: Soya needs the correct temperature, day length and amount of water to grow well.

Adaptation to cold

Much soya is grown in areas with temperatures around 25°C – 30°C. It seems that night-time temperature has a greater influence on the crop than daytime temperature. If the night-time temperature falls below the critical level of 10°C the crop will undergo more damage than if the night-time temperature stays above 10°C, regardless of the optimal daytime temperature range of 25°C – 30°C.

In Tokachi (Japan, between 42°20' and 43°30' N) soya yields per hectare are considerably lower in years when the temperature is cooler than average. When temperatures are lower the soya flowers later, ripens later, develops fewer pods and produces a lower weight of beans.

Generally speaking, cultivars with big seeds, pubescent (hairy), wide leaves and vigorous early-stage growth have relatively good yields in cool years. Glabrous (smooth-leaved), less robust cultivars form fewer beans and have lower yields. There is a clear connection between early-stage growth vigour and yield. The better the plant develops in the early stages of growth the higher the bean yield will be, especially under cool temperatures. Cultivars with small seeds germinate quickly, but are not resistant to cold temperatures.

Water requirements

Soya has two critical periods concerning water requirements: from sowing to germination, and the period during which the beans grow in the pods. Before a seed can germinate it needs to absorb 50% of its weight in water. Nevertheless during the germination phase too much water causes more damage than too little water. The soil needs to be between 50% and 85% saturated with water. The amount of water needed increases as the crop grows, reaching its maximum as the beans develop in the pods (7 – 8 mm per day), and then decreases again. To be sure of a good yield, soya needs between 450 and 800 mm water each day during its whole growth cycle, depending on the climate. In high temperatures more water evaporates, so more rainfall is needed to provide the crop with enough water.

3.3 Varieties and cultivars

Legumes

Fig. 3: Seeds of different types of legumes. Note the differences in shape and size!

Local varieties of most sorts of legumes have developed and many agricultural institutes all over the world have bred cultivars with desirable characteristics such as resistance to disease and pests, higher yields and shorter ripening time. Farmers often know a lot about local varieties and the conditions under which they grow well. They often grow different varieties of the same crop in order to spread their risks. If a field sown with one variety suffers damage in the form of disease, pests or bad weather, it is still possible that a field with a different variety will suffer less from the problems. The cultivars developed by agricultural test stations can often be a good addition. In cases where a new type of legume is introduced, farmers often have no choice but to use the cultivars offered by the local agricultural institute. The choice is usually too limited to be able to spread risks. The introduction of a single cultivar or variety carries high risks for farmers. If a new legume crop is to be introduced into a certain area it is important to ensure that farmers can choose between a number of cultivars and/or varieties. If this is not possible it is recommended that different types of legume crops are introduced (Appendix 1).

Different varieties of a crop have different genetic characteristics. The differences have arisen as a result of the crop being cultivated under different conditions to which it has adapted.

Cultivars also have different genetic characteristics, but these have arisen through cross breeding or genetic manipulation under controlled conditions, for example in an agricultural institute.

Day-length sensitivity will determine the choice of legume made, not only the type but also the variety. (Labour requirements are also important when choosing a variety. See paragraph 4.4.)

Soya

Soya is a short-day plant, and is sensitive to day length. It flowers when the day length is shorter than 16 hours. Short-cycle varieties flower 30 – 35 days after sowing and ripen within 75 – 105 days. These varieties have low yields. The middle-length varieties also flower 30 – 35 days after sowing and mature within 110 – 140 days. These have good yields. The long-cycle varieties produce a large amount of leaf material.

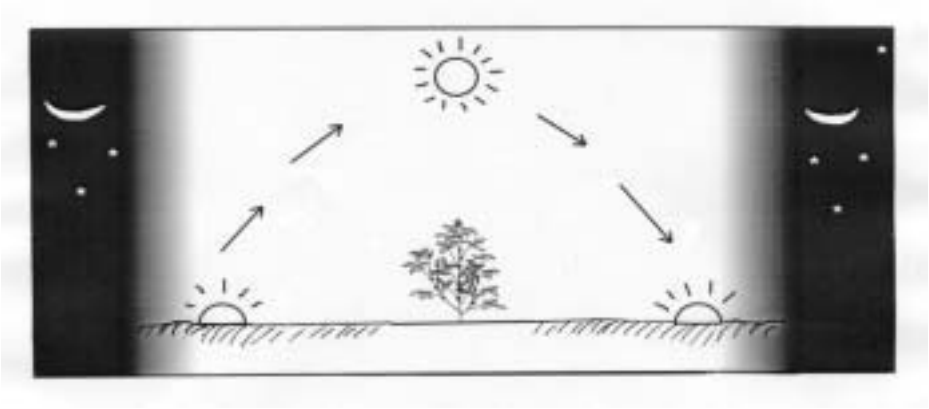


Fig. 4: Day length: soya flowers when the day length is shorter than 12 – 14 hours.

In integrated farming systems where livestock are raised this soya leaf material is an attractive form of animal feed; it is easily digestible and contains a lot of protein. In Ivory Coast (West Africa) short-cycle varieties do better because the rainy season is short.

3.4 Soil

If legumes are to grow well, the soil must fulfil certain requirements. You can find more information on these in the tables in Appendix 1. However, it is not a one-sided relationship. Legumes also contribute to soil fertility, which is good for the crops grown after the legume crop.

Soil conditions

Legumes grow in different soils, even very acid soils (up to pH 3.8).

Groundnuts and Bambara groundnuts (*Vigna subterranea*) grow in poor sandy soils and loamy soils, but also in clay soils such as vertisols, although harvesting the pods from under the ground is difficult. While groundnuts grow well in chalky soils, Bambara groundnuts do not. Good drainage is important, especially for Vigna and Phaseolus types.

The butterbean *(Lablab purpureus)* has deep roots, which enable it to grow better on badly draining soils than most legumes. The butterbean however does not do well in saline (salty) soils. Generally speaking, legumes do not do well on salty soils, although there are a few exceptions: pigeon pea (*Cajanus cajan*) and pea.

Soya grows best in soils that are not too light and not too heavy in texture. Soya does not germinate easily in heavy clay soils, although it does grow well in them after germination. If a heavy soil has been well prepared it is preferable to a light sandy soil, as the yields are likely to be more certain. Soya grows well in soils with high organic-material content. Soya prefers a pH of between 5.8 and 7.8, and does not like alkaline or acid extremes. Soya will not tolerate saline soils.

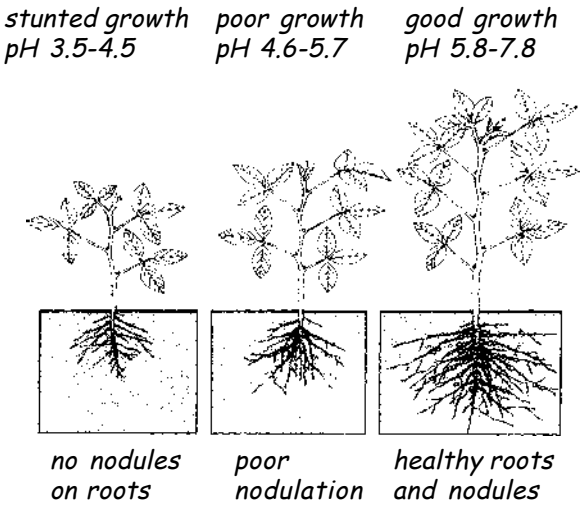


Fig. 5a: If the soil has the correct degree of acidity (pH) the crop and its root nodules will develop well. (See Appendix 1 for the requirements of the different legumes).

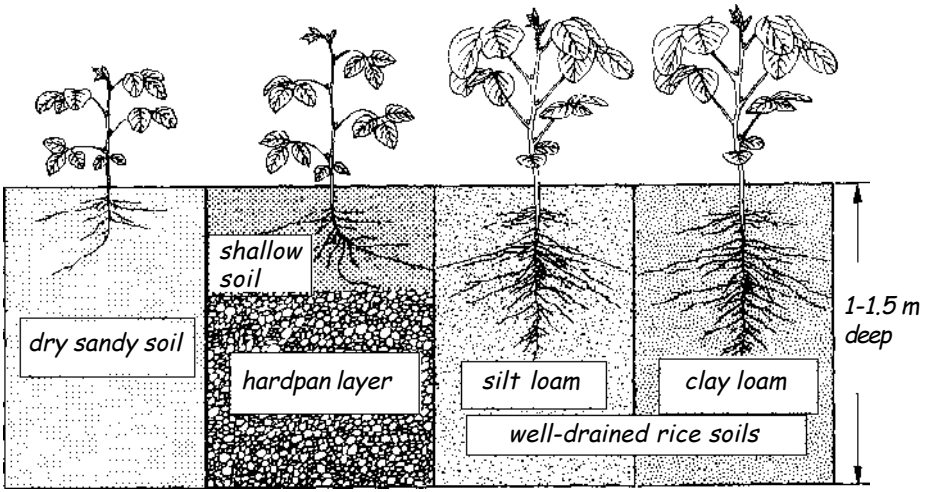


Fig. 5b: Examples of different types of soils and their effects on the growth of soya.

Improving soil fertility

It appears that high-yielding strains do not contribute much nitrogen to the soil. The most important role of legumes in a farming system is their bean production. During the growth cycle the transfer of nitrogen to other crops is small. It is only when the crop remains have been dug into the soil and have decomposed that they start to release their nitrogen into the soil, making it available to the next crop. Figures from Bolivia show that maize and wheat grown after soya can have an increase in yield of up to 22%. Where legumes are used as green manure, maize yields are clearly higher than maize grown after a short fallow period where nothing is grown. If soya is grown for use as green manure, where the whole crop is dug under, it can increase soil fertility by up to 200 kg nitrogen per hectare. Soya dug in in this way also improves the texture of the soil because the crop residue contributes organic material.

If soya is grown as part of a mixed cropping system it is important to ensure that nitrogen given to the other crop in the form of artificial fertilizer does not come into contact with the roots of the soya. Soya will not fix nitrogen (or only very little) if there is nitrogen present in the soil (in this case from the artificial fertilizer).

When the remains of the soya and other crops are dug into the soil together, the nitrogen-rich soya remains will ensure that the organic material in the soil is broken down quickly. This will increase the amount of nutrients in the soil by more than if the remains are dug in separately.

4 Integrating legumes into existing farming systems

Farmers and extension workers who have no experience of legumes need to find the answers to a number of questions.

- What is the best season for growing legumes?
- What crops grow best before or after the legumes?
- Or is it better to grow them at the same time?

The existing farming system must be taken into account if you are to understand how you can integrate leguminous crops.

Farming and crop systems

A farming system consists of all the farming activities that take place on a farm. These may include crop cultivation, raising livestock or planting trees.

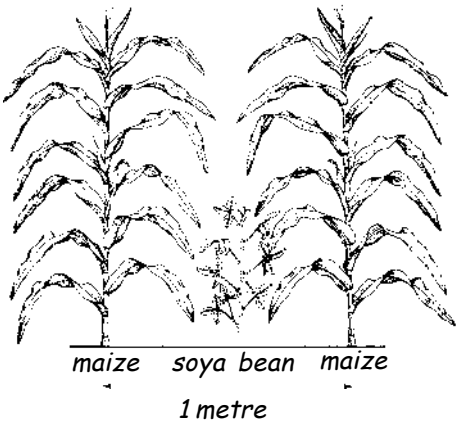
A crop system consists of all the crops that are grown. Sometimes this is one crop on a field (monocropping), sometimes several crops. If several crops are grown together on one field, they can be mixed up together (mixed cropping) or planted in alternating rows (intercropping). It is also possible to sow one crop later than the other one in the field (relay cropping).

Appendix 1 is a list of leguminous crops and their climate, water, temperature and soil requirements. The table can be used to make a preliminary selection from the many legumes available.

This chapter is mainly devoted to soya. However many of the characteristics of most other leguminous crops are similar. With a few excep-

tions, most leguminous crops are sensitive to day length: they are either short-day or long-day plants. Soya is a short-day plant: it starts to flower when the number of hours of sunshine in a day decrease. The exact amount varies between 12 and 14 hours, depending on the variety of soya. For this reason the latitude where particular varieties can be grown is always included in the examples given in this Agrodok (paragraph 3.4: Varieties). The nearer the equator (lower latitudes) the more constant the day length is and the warmer the nights are throughout the year. Further away from the equator (higher latitudes) the days are shorter and colder during the winter. During the summer the days are longer and temperatures are higher both during the day and at night.

In Africa, Asia and to a lesser extent Latin America, most crops are cultivated manually. This makes it easier to integrate legumes into the farming system. They can be grown as a monocrop (crop grown on its own), as an intercrop with dry rice or maize, or as a relay crop just before or after the main crop that requires the rain. All these crop systems are used successfully in Taiwan. The introduction of groundnuts, soya and mung beans in rain-dependent farming systems in northern Thailand has also had good results.



Soya bean is grown between two rows of maize.
Both crops are planted at the start of the rains.

Fig. 6a: Example of intercropping maize and soya.

Fig. 6b: Example of several crops grown on one field, including legumes.

4.1 Livestock keeping

We describe two ways of integrating legumes with livestock keeping.

1. When the beans have been harvested the crop residue is used as animal feed for the livestock kept in the village, e.g. cattle or buffalo. The dung from the animals is used to fertilize the land together with the crop remains left in the soil, which increases the nitrogen content of the soil.
2. You can also let livestock graze in a mixed crop of a legume and grain. For example, you let the animals eat half of the legume crop. Animals will first eat legumes because they contain a lot of protein, which means they will leave the grain crop undisturbed. As they eat the legumes, nitrogen will be released which is good for the grain crop, such as maize. The animals convert the nitrogen in the soya into urine and dung. The nitrogen in the urine is immediately taken up by the grain crop.

The second method appears to provide more nitrogen, but farmers are unlikely to let their animals eat much of the legumes that are meant for human consumption. It is difficult to calculate exactly how much this

method improves soil fertility. If a farmer is accustomed to using artificial fertilizer it would be possible to carry out a cost-benefit analysis to determine which form of fertilizing is cheaper.

4.2 Mixed/rotational cropping systems in Asia

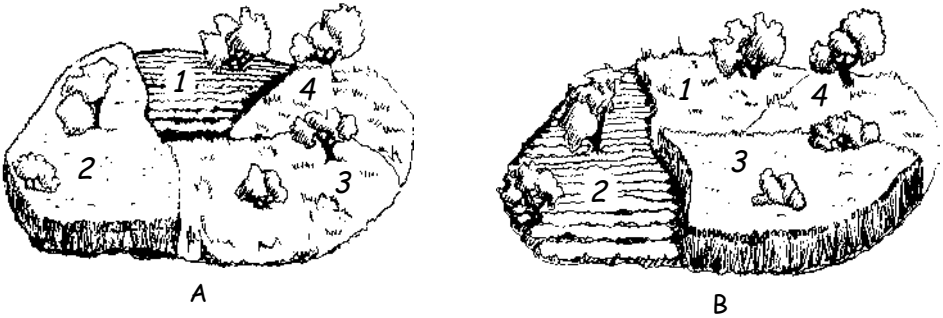


Fig. 7: Example of rotational cropping: in the first year fields 1 and 2 are cultivated (A). In the following year all crops move round one field, so fields 2 and 3 are cultivated (B).

The main leguminous crop in Asia is soya, so the examples below all refer to this crop. Soya is usually sown in the dry season, after rice, wheat or maize while the soil still contains sufficient moisture, or where irrigation is possible. Soya is also often intercropped with maize or sorghum.

In Indonesia a similar system at 6°N yields 700 kg soya per hectare. The soya is sown at the end of the rains in February or March, or just after the rains have stopped in April. If the rains are to be used for the legume crop, then sowing is done in July/August just before the first rains start, so that the seed is ready to benefit from the rains that start in September. The harvest takes place at the end of the rainy season, between December and April or in the dry season at the end of June, depending on when the soya was sown. If the seed is sown in the dry season, the crop starts to grow during the rains and it takes one or two months longer before it can be harvested.

In Thailand yields up to 1200 kg/ha are harvested at a latitude of 15°N. In this area most soya is sown during the rains between April and July. Where there is irrigation, soya is sown at the beginning of the dry season in December. In Taiwan a similar system of cultivation is used at 23°N and yields of 1500 kg/ha are achieved. Here the dry season is from November to May and the rains fall between May and October.

4.3 Mixed/rotational cropping systems in Africa

In Uganda legumes are grown in various shifting cultivation systems. A number of crop systems in which different legumes are grown are listed in Table 3.

Table 3: Crop systems used in Uganda (from: Grain Legumes in Africa, FAO 1966: 61)

	Sole crop or intercrop	**Intercropped with**	**Position in rotation**	**Sole crop recommended spacing (cm)**
groundnuts	both	maize/cotton	1st or 2nd year of cultivation	60-40 x 15 with animal traction or 30 x 30 hand cultivated
kidney bean	usually intercropped	maize/cotton/ sorghum/ young coffee, bananas and cassava	1st, 2nd or 3rd year	60 x 15 (in double rows)
cowpea	usually sole crop		2nd or 3rd year	50 x 40
pigeon pea	intercrop	finger millet *(Eleusine coracana)*	2nd year of	
garden pea	both	kidney beans/maize	1st or 2nd year	

The legumes in this example are not cultivated on ridges, and they are not irrigated. Reading the table it can be seen that groundnuts are grown as sole crop, but are also grown between other crops (intercropping), usually maize or cotton. Groundnuts are the first or second crop grown after a fallow period. Optimal spacing has also been calculated: if the groundnuts are the sole crop and the soil is worked using animal

traction it is best to allow 40 to 60 cm between the rows and 15 cm between plants within the rows. If the work is done by hand it is better to have crop spacing of 30 x 30 cm.

4.4 Labour requirements

Table 4 below gives an indication of the amount of time in hours needed to cultivate one hectare of soya (monoculture).

Table 4: Labour required (in hours) to cultivate one hectare of soya.

Soil preparation	mechanized	84
Sowing	manual	100
	mechanized	8
First weeding	manual	100
	mechanized	8
Second weeding	manual	80
	mechanized	8
Harvesting	manual	90
Transport to storage place		40
Threshing		150
Winnowing		69
Total	manual (soil preparation mechanized)	724
Total	weeding also mechanized	364

Sowing soya by hand is very labour intensive. The sowing density must be very high to ensure a good yield. The only way to keep weeds down is by letting the soya plants cover the whole of the ground. Most other leguminous crops have a wider branching pattern, which means that the sowing density is lower. Other legumes therefore take less time to sow.

The other figures in Table 4 give an indication of the amount of labour needed for growing most legumes, not just soya. The amount of time needed for harvesting however varies depending on the crop: how it

grows and the size of the pods. There are varieties of legumes that all ripen at once, so that suddenly a large amount of labour is needed at the same time if no beans are to be lost. Where cultivation is largely mechanized, a crop that ripens all at the same time is preferred as this is easy to do by machine. Where farming families harvest by hand it is usually better if the work can be spread out over a longer period with a variety that does not ripen all at once. It is important to be aware that these characteristics vary in some legumes depending on the variety.

5 Cultivating soya

This chapter covers the practical details of growing soya. These are most important for those who have already decided to grow soya. If you have not yet made the decision, the information in Chapter 3 is very important.

5.1 Storage of beans and seed selection

Soya beans are rich in protein which makes them very attractive to insects. They also decay quickly, especially when the climate is humid. Soya therefore has to be stored carefully, whether it is used for food, trade or seed material.

A women's group in North Ghana has done experiments to determine how effective local storage methods are. They used different sorts of beans and they stored them using different methods. They assessed the colour and taste of the beans, as well as noting how much insect damage (holes) there was. The conclusion was that beans stored in ash kept best. Storing seeds in ash of the neem tree and treating seeds with a neem tree solution had good results.

If a farmer has plastic bags which can be hermetically sealed (made airtight), these can be used to store soya beans (at least those to be used as seed material). The beans must be well dried (less than 11% water in the bean) and the plastic bags must be carefully sealed.

- Experiments in Senegal and Cameroon show that seed stored under these conditions for nine months retains 90% of its germination capacity.
- In Guyana seeds can only be stored for six months before they lose their germination capacity.
- In all three countries seeds which are kept in cold storage places maintain 90% of their germination capacity for nine months.

➤ In the highlands of Madagascar it is not necessary to store seed in cool houses because the temperatures are low enough anyway. Plastic bags are also not necessary for storing the seed.

Fig. 8: Example of a healthy soya plant with many pods.

We conclude that if you want to ensure 90% germination capacity then it is a good idea to keep seed in cool storage places.

Whether farmers use their own seeds for planting material or whether they regularly buy new seeds will depend on whether there is a local distribution network and the price of new seed.

If farmers use their own seed they need to make sure that it comes from healthy plants and that the seeds look good. Plants with many healthy pods can be marked in the field using brightly coloured thread, so they are easy to see later on.

In countries such as Bolivia where soya has been grown for a long time, certified seed is easily available. If you buy certified seed make sure it has a label with information about the germination percentage, seed purity and the variety, and that it is guaranteed disease free.

5.2 Nitrogen fixation

Soya is a member of the legume plant family (Leguminosae). Legumes have a special characteristic, that they can absorb nitrogen from the air and use it for their own growth. They store the nitrogen in nodules on their roots, with the help of special bacteria (Rhizobia). As the root nodules grow they start to produce nitrogen. The root provides the rhizobium bacteria with food and shelter and in return the bacteria helps the plant to store nitrogen.

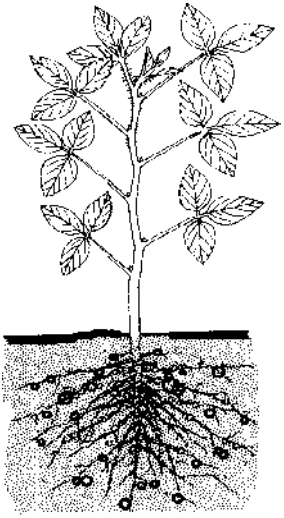


Fig. 9:
Soya plant with root nodules.

Rhizobia are bacteria which induce the root hairs of the plant to form nodules in which nitrogen is stored. Rhizobia are found in most soils, but they do not always form nodules. Sometimes there are not enough bacteria in the soil to form nodules, or they might not be the right type of rhizobium for soya plants. Just as there are different sorts of legumes there are also different sorts of rhizobia. For nitrogen fixation to take place, the correct combination of rhizobium and legume is needed. The best 'partners' for soya are *Rhizobium japonicum* or *Bradyrhizobium japonicum*. The latter is used successfully in Bolivia, especially the strains USDA 136 and E109.

The amount of nitrogen that a plant can fix depends on the variety, the productivity of the rhizobium bacteria, the soil and the climate. Soya is capable of fixing between 60 and 168 kg of nitrogen per hectare per year.

Root nodule activity

It is possible to tell from the colour of the root nodules whether or not they are active, and therefore fixing nitrogen. Active root nodules are pink inside. By cutting through a root nodule it is possible to see whether it is active or not. The best time to do this is when the plant is flowering.

Root nodules that remain white or light green on the inside throughout the growth cycle of the soya plant are not active. Even if the soya receives nitrogen in the form of artificial fertilizer the root nodules remain small and white. Only once the nitrogen from the fertilizer has been used up do the root nodules become active and grow bigger. For this reason it is worthwhile giving soya extra nitrogen if it is grown on poor soil.

Rhizobium treatment

If the soya plants do not develop active root nodules on their own, it is possible to add rhizobium to the seed or the soil. This is called inoculation. See Appendix 3 for a description of how to do this and how to provide information to farmers.

It is possible to check whether a rhizobium treatment has been effective. Check the development of the root nodules four or five weeks after sowing. Check again when the soya plant is flowering. Check for a third time while the pods are forming to see how much the different types of rhizobium have contributed to pod formation. You will gain the most information by carrying out all three checks.

5.3 Plant density and sowing methods

A crop yield depends on the yield per plant and the number of plants in a field. Plants with more space between them look different from plants that stand close to each other. Plants spaced not too far apart will grow less tall, are less likely to be flattened by wind or rain and will have more branches. They also form more pods with heavier beans, which means a bigger yield per plant. Where the plant density is low and plants are far apart, the yield for the whole field will be relatively low. If there is a lot of space between plants, weeds will be a problem. It is important to find the optimal plant density. This can vary even for the same place, depending on the season. The sowing density has to be adjusted in areas where day length varies depending on the time of the year.

We give an example from Bolivia, where soya cultivation is mechanized. The extension services there provide precise information on how to adjust the sowing machine. In the summer the sowing distances are 5 –7 cm within the rows and 40 – 60 cm between the rows. In the winter the distance between the rows is 20 – 30 cm, and the distance between plants remains the same. This gives a plant density in the summer of 250,000 – 300,000 plants per hectare, and in the winter of

500,000 – 600,000 plants per hectare. The high number of plants in the winter compensates for the lower yield per plant as a result of the shorter day length.

In Asia plants are usually planted more densely than in Africa. An average figure is 55 – 65 kg seed per hectare in Asia, and 22 – 34 kg seed per hectare in Africa. These are figures for good quality seed. If you are not sure about the germination quality of your seed, it is better to use larger amounts.

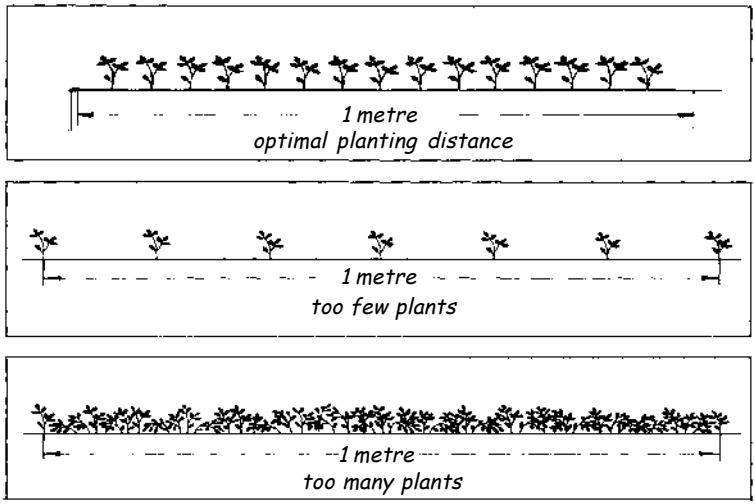


Fig. 10: Optimal planting distance: 15 – 18 plants in a row one metre long. Too few plants: 6 – 8 plants in a row. Too many plants: 20 – 30 plants in a row. The distance between the rows is 30 – 60 cm.

Where soya is sown by hand in Africa and Asia it is often sown at the foot of the stalks of the previous crop, such as rice (Asia).

Where mechanized cultivation takes place, e.g. Bolivia, Nigeria and Cuba, the plants are sown in rows. The sowing machine should not be driven faster than 6 – 7 km per hour. If the machine goes faster, the sowing density will be too low.

5.4 Sowing period

The following climate requirements must be taken into account for deciding when to sow:

- temperature required for the seed to germinate
- period when water will be available
- correct day length during the flowering period

In countries where soya is already grown it will be possible to obtain information and advice from the extension service. Generally speaking soya is sown at the start of the rains. In countries with more than one rainy season it is sometimes possible to raise two crops in a year.

The table below shows how the time at which soya is sown determines the crop yield.

Table 5: Sowing date and yield obtained (Source: ICARDA/IFPRI Report, 1990)

Senegal Sefa Casamance 1978		Cameroon Foumbout 1979		Togo Atalote 1981		Ethiopia Awassa 1979		Madagascar Middle-west 1981	
Sowing date	Yield (kg/ha)	Sowing date	Yield (kg/ha)	Sowing date	Yield (kg/ha)	Sowing date	Yield (kg/ha)	Sowing date	Yield (kg/ha)
1 July	3 469	15 June	2 680	17	2 235	13 June	2 300	5 Nov.	816
7 July	2 030	1 July	2 215	June	2 522	4 July	2 550	11 Nov.	1 108
17 July	1 544	15 July	1 700	1 July	2 091	20 July	1 340	25 Nov.	1 030
26 July	770	-	-	15 July	1 194	-	-	4 Dec.	379
				3 Aug.					

Example from Ivory Coast

Soya is a new crop in Ivory Coast. It was first cultivated in 1998. The short rainy season from mid-September to November produced good results: 1 ton per hectare. The yield from the long rainy season (March to June) was low because the soya plants were attacked by many insects. The farmers decided to only grow soya during the short rains.

5.5 No-tillage cropping

There are also systems for growing legumes which involve no soil tillage: no-tillage cropping. Using a stick or a knife holes are made in the ground at the foot of the mounds upon which the previous crop grew. The soya seeds are planted in the holes. Soya is planted in this way after a rice crop.

In Taiwan the same field is used for two rice crops and one soya crop. The soya yield varies between 1.5 and 2 tons per hectare. The soya takes 85 – 100 days to ripen.

5.6 Weed control

Weed control is very important when growing soya. The most critical period is between the 15th and the 35th day after sowing. If you only start weeding after the 35th day, the yields will be lower. It is best to keep the crop weed-free from the moment it is sown until the harvest. Weeds take light, nutrients and water away from the crop, and they provide a place for insects that can also damage the crops either by eating them or passing on disease. The more weeds there are, the higher the relative humidity between the plants, which increases the risk of fungi that can also damage the crop. Weeds also get in the way of machine harvesters, which leads to more beans being lost because they are damaged.

The best way to fight weeds is by encouraging the growth and development of the crop as much as possible so that it does better than the weeds. Below is a list of ways to do this.

- crop rotation; i.e. do not grow crops of the same family on the same piece of land after each other
- use groundcover plants
- prepare the soil well before planting
- sow at the right time
- make sure the sowing density is correct

It is also possible to control weeds using machinery. Often it is enough to do this two or three times during a crop cycle: the first time should be from two weeks after the crop has germinated and the last time up to 45 days after germination or just before the crop flowers. A machine should not be used during or after flowering as it can pull the flowers off the plant, which will lead to lower yields.

In countries where weeding is done by hand, such as in Senegal, it is best to weed five times during the first six weeks. The importance of weeding is easy to see in the table below, which is based on trials done in Senegal.

Table 6: The effect of good weeding on yield
(Source: ICARDA/IFPRI Report, 1990)

Treatment	Yield kg/ ha
Correct treatment: weed 5 times	2 635
Weed twice (after 3 and 5 weeks)	1 765
Weed once (after 3 weeks)	1 185
No weeding at all	421

5.7 Pests

Insects

Different insects can cause damage to the crop. Although insect damage leads to reduced yields we do not recommend using insecticides to prevent insect damage. Doing this makes growing soya very expensive and another disadvantage is that pesticides also kill the natural enemies of the insects that cause the damage.

It is only worth using insecticides if you can reduce your crop losses by more than the costs of using insecticide. In order to be able to estimate accurately whether this is possible you have to inspect your crop regularly. You can do this by laying down a sheet measuring 100 cm x 70 cm between the rows and then shaking the plants on both sides so that the insects fall off.

In Bolivia the following rules of thumb are used:

- If more than 30 – 40 caterpillars fall onto the sheet or if more than 35% of the plants are seriously damaged it is worth fighting the caterpillars.
- Insects that attack leaves with their mouthparts should be controlled if there are more than two adults found per metre of a row.
- Caterpillars that bite through stems of the plants must be controlled if 20 – 25% or more of the plants are damaged.

Nematodes

Nematodes are small worms that damage the roots. The effects of nematode damage are yellow leaves, stunted growth even though soil fertility is good, and wilting even though there is enough water in the soil. The best way to control nematodes is to plant resistant varieties and to use crop rotation.

5.8 Diseases

Most diseases are transferred through the seed. It is therefore very important that you use seed that is free of disease pathogens, or treat seeds chemically so that they become free of disease. This way you can prevent losses or reduce them to a minimum.

5.9 Harvesting legumes

Harvesting must be done at the correct time. If harvesting is done by hand, when the leaves first start to turn yellow, it is best to cut down the plants and spread them to dry in a place where it is easy to collect the beans as they fall out of the pods. Once the plants have dried they can be threshed. Where not all plants ripen at the same time the beans should be harvested from the plants that ripen first, while the other plants are left standing to ripen further. This spreads the harvesting work out over a longer period, which also means there are no peaks in labour requirements which can be a difficult problem.

If you harvest with a machine you have to be very careful that it does not cause damage. Damaged beans cannot be kept for long, sell for less money and are less suitable for seed material. The period during which mechanical harvesting can take place is not long. The crop is ready to be harvested when the leaves turn yellow and fall off, when the stems become brittle and if it is easy to open the pods by pressing them between the fingers. If the moisture percentage in the beans falls below 12% the pods open and the beans fall on the ground. This can lead to considerable harvest losses. (In Argentina 8 – 12% harvest losses are common where the crop is harvested mechanically.) The losses will be lower if harvesting is done early in the morning or at the end of the afternoon, when the pods are wetter.

The optimal moisture content during harvest for soya that is going for industrial processing is 13 – 15%. For seed material the optimal moisture content during harvest is 13%.

5.10 Large-scale production in South America

In South America it is expected that the export of soya pulp, soya oil and soya bean will soon start. When this happens the area under production will increase. It is worth noting the experiences in Bolivia. Most of the economic returns from soya production in Bolivia go abroad: to the manufacturers of the agricultural machinery, fuel and pesticides. Growing soya in Bolivia has high ecological costs: thousands of hectares of forest have been cut down, organic biomass is burned, soil nutrient losses are high and the soils are becoming physically degraded. If production is to become sustainable, appropriate technology forms have to be developed and used.

6 Soya: nutricious food

Farmers are more likely to start growing soya if they know more about its advantages. We have already mentioned that it is a good source of nutrition and provides a welcome addition to diets that are not well balanced. This chapter contains a lot of practical advice on how to cook soya and include it in meals.

6.1 What is good nutrition?

We need food to stay healthy. Food gives us:

- energy to work or go to school
- nutrients we need to grow or recover from wounds
- substances that protect and heal us from disease

A well-balanced diet is made up of foods that provide us with all these vital needs. A shortage (deficiency) can lead to malnutrition and health problems. Malnutrition can also occur even if sufficient quantity of food is available, but does not provide all the nutrients we need. Therefore it is important to know what nutrients we need: carbohydrates, fats, proteins, vitamins, minerals. We also need to know which foods contain these different nutrients.

Fig. 11: Examples of products that are good sources of carbohydrates.

Carbohydrates give us energy, they function as fuel for the body. There are also carbohydrates that our bodies cannot digest. These stimulate the intestines (our insides) and help our bowel movements so we do not become constipated. Foods that are rich in carbohydrates include: grains (e.g. rice, millet, sorghum, wheat), potatoes and fruit.

Fats

Fats are the most important source of energy. Fat also contains the fat-soluble vitamins, A, D, E and K. The most important fat-containing foods are: oil, nuts and animal products such as meat, fish and milk.

Fig. 12: Examples of products that are good sources of fats.

Protein

Proteins are the building blocks of the body. Children need protein to grow, and adults need protein to replace cells in the body. If the diet contains too little carbohydrate or fat then the body converts protein into energy. But this leads to a protein deficiency in the body, and to protein malnutrition in children. Foods that are good sources of protein include meat, fish, eggs, milk, legumes and nuts (e.g. groundnuts).

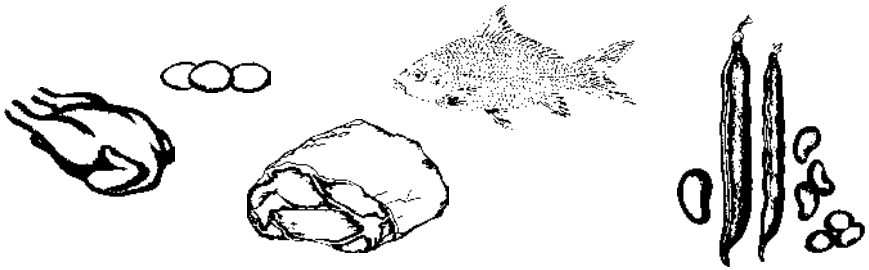


Fig. 13: Examples of products that are good sources of proteins.

Vitamins

Vitamins protect our bodies from disease. Nearly all foods contain vitamins, but not always the vitamins we need. Therefore it is important to know which foods contain which vitamins. Vitamin C is found in fresh vegetables and fruit. Vitamin B is found in animal products and grains. Vitamin A is found in oil and certain types of vegetables and fruit.

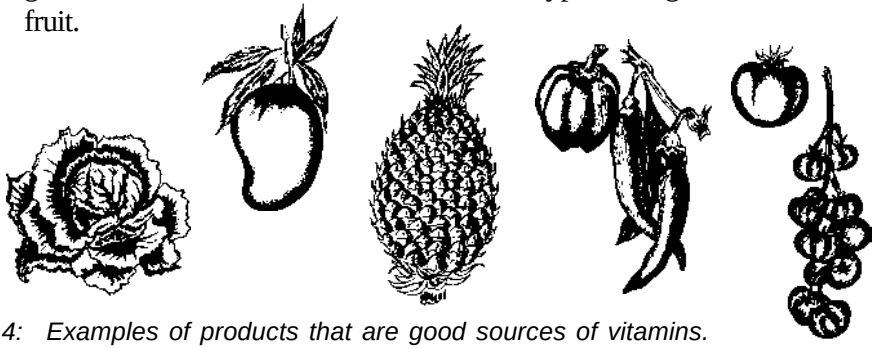


Fig. 14: Examples of products that are good sources of vitamins.

Minerals

Minerals are substances that protect, but they also have specific functions in building up the body and helping it to recover from sickness.

The most important minerals the body requires are iron (needed to make blood) and calcium (needed for bones to grow and repair themselves). Iron is found in meat, green leafy vegetables and grains. Calcium is found in milk products and also in some vegetables.

6.2 Malnutrition

Malnutrition occurs when the food eaten does not contain enough of the nutrients we require. Malnutrition occurs in all countries, but is a worse problem in developing countries. Young children are especially at risk because malnutrition not only retards but also interferes with their growth and development. The effects of malnutrition are also felt later on in life. Malnourished children often have learning difficulties and are quickly tired. They are thin, and often smaller when fully grown than adults who were not malnourished as children. Generally speaking it is

difficult to reverse the lags in growth and learning that arise as a result of malnutrition.

There are a number of causes of malnutrition.

- Too little food: not enough food eaten each day, or not often enough.
- The body uses a large amount of energy fighting common infections.
- The meals are not well balanced. E.g. they consist mainly of bulky food that contains a lot of water and few nutrients, such as many roots and tubers.

There are three different forms of malnutrition: energy malnutrition, protein malnutrition and malnutrition as a result of vitamin and mineral deficiencies. Each type of malnutrition has different symptoms. E.g. a shortage of vitamin A in the diet can lead to night blindness, and a shortage of iron can lead to tiredness and concentration problems. The different types of malnutrition are often found together in combination. Malnutrition can be prevented by making sure the diet is varied and that the combinations served provide sufficient energy, protein, vitamins and minerals. Soya is a product that is easy and useful to include in a varied diet.

Protein malnutrition

Protein malnutrition, also called kwashiorkor, is caused by too little protein in the diet. This often occurs where the diet consists mainly of starchy products such as potatoes or bananas.

Children with protein malnutrition do not grow properly as their bones cannot develop sufficiently. It is also possible to see the difference in school performance between children with protein malnutrition and those with a good diet. Adults with protein malnutrition have reduced resistance to disease and infection, and wounds do not heal easily.

Fig. 15: Child with protein malnutrition (kwashiorkor).

People's protein requirements vary depending on body weight and whether or not the person is still growing. Protein requirements also vary depending on whether the proteins in the diet come mainly from animal or plant products. Animal proteins are processed more efficiently by the human body and therefore less is needed than proteins from plants. Table 7 shows the recommended daily protein intake for different ages.

Protein-rich foods such as meat, fish, eggs and milk are often scarce and expensive. They are often therefore not available to poorer groups of the population. Other sources of protein must then be sought, especially among plant products. Soya is an excellent alternative. It is a good source of plant protein and is cheap.

Table 7: Recommended daily protein intake

	Protein g/day average
Children ½ (1) - 5 years	15-25
Children 5 – 12 years	30-40
Teenagers	50-70
Adults[2]	40-60

[1] Babies up to six months receive sufficient protein from breastfeeding.
[2] Pregnant and breastfeeding women have slightly higher protein requirements.

Energy malnutrition

Energy malnutrition, also called marasmus, arises when the body does not get as much food to eat as it needs. Food provides the body with energy. The body gets the energy mainly from fats and carbohydrates, and when it does not get enough from these it also uses proteins as a source of energy. But there may be a shortage of food, or it may be too expensive to buy, so people do not have enough food to eat. If this is the case people suffer from energy malnutrition. Children and adults become very thin and they are hungry.

Children can also become undernourished because they do not have a balanced diet and they eat food that contains too much water. They fill their stomachs but do not get enough nutrients. Children need to eat more often each day than adults.

To prevent energy malnutrition it is important to choose as varied a diet as is possible within the household budget. Soya is a cheap and energy-rich product that can help in putting together a balanced diet.

Fig. 16: Child with energy malnutrition (marasmus).

6.3 Soya and other legumes

Soya belongs to the legume plant family (Leguminosae), a group of plants with high nutritional value. Soya makes a healthy addition to the daily diet. Soya contains a lot of high-quality protein and is an important source of carbohydrates, fats, vitamins and minerals. Other legumes, including various bean types and groundnuts, can also make a valuable contribution to the diet. Unlike other legumes, soya is not so well known. However, it deserves extra attention because it can contribute to decreasing malnutrition, especially protein malnutrition (kwashiorkor).

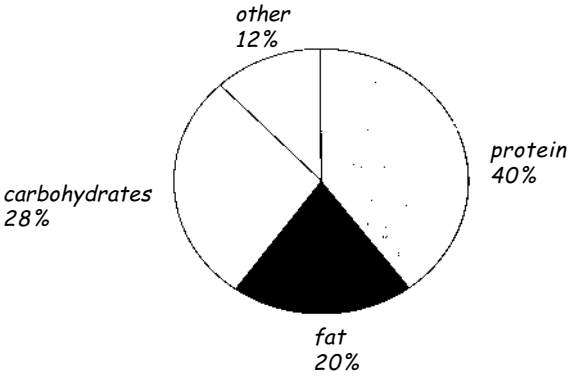


Fig. 17: Pie chart showing the percentage of different nutrients found in soya.

Soya is rich in protein

Of all plant food products, the soya bean is the most balanced source of protein. Soya contains a high amount of protein: 100 g soya beans (dry weight) can contain as much as 40 g protein! Other legumes such as beans and groundnuts also provide extra protein in the daily diet (see Table 8 for amounts).

Soya is rich in fat

Many people's diet consists mainly of starchy foods (e.g. grains, tubers) with a low amount of fat. Soya can be a valuable addition to these diets, providing a good source of energy. Soya beans contain about 20% fat (oil), a higher percentage than most other plant food products. Groundnuts are legumes that are also very rich in fat, containing 50% fat.

Table 8: Protein-rich foods (Source: Nevo)

Crop	Protein in g/ 100 g dry weight	Protein in g/100 g cooked/prepared product
Soya	20-40	10-15
Beans (black/brown/white)	20	8
Peas	21	8
Lentils	21	9
Groundnuts	n.a.	28
Meat	n.a.	20
Milk	n.a.	3,5
Eggs	n.a.	13

Soya is rich in carbohydrates

In addition to protein and fat, soya beans contain about 28% carbohydrates. A large proportion of the carbohydrate content consists of indigestible fibres as in most legumes. The fibres ferment in the large intestine as a result of the action of bacteria. This stimulates bowel movement, but can also result in unpleasant windiness (flatulence). This is not a problem however, for people who regularly consume legumes. Windiness can be reduced by processing the soya beans or other legumes, for example by fermenting them. The digestible carbohydrates form a good source of energy, as does the fat in soya.

Soya is rich in vitamins and minerals

Soya beans contain various vitamins and minerals. In particular they are rich in vitamin B, the fat-soluble vitamins A and E, and iron and calcium. This makes soya beans a good alternative to meat, milk products and eggs, which are also rich in the same vitamins and minerals, but are often expensive or difficult to find.

Table 9 compares the amounts of vitamins and minerals found in soya beans with the recommended dietary intake (RDI) for adults.

Table 9: Nutritional value of soya compared to recommended dietary intake for vitamins and minerals (Source: Nevo table, 1996)

	RDI/day		**Average content per 100 g dry soya beans as purchased**
	Men	Women	
Vitamin A	600 µg RE	500 µg RE	80 µg RE
Vitamin B1 (thiamin)	1.2 mg	0.9 mg	1.1 mg
Vitamin B2 (riboflavin)	1.8 mg	1.3 mg	0.3 mg
Niacin	19 mg	15 mg	2.1 mg
Vitamin B6	2.0 mg	1.6 mg	1.2 mg
Vitamin B12	1.0 µ	1.0 µ	-
Vitamin C	30 mg	30 mg	0 mg
Vitamin D	5 µg	5 µg	0 mg
Vitamin E	10 mg	10 mg	0.14 mg
Iron	9 mg	15 mg	7 mg
Calcium	400-500 mg	400-500 mg	225 mg

7 Soya in the daily diet

Soya can be an important addition to your diet. But how can you use it in your daily cooking and meal preparation? This question is answered in this chapter. First we describe some of the things you need to know about storing and processing soya. Then we describe some of the ways in which soya and other legumes can be prepared for eating.

7.1 Good storage

Dried legumes should be kept in a cool, dry, dark place in airtight containers. The longer beans and peas are kept, the harder their seed coat becomes and the longer they need to be cooked. Beans start to germinate when they are exposed to light, moisture and heat. They discolour in light and when exposed to moisture they are attacked by fungi. Groundnuts in particular start to turn mouldy if they become moist and there is a big risk of poisonous mycotoxins, which if eaten can cause serious illness. These problems, as well as damage from insects and rodents, can be avoided by storing properly.

Correctly stored legumes can be kept for about one year. Soya beans do not keep so long. Due to their high fat content they become rancid more quickly.

7.2 Heat first!

Soya and some other legumes contain substances that need to be removed before they can be eaten. These are called the antinutritional elements. These reduce the nutritional value of the beans and are dangerous to health. The most important of these substances are lectins (especially trypsin inhibitors and haemagglutinins) and fasin. Lectins can cause red blood cells to agglutinate (clump together). Trypsin inhibitors also interfere with protein digestion and growth. Fasin is a poisonous protein found in raw legumes, or ones that have not been sufficiently

heated. These also cause agglutination of red blood cells. Raw soya beans can also contain substances that cause goitre, a swelling of the thyroid gland. Soya also contains an enzyme that gives it an unpleasant taste and smell if it is not inactivated by heating.

Not all legumes contain the same amounts of these substances, but it should be clear that correct preparation is very important for all legumes. This is not a problem as all these substances can be removed simply by heating, leaving a valuable product that is not harmful to humans.

Fig. 18: Heating legumes is important.

7.3 Preparation of meals and products

Soya beans can be eaten as they are, once they have been cooked. Or they can be used to make other products such as soya oil, soya flour, soya milk and soya cheese (tofu) and tempeh.

Peanuts are often roasted and eaten as a snack. They can also be added to a dish, or ground up and made into a sauce. Peanuts can also be ground to make peanut butter. This has become a successful product for selling because it is easy to produce on a small scale.

It is worth repeating that legumes must always be cooked or roasted before eating in order to deactivate the antinutritional elements and to be able to derive maximum benefit from the nutritional value.

Soaking, blanching and roasting

Beans have to be soaked before they are cooked. Some sources say that soya beans must be soaked for at least 18 hours to get rid of the bitter 'beany' taste. Do not soak beans for longer than 24 hours, however, as this encourages the growth of micro-organisms. One cup of beans needs about 3 cups of soaking water. Always throw the soaking water away. It is not suitable for cooking the beans, as it tastes bitter.

Other sources suggest not soaking the beans but blanching them instead for 20 minutes: add them to already boiling water, boil them for 20 minutes and then plunge them in cold water. The skins can be removed by rubbing the beans between both hands.

It is also possible to roast soya beans in a dry pan. After roasting let the beans cool. The skins can be removed by placing the beans on a clean surface and rolling over them with an implement such as an empty bottle or a rolling-pin.

Cooked soya beans

Like many legumes, soya beans can be eaten whole when cooked.
Use half-ripe but fully-grown soya beans

- remove dirt from shelled soya beans
- soak the beans for 18 to 24 hours
- rinse the beans in clean water
- bring a large pan of water to the boil and cook the beans in the water for 30 to 60 minutes, depending on local conditions. Add some salt towards the end of the cooking time.

Cooked soya beans can be eaten as part of a meal or as a cheap but nutritious snack.

Soya oil

Soya beans are very rich in oil. In many areas soya beans are grown mainly for oil production. There are various ways of obtaining the oil,

from simple wooden oil presses to using organic solvents such as hexane. When soya beans are pressed it is impossible to separate the proteins from the oil. For this reason, commercial production of soya oil is done using the extraction process. In the United States 95% of the soya oil is produced using this method. The advantage of pressing soya beans to extract oil, is that it is easy to make the equipment yourself, and it can be done on a small scale. Soya oil is used to prepare foods – for frying or in a salad dressing – and also in the production of margarine and soap. The residue left after pressing is usually made into animal feed.

Soya flour

Soya flour is a by-product of oil pressing, but it can also be made in other ways. The following is one method.

- Remove the dirt from the shelled soya beans.
- Bring 4 cups of water to the boil for each cup of soya beans.
- Add the beans and cook them for about 30 minutes.
- After cooking rinse them in clean water.
- Dry the cooked soya beans in the sun on a clean mat or rug.
- Grind or pound the dried soya beans or take them to a mill.
- Sieve the ground or pounded beans to make flour.
- Store the flour in sealed containers in a dry place.

Soya flour is nutritious and can be used to make porridge, biscuits (cookies), pasties or pies. Soya flour cannot be used on its own to make bread because it does not contain gluten and therefore does not rise. It also contains very little starch. It can be added to other types of flour to improve their nutritional value.

Soya milk

Soya milk cannot totally replace cow's milk, and is certainly not as nutritious as mother's milk. However, it is a healthy drink and can improve the nutritional value of the daily diet. If there is no cow's milk available for children, soya milk is a good alternative as it contains

nearly as much protein and fat as cow's milk. In addition, soya milk can be used for other drinks and products such as soya coffee, soya yoghurt and soya cheese.

Preparation of soya milk:

- Wash the soya beans and remove dirt.
- Soak the beans for at least 18 hours.
- Drain and rinse the beans again in clean water.
- Pound the beans with twice their weight of water.
- Squeeze the pulp through thin material such as cheesecloth.
- Catch the liquid (the milk) in a separate container.
- Pound the remaining residue with twice its weight in water and squeeze through cheesecloth again, and repeat once more (total of 3 times pounding and squeezing).
- Boil the soya milk for 10 minutes to remove the antinutritional elements.

Fig. 19: Wringing out soya bean pulp to obtain soya milk.

Soya milk has a neutral taste, which means that flavours can be added, such as sugar, salt, palm sugar, vanilla, cacao, coffee or other flavours.

Tofu or soya bean curd

Tofu or bean curd is made by curdling soya milk and it resembles fresh cheese. Tofu has been produced and eaten in China and Japan for many centuries. Tofu has a high nutritional value and a neutral taste, which makes it good for combining with other ingredients. Tofu can be eaten together with meat and fish, but is a very good substitute for these and much cheaper.

Preparation of tofu or bean curd:

- Boil 1 litre of soya milk for 3 – 5 minutes in a pan. Stir continuously to stop it sticking.
- Remove the pan from the heat and add 20 – 40 ml vinegar (4% acetic acid solution) to the soya milk. Continue to stir until the milk has curdled.
- Pour the mixture through a cloth placed over a sieve to filter it
- Fold the cloth over the cake that remains and place a weight on top in order to press out the remaining water. For a light pressing use a weight of 2 kg/100cm^2. For a heavy pressing use a weight of 5 kg/ 100cm^2.

The result is a compact cheeselike product. A heavy pressing will result in tofu with a water content of about 65%.

Tofu must be stored in water to prevent it from drying out and discolouring. It can be kept in this way at room temperature for 1 to 2 days. If it is cooled it can be kept a little longer.

Tofu can be used for many dishes. It can be cut into blocks and fried in hot oil and then added to various dishes: soup or stews. The fried blocks can also be covered with a vegetable, groundnut or tomato sauce to make a tasty meal.

Note: Other chemicals can be used instead of vinegar to curdle the soya milk.

- 20 – 40 ml 10% calcium chloride solution
- 20 – 40 ml 10% magnesium chloride solution
- 20 – 40 ml 4 % lactic acid solution

Do not use more than 20 – 40 ml of any of these substances per litre soya milk. If you use too much you will end up with less of the final product.

Tempeh

Tempeh is a soya product made by inoculating soya with mould. It is a good meat substitute in a warm meal. Tempeh is easy to recognize because of its structure: the soya beans are still visible in it. The fermentation process is started by using a piece of tempeh. Tempeh can be marinated, for example in soya sauce, and then cooked, fried or steamed.

Preparation of tempeh

- Wrap a portion of already prepared tempeh in banana leaf that has holes in it.
- Lay this tempeh in a warm, damp place until mould starts to grow and can be seen through the holes in the banana leaf. Use this as inoculation material (starter).
- Rinse a quantity of dried (yellow) soya beans.
- Soak the beans overnight.
- Cook the beans in water for 2 hours.
- Then soak the beans for 24 hours in cold water. During this period fermentation starts, and the beans become acid (lower pH).
- Remove the seed coats from the soya beans, and spread them out so that the excess moisture dries from the beans and then pound them lightly.
- Spread the mould mixture over the bean pulp so that the mould is touching the beans. Good moulds for tempeh are *Rhizopus oryzae*, *Rhizopus oliogsporus* and other strains of Rhizopus.
- Spread the pulp over a number of banana leaves. Wrap the leaves around the mixture, and tie them up into little parcels.

In tropical areas the fermentation process is completed within 24 hours. The mould has then grown through the pulp and a compact cake is formed. Fresh tempeh should be eaten with 1 to 2 days. Dried tempeh can be kept for a few months.

8 Recipes

In the previous chapter we saw how soya can be prepared in different ways and used in tasty and healthy dishes. In this chapter we give a number of recipes gathered from various countries. In Ghana for example, women's groups have done much work on experimenting with soya. You can also use your own imagination and ideas to think up ways to use soya in your daily diet.

8.1 Snacks

Deep fried soya beans

You need:

- soya beans
- oil

Preparation:

① Rinse the soya beans in clean water and remove dirt.

② Soak the beans in plenty of water for 18 hours or boil them for 30 minutes in water that has already come to the boil (depending on the flavour you want them to have).

③ Remove the seed coats if you wish by rubbing the beans between your hands and rinsing them in clean water (not the soaking water!).

④ Heat the oil in a pan and fry the soya beans in small batches until they are light brown (about 5 minutes).

⑤ Drain the rest of the oil.

⑥ Add salt or sugar to taste and serve.

8.2 Main courses

Tofu salad with peanut sauce

This is a recipe from Indonesia where it is called Gado Gado.

Tofu salad:
- tofu
- hard boiled eggs
- local vegetables (e.g. carrots, green beans, cabbage, leafy vegetables)
- mung or soya bean sprouts
- peanut sauce (see recipe below)
- finely chopped fried onions

Preparation:
① Cut the tofu into blocks or strips and fry them golden brown in hot oil.
② Cook the vegetables for 5 – 10 minutes.
③ Blanch the sprouts by quickly plunging them into boiling water and then draining them.
④ Divide the vegetables and the tofu over the plates and lay the eggs on top.
⑤ Pour the peanut sauce over the salad and sprinkle the onions on top.

Peanut sauce:
- 100 g groundnuts
- 2 hot chilli peppers
- salt
- 40 g palm sugar or cane sugar
- piece of tamarind or 1 teaspoon lemon juice

Preparation:
① Roast the groundnuts in an oven or fry them in hot oil.
② Remove the seed coats and grind the groundnuts until you have a smooth paste.
③ Grind the chilli peppers with a little salt as finely as possible.
④ Mix the sugar with the tamarind and then knead all the ingredients together until they are well mixed.
⑤ Now you have the basis for peanut sauce.
⑥ To make it more liquid, add 2 parts hot water to 1 part peanut mixture.

Tofu omelette

You need:

- 100 g tofu
- 1 egg
- salt and herbs to taste
- oil

Preparation:

① Cut the tofu into small blocks.
② Break the egg into a bowl and beat it with a fork.
③ Add the tofu and salt if you wish.
④ Heat oil in a frying pan and fry the mixture gently until the top of the egg mixture is dry.

Suggestions:

Add local vegetables to the egg mixture.
This tofu omelette goes well with rice or potatoes instead of meat.

Soya - vegetable sauce

You need:

- 1 cup soya flour
- mixed vegetables of your choice
- salt
- tomatoes
- onions

Preparation:

① Wash the vegetables and chop them into small pieces.
② Cook the vegetables in a saucepan for 10 minutes.
③ Add salt and a little water to the soya flour to make a smooth paste.
④ Add the soya paste to the vegetables.
⑤ Cook for another 5 minutes.
⑥ Serve with rice, sorghum, corn mush or potatoes.

8.3 Bread and baking

Soya pancakes

You need:

- 1 cup soya flour
- ½ cup vegetable oil
- 3 ½ cups soya milk
- 4 teaspoons baking powder
- ½ cup sugar
- 2 cups wheat or maize flour
- 2 eggs
- salt

Preparation:

① Mix the eggs with the soya flour.
② Dissolve the sugar in a small amount of soya milk and then add the rest of the soya milk.
③ Add the wheat (or maize) flour and the salt to the soya flour.
④ Add the sugared soya milk to the flours and beat until you have a smooth batter.
⑤ Grease a frying pan or metal sheet and heat it.
⑥ Pour a small amount of batter into the frying pan and let it spread out.
⑦ Turn the pancake over when the top side is dry, and fry until it is golden on both sides.

Soya biscuits

You need:

- 1 cup soya flour
- 1 cup wheat- or maize flour
- 4 tablespoons sugar
- pinch of salt
- oil for frying

Preparation:
① Mix all the ingredients.
② Add water until you have a stiff dough.
③ Break and roll the dough into small balls.
④ Press them a little flat.
⑤ Fry the biscuits in the hot oil until they are golden brown on both sides.

Soya bean sprouts

You need:
- Soya beans
- Water

Preparation:
① Remove the dirt from the beans and any broken beans.
② Soak the soya beans for 10 hours (one day) in a large amount of water.
③ Drain the beans in a sieve and rinse them well in clean water.
④ Spread the soya beans in a thin layer (not thicker than 1 cm) on a moist cloth spread out over a flat surface with holes, such as a sieve or strainer.
⑤ Sprinkle the soya beans twice a day with a little clean water so that the beans stay moist.
⑥ After 3 – 5 days the beans will have sprouts about 3 – 5 cm tall.
⑦ To eat the beans, cook them for 3 – 5 minutes in boiling water.

Soya bean sprouts can be used in salads and cooked dishes.

8.4 Other recipes

Soya yoghurt

You need:
- soya milk
- yoghurt bacteria in powder form: *Lactobacillus bulgaricus* and *Streptococcus thermophilus*

Preparation:

① Boil 85 ml soya milk for 5 minutes. Let the milk cool to 30°C (room temperature in a tropical climate) and dissolve 1 g of powdered yoghurt bacteria well in the milk.
② Leave the mixture to stand at a temperature of 37°C or at room temperature in tropical areas for 15 – 18 hours. This is the starter.
③ Boil 1 litre of soya milk for 15 minutes and let it cool to room temperature.
④ Mix the 85 ml of soya milk (starter) with the 1 litre of soya milk and keep the mixture for 24 – 48 hours a room temperature, after which the yoghurt will have formed.
⑤ The yoghurt tastes good with sugar, fruit syrup, fresh fruit or stewed fruit.

Soya porridge

You need:

- 3 tablespoons soya flour
- 1 cup maize flour
- 3 cups water
- salt and sugar to taste

Preparation:

① Mix the maize flour and soya flour together and add a little water until you have a smooth mixture.
② Bring the rest of the water to the boil.
③ Add the flour mixture and keep stirring to prevent the mixture from becoming lumpy.
④ Cook the porridge for about 20 minutes.
⑤ Add salt and sugar to taste.

This is very nutritious for young children!

9 Introducing soya at the local level

Introducing new foods into an area is not always easy. People eat what they are accustomed to, which is often determined by local traditions and these are difficult to change. New foods are often first greeted with suspicion. For this reason it is important to emphasize the good qualities of soya and in particular its high nutritional value.

A good way to introduce soya is to offer it along with the usual food of an area, for example in the form of a snack or drink. Then it is perhaps worth mixing some soya beans into a vegetable sauce for people to try. In many parts of the world people eat beans which have been mashed (e.g. refried beans in South America and Mexico). Soya beans could be added to these dishes. Refried bean dishes are often heavily spiced, which also makes the soya tasty.

A good way to introduce soya into an area is through women's groups. Discovering a new crop and food together encourages people to exchange their findings and experiences with each other, and to exchange recipes. In this way women can learn to make new meals and soya products which can be sold. These products can provide a new way of earning income, which can help to increase food security. In Ghana there are women's groups that are actively working with the introduction of soya. They cultivate the soya together and jointly work out ways of preparing soya products and look for ways of selling them on the local markets.

It is not always women who cultivate soya everywhere. In some places it is the men who grow the soya. They could start by cultivating small test plots to see which crop has the best yield. The information in the first chapters of this book is useful for these experiments.

The introduction of a new food requires time and patience. But if you are creative and persist you will be able to convince many people that soya not only enriches their farming system, but also their daily diet. By setting a positive example locally you will win over people in the area. Your enthusiasm will spread and with it the news and information about the new crop.

Appendix 1: Legumes

Table 10: Growing conditions for food legumes.

English name	Scientific name	climate/ water requirements	temperature	soil
groundnut, peanut	*Arachis hypogaea*	250–650 mm in 3–4 months or 650–1300 mm in 4–5 months cannot tolerate too much water	20^{0}–35^{o} C	light sandy soil with sufficient nutrients for beans which grow under the ground
pigeon pea, congo pea, red gram	*Cajanus cajan*	800–1000 mm	20^{0}–40^{o} C	Only legumes on this list that can tolerate slightly saline (salty) soils
chickpea, gram pea	*Cicer arietinum*	Demanding in terms of requirements: sufficient water during vegetative growth, will not tolerate heavy rainfall during flowering period	15^{0}–30^{o} C	Grows on light and heavier soils that are well drained. Requires a pH of 6 - 9, cannot tolerate saline or acid soils
soybean, soya bean	*Glycine max*	700–1000 mm	20^{0}–30^{o} C	Grows well on heavier soils that are well drained. Cannot tolerate saline or alkaline soils.
butterbean, hyacinth bean	*Lablab purpureus*	600–900 mm drought resistant, better than soya or *Phaseolus sp.*		
lentil, gram	*Lens culinaris*	800–2000 mm	2^{0}–30^{o} C	
butterbean lima bean	*Phaseolus lunatus*	700–1000 mm		
garden bean, kidney bean haricot bean, common bean	*Phaseolus vulgaris*	700–1000 mm cannot tolerate too much water	10^{0}–30^{o} C	loamy soil, reasonably fertile, pH 5.0–7.5 crumbly soil structure important for a good yield.
pea	*Pisum arvense* and *pisum sativum*	500–800 mm	10^{0}–30^{o} C survives temperatures below freezing point	PH 5.5–6.8, can tolerate somewhat saline soils. Requires a well prepared soil with crumbly structure and good drainage.
cowpea, blackeyed pea	*Vigna unguiculata* syn. *Vigna sinensis* syn. *Vigna sesquipedalis*	600–900 mm	20^{0}–35^{o} C	
bambara groundnut	*Vigna subterranea* syn. *Voandzeia subteranea*	Dry, Sahel, cannot tolerate too much water		light sandy soil with sufficient nutrients, because beans grow underground

Table 11: Sowing distances and densities			
English name	**Scientific name**	**Sowing density (cm x cm)**	**Sowing density (kg grain/ha)**
groundnut, peanut	*Arachis hypogaea*	30 x 30 hand cultivated 60–40 x 15 cultivated using animal traction	50–80
pigeon pea, congo pea, red gram	*Cajanus cajan*	60–40 x 30–45; 180 x 150 Puerto Rico; 150 x 150 East Africa; 90 x 60 Sri Lanka	13–22 India; 9 Sri Lanka
chickpea, gram pea	*Cicer arietinum*	30–60 x 10	
soybean, soya bean	*Glycine max*	60 x 5 ; 50 x 2–3 cultivated using machine	55–65 Asia 22–34 Africa
butterbean, hyacinth bean	*Lablab purpureus*	80 x 10; 80 x 20 Sudan	55–65 Asia 22–34 Africa
butterbean lima bean	*Phaseolus lunatus*	75–60 x 10–15 cultivars with big bean 75–60 x 7.5–12.5 cultivars with small bean	36–78 small beans, 130–170 big beans
garden bean, kidney bean haricot bean, common bean	*Phaseolus vulgaris*	90–5– x 22–5; double rows 60 spaced out and 15–30 in the double rows; the climbers need support such as canes.	30; 45; 55; 70; 90; 115
pea	*Pisum arvense* and *Pisum sativum*	Dwarf cultivars 18 – 25 x 5, semi-dwarf cultivars 30–65 x 5, Many-branched cultivars 100 x 5	80
cowpea, blackeyed pea	*Vigna unguiculata* syn. *Vigna sinensis* syn. *Vigna sesquipedalis*	90 x 30; 45 x 15; 50 x 50; 50 x 40	22; 33
yard bean	*Vigna unguiculata ssp sesquipedalis* syn. *Vigna sesquipedalis*	100 x 30–50 support necessary (canes or wires)	25–50
bambara groundnut	*Vigna subterranea* syn. *Voandzeia subteranea*	45 x 10–15; 2 rows on ridges 90 cm apart	35; 50; 65

Appendix 2 : Inoculating soya with rhizobium

If the soya plant does not form active root nodules on its own then the crops needs treating or inoculating with rhizobium. It is not always easy to find rhizobium. In countries where rhizobium has been used for a long time it will be easy to find rhizobium products through the agricultural extension services. In other places it may be necessary to contact agricultural research stations in your own country or neighbouring countries.

Inoculation methods

There are two ways of carrying out inoculation

- Inoculating the seed material with rhizobium before sowing it.
- Inoculating the soil with rhizobium in the field where soya is to be sown.

Generally speaking the first method is preferred because it is simpler to carry out and is far cheaper to do.

However, sometimes it is necessary to inoculate the soil; for example if the soil is very dry and acid (pH < 5), or contains many rhizobia that do not create active root nodules, or if the soya has been treated with a chemical such as a fungicide or insecticide which rhizobia cannot tolerate. Because it is not yet known which chemicals rhizobia can tolerate, it is better to assume that inoculating any soya seed that has been treated with fungicides or pesticides will not help root nodule formation. In these cases it is better to inoculate the soil.

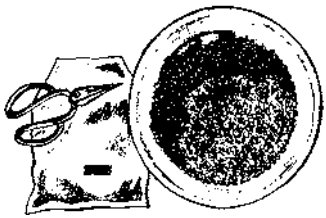
Inoculating seed

Rhizobium bacteria comes in powdered form, called inoculant. It has to be mixed with water until you have a mixture you can pour (slurry).

items required to inoculate seed: seed in a mixing bowl, packet of inoculant, beaker of water

inoculant is mixed with water to form a pouring mixture (slurry)

the mixture is added to the seed



seed and inoculant mixture are mixed well so that all seeds are covered evenly with the mixture, but not soaked through. It is best to sow the seed immediately once this has been done

Fig. 20: Inoculating seed.

This is the most commonly used method throughout the world. Bolivia has been producing inoculant on a commercial scale since 1991 with very good results. If you add some sugar to the slurry mixture the rhizobium bacteria die less quickly during the drying. It is important that the seed does not get too wet, so that it does not stick together or get damaged by the sowing machine.

The following quantities are recommended for soya: 25 kg seed, 250 ml water and 110 g rhizobium powder. Adjust these quantities for the amount of seed you are using. If necessary make a table of quantities for yourself.

Sometimes the powder is added dry to the seed in the sowing machine. This is not advisable because the powder blows away easily and so is lost.

Inoculation of seeds only works if it is done just before they are sown. Preinoculated seed sold in shops usually gives disappointing results and we do not advise you to use it.

How often should I inoculate?

The advice given in Bolivia is to assume that there will not be sufficient rhizobia present in the soil of fields where soya has been grown for longer than five years. Even better is to always inoculate your seed. In Bolivia this is considered a 'cheap form of insurance'.

Inoculating the soil

Fluid mixtures

Inoculating soya beans in Senegal gave good results with 5 litres per hectare of a solution of 2 parts powder and 1 part water. The solution was sprayed on to the soil.

Granules

Porous granules can be treated with rhizobium and mixed with the seed in the sowing machine or spread by special machines that spread

insecticide in the form of granules along the rows. In this case 6 – 8 kg of inoculant can be sufficient. We do not have details of how much rhizobium this kind of inoculant contains.

When buying inoculant you should check that the following things are listed on the packaging:

- The scientific (Latin) name of the rhizobium (for soya this is *R. japonica*).
- Instructions for use.
- How to store the product; not above 40°C because the rhizobium will die. At a temperature of about 20°C inoculant will remain good for about 6 months. At 4°C it will last even longer.
- The shelf life of the product must be given: the date after which the product can no longer be used.

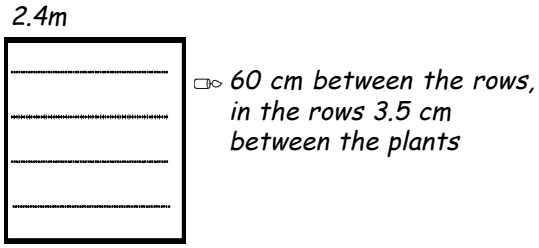
Appendix 3: Giving advice on inoculation

You can carry out a simple comparative trial to convince farmers that inoculation is worthwhile. The soya plants are treated in three different ways.

1. inoculation with the best inoculant available in the area.
2. no inoculation and no artificial fertilizer given.
3. only artificial fertilizer applied (if this is advised in the area).

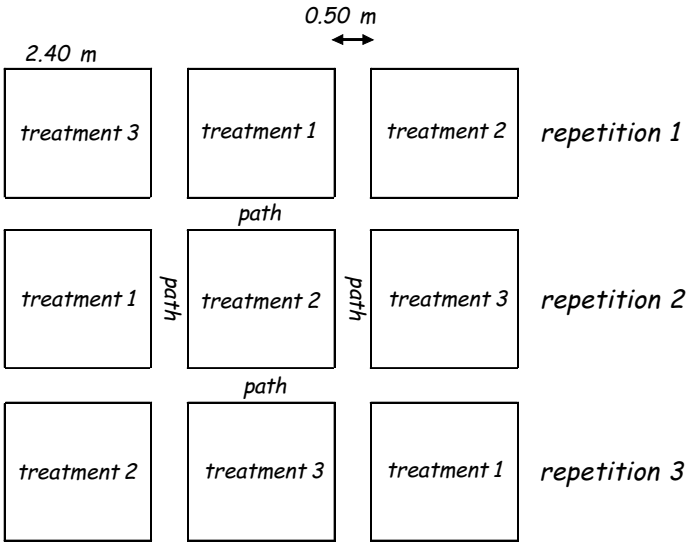
For each treatment a plot is prepared with spacing of 60 cm between the rows and 3.5 cm within the rows. Each plot should have at least 4 rows. This means that the plot will 2.4 x 2.4 m.

Each plot looks like the one below:



Each treatment is repeated 3 times in order to exclude the possibility of coincidence. Each trial is therefore carried out 3 times. A total of 3 plots for each of the 3 treatments means a total of 9 plots.

With paths of 0.5 m between the plots the whole trial field will look like this:



Calculating further for 450,000 plants per hectare:

With a seed weight of 9000 seeds/ kg, 65 kg seed/ ha is required with 286 g inoculant.

Only the middle two rows of each plot are compared with each other, because the treatment at the edges may be influenced by the treatment on the other plots.

Further reading

Cultivation of soya

ACIAR Proceedings no 18. 1986. **Food Legume Improvement for Asian Farming Systems**, Proceedings of an international workshop held in Khon Kaen, Thailand, 1-5 September 1986 (editors Wallis, E.S. and D.E. Byth.) isbn 0949511 28 5.

S.K. Sinha. 1977. **Food legumes: distribution, adaptability and biology of yield.** Food and Agricultural Organization of the United Nations (FAO), Rome , isbn 92-5-100186-3.

Food and Agricultural Organization of the United Nations (FAO). 1984. **Leguminous Inoculants and their use.** A pocket manual jointly prepared by Nitrogen Fixation for Tropical Agricultural Legumes (NifTAL) Project USA and FAO Fertilizer and Plant Nutrition Service.

Food and Agricultural Organization of the United Nations (FAO). 1994. **Tropical Soybean, Improvement and production.** Plant Production and Protection Series, Brazilian Agricultural Enterprise, National Soybean Research Centre (EMBRAPA-CNPSo).

Meneses, R.; H. Waaijenberg; L. Piérola (editores).1996. **Las leguminosas en la Agricultura Boliviana Revision de Información.** Cochabamba, Bolivia.

Summerfield, R.J.;Roberts, E.H. (editors). 1985. **Grain Legume Crops.** Collins. isbn 245547-03.

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). 1992. Multilingual illustrated dictionary, isbn 3-8236-1126-7.

ICARDA. 1988. **Winter Cereals and Food Legumes in Mountainous Areas.** International Centre for Agricultural Research in the Dry Areas (ICARDA).

Oram, P. and B. Abderrezak. 1990. **Legumes in Farming Systems.** ICARDA/ IFPRI Report.

Johansen, C. et al. (editors). 2000. **Legumes in Rice and Wheat Cropping Systems on the Indo-Gangetic Plain – Constraints and Opportunities.** International Crops Research Institute for the Semi-Arid Tropics.

Pandey, R.K. 1987. **A farmer's primer on growing soybean on riceland.** IRRI AND IITA.

Dupriez, H.; DE Leener, P. 1988. **Land and Life, Agriculture in African Rural Communities, Crops and Soils.** Macmillan Publishers in association with Terres et Vie and CTA.

Nutrition and recipes

Catsberg, C.M.E.; Kempen van Dommelen, G.J.M. 1990. **Levensmiddelenleer, produktinformatie over voedings- en genotmiddelen.** Nijgh en Van Ditmar, tweede druk.

Food and Agricultural Organization of the United Nations (FAO). 1989. **Utilization of tropical foods: tropical oil seeds.** FAO Food and nutrition paper 47/5.

Food and Agricultural Organization of the United Nations. 1992. **Technology of production of edible flours and protein products from soybeans.** FAO service bulletin 97, FAO.

Schempp, R. 1989. **How can I cook soyabean?** Recipe book produced by the United Church of Zambia.

Thio Goan Loo. 1971. **Small-scale processing of soybeans and some applications.** Royal Tropical Institute, Amsterdam, The Netherlands.

Food and agricultural organization of the United States. 1994. **Tropical Soybean, improvement and production.** FAO, Rome.