Technical guide

Agroecological and agroforestry practices in tropical wet zones

A collective work coordinated by Justine Scholle (GRET)

Éditions du Gret

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Its contents are the sole responsibility of GRET and can in no way be considered to reflect the European Union's and the International cooperation of the French department Hauts-de-Seine point of view.

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Contents

Preface

From the outset forty years ago, GRET became known for its technical publications, humorously qualified by some people as "development recipe cards". The best known and most voluminous publication is the *Mémento de l'agronome*, published with CIRAD. This guide devoted to agroecology in tropical wet zones continues this tradition.

It was produced using a similar approach, which consists of capitalising on experiences in the field (in this case mainly Democratic Republic of Congo and Cambodia) and providing a support tool for technicians and farmers, who are central players in relaying actions to promote and develop agroecological know-how.

Given the risks of climate change and growing demand for foodstuffs, agroecology is emerging as a pertinent approach, for at least five reasons: it improves soil fertility; it minimizes solar energy, air, water and nutrient losses; it protects soil for plant growth; it strengthens genetic diversification over space and time; and lastly, it makes it possible to fight effectively against pests (disease, insects and weeds) while reducing insecticide spraying. So agroecology is a resilient agriculture in the face of climate change, and it emits low levels of greenhouse gases.

Promoters of agroecology, including GRET, are very rightly underlining the major challenges agroecology can meet, in terms of food security and in terms of transition of modes of production and consumption given the current ecological crisis, which is likely to worsen. They are also demonstrating the advantages of agroecology, whether in terms of responding to fertility problems in ecosystems, variability of agricultural production, improving nutritive quality of food, contributing to income for farmers and territories, improving management of non-renewable resources and land, and lastly, climate-compatible policies. It is also recognised that while support for agroecology among farmers involves all stakeholders concerned and requires changes in attitude and practices, it is above all a challenge for technicians and practicians working in agriculture and breeding, because they must renew agricultural and management advice, which is the objective of this guide.

Applied in tropical wet zones, the guide provides details of numerous techniques. It describes the very essence of agroecology, distilling local knowledge accumulated by family farming, while contributing to improvement and dissemination of this knowledge. When used by practitioners, it should be kept in mind that this guide does not promote a rigid, uniform or reductive approach, but a pragmatic approach that must be adapted to suit each territory, local know-how, ways of creating economic added-value, etc. Generalization of these practices remains complex, and should not conceal the difficulties they entail. There are significant risks involved in switching from conventional agriculture to agroecology, with a reconversion phase that can lead to a temporary decrease in yields. Time always plays a key role in the dissemination of agroecology techniques: time to experiment, to learn, and to spread. A tailored approach is often necessary to manage the complex interactions between soils and plants, taking into account local agricultural practices.

This is why technical orientations must be flexible and progressive, with a view to facilitating ownership, combining management advice, learning, credit and professional organizations taking charge. No agricultural route is easy or linear, hence the importance that must be attributed to research, farmer-led experimentation and impact studies. There is no single set of instructions. A lot of coming and going is necessary. I could conclude with a farming adage: "agriculture is a long process of learning on a daily basis...".

Pierre Jacquemot
Chairperson of GRET

Why this guide?

This guide is designed as a support tool for technicians and farmers involved in actions to promote and develop agroecology.

It is a follow-up to a first technical guide published in 2014 in the Democratic Republic of Congo as part of the DEFIV project, a food security project implemented by GRET, funded by the European Union and Agence française de développement.

As part of this project, farmers in Mayanda, an agricultural area located on the outskirts of Boma in Bas-Congo province, received agroecology and agroforestry support. New techniques were proposed and tested in farming field schools, and subsequently in pilot farmers' plots. Techniques that proved effective were then promoted in the area. Agricultural producers then expressed their wish to have a written support recording crop management sequences and know-how developed as part of the project. They wanted to be able to refer to these if necessary. So a booklet was written in Kikongo, the language of Bas-Congo. It featured numerous illustrations, so that people with poor or no reading skills can use it.

Beyond this African region, it emerged that technicians and farmers involved in promoting agroecology in tropical wet zones had little technical information that could be quickly and easily mobilized in the field. Hence the idea for this guide, which aims to respond to their needs.

This guide features two parts:

The first part presents the current context and issues of agroecology in tropical wet regions. Having demonstrated the limits of conventional agricultural systems, analysed the effects of deforestation, the green revolution and climate change, the authors specify the objectives and the principles of agroecology, and remind readers of the conditions necessary to promote it.

The second part is very operational and covers the various agroecological techniques, which were tested in a tropical wet context with satisfying results in the Democratic Republic of Congo (DEFIV project), Cambodia (APICI project) and Myanmar (Delta and NRS projects). Firstly, the various agroecological techniques are presented, and secondly the plants used to implement these techniques are described. Naturally, techniques such as plant inventories mentioned in this guide are not exhaustive.

Each factsheet – whether it covers a technique or a plant – presents the advantages and disadvantages of the subject covered.

The factsheets on techniques specify their various features. Each technique can have one or several cross-cutting features. However, to facilitate reading, they have been grouped together according to their main feature, in six categories:

- integrated pest and disease management,
- soil fertility management,
- system of rice intensification,
- combating soil erosion,
- production of quality seeds and plants,
- management of natural resources.

Each technique is detailed and illustrated with diagrams and photos. And references are given to related literature with a view to exploring the subject further.

The factsheets on plants describe the plants used in agroecology, present their biophysical limitations and their multiple uses. The various techniques implemented to cultivate them are also presented, except when these plants are found naturally in the environment. References are made to the technical factsheets using the plants in question.

Designed to provide very practical data, this guide should not be taken at face value. It does not deliver miracle methods having proved their worth that must be disseminated as they are. The solutions proposed must be tested every time and adapted to suit the local context, according to the needs previously expressed by farmers.

Agroecology: context and challenges

We define agroecology as agriculture that:

- makes it possible to reproduce, or even improve, the productive potential of the ecosystem being cultivated;
- is largely autonomous in terms of non-renewable resources;
- produces quality, diverse food;
- does not contaminate the environment or populations;
- contributes to the fight against global warming.

The limitations of conventional agricultural systems

Traditional slash-and-burn systems are in crisis

In the majority of tropical wet regions, the form of agriculture traditionally practised was forest-based or slash-and-burn (or sometimes slash and decay): every year, farmers cleared a plot of forest, burnt the felled vegetation or let it decay, and then sowed seeds on the plot. Yields were relatively high, and the plants cultivated benefitted from the organic and mineral fertility accumulated beneath the forest. At the same time, weeds and parasites specific to the plants cultivated were practically inexistent because of the predominance of the forest ecosystem. After one or two years of growing, farmers abandoned the plot to clear a new one, leaving the forest – and therefore fertility – to grow back over periods that could last up to several decades.

Due to demographic growth, this system became fragile and was subject to increasingly intense cycles of fertility crises. This is what happens when the availability of land under the forest canopy is no longer sufficient to enable complete regeneration of the forest: the time allowed for forest regrowth gets shorter (in the long term only shrubs and grasses grow back), and soil fertility is not totally restored.

As yields are tending to decrease, farmers are forced to clear larger plots to obtain an equivalent level of production. This tends to increase the surface areas cultivated and decrease the time for forest regrowth. The crisis is worsening even more because in tropical wet climates, soil with no forest cover is very quickly depleted, with rapid decay of organic matter, leaching of minerals and water erosion on slopes. At the same time, the surrounding ecosystem loses its dominant forest and is gradually invaded by weeds. The need to weed significantly increases farmers' working time. Greater competition for crops from weeds and the presence of parasites generate a decrease in yields. The latter can drop to less than half a ton of dry matter per hectare, compared to several tons in a balanced forestry system. In these systems in crisis, crops can grow on the same plot year after year without ever being left fallow. This type of conversion is sometimes even encouraged by public authorities promoting single-crop farming with a technical model generated by the green revolution.

In a number of regions, the most widespread process of deforestation results from advancing frontiers. The latter are related to natural demographic growth in areas close to forests and migration of farming populations looking for new land. Yields on cleared land decrease after the first or second year. Very often, land is abandoned or used for extensive grazing that is not very productive, with farmers continuing to cut into the forest in order to obtain better yields for their crops. When there is no longer any available forest, farmers cultivate the same land, with short (one to several years) or continuous fallow periods, tilling the land – often manually – to better control regrowth of weeds. In all cases, yields remain low and in the long term, farmers are forced either to migrate or change their systems more radically.

In general, farmers are confronted with a crisis in terms of reproducing fertility, whereas they have neither the means nor the technical knowledge to put alternative fertility management systems in place. Adopting such systems and putting them in place is all the more difficult as the farmers in question, who are usually in a situation of economic and social crisis, do not have the resources to invest in new means of production.

A green revolution with mixed effects

Sometimes farmers try to replace the old way of managing fertility with solutions generated by the green revolution, such as the use of chemical fertilizers, weed-killers and pesticides. In areas benefitting from favourable, stable soil and climate conditions, green revolution solutions improve yields and new agricultural systems that are more or less stable are being put in place.

However, over the medium term, yields generally tend to decrease, or remain stable due to the use of increasing quantities of chemical inputs; the fertility crisis does exist, but it is partially concealed. In some cases, the system can be stabilized, but it is totally dependent on external contributions, especially because of low organic fertility of soils and significant pressure from competitors (weeds and parasites).

In impoverished ecosystems with unstable climate and market conditions, when green revolution solutions are applied without any support measures, they tend to make farmers significantly more fragile. Very often, structural weaknesses in the ecosystem (low rate of organic matter in soils and significant pressure from competitors) prevent green revolution techniques from providing a satisfactory response. Increase in yields does not compensate for higher production costs. There is a very high risk for farmers. If there is an accident with yield or the market (drop in prices), it is impossible for them to cover production costs. In which case they may have difficulties reimbursing seasonal credits and have to borrow for cash flow requirements.

The green revolution has also led to greater dependency of farmers on companies upstream (supply of equipment, seeds, fertilizers and other inputs) and downstream (vertical integration with modes of production and market conditions imposed by agrifood businesses). Farmers often become overindebted, which can be the cause of major crises (farm bankruptcies, suicides, etc.).

In most cases farmers are reticent to use "improved" varieties from plant breeding stations. These varieties seem more fragile than traditional varieties and do not meet certain requirements (taste, suitable for cooking, etc.). Yet use of green revolution inputs often has less effect on traditional varieties (for example, lower increase in yield) and is in fact not economically sound. This is one of the reasons why farmers are reticent to use these techniques. In addition, the poorest farmers do not always have the means to acquire green revolution inputs. In some regions, the latter are simply not available on the market.

Lastly, when farmers have largely integrated green revolution techniques, intensive use of fertilizers and pesticides very often leads to a decrease in biodiversity and contamination of the environment and food. It should also be noted that practices generated by the green revolution contribute to increasing greenhouse gas emissions (nitrogen fertilizers, manufacture of pesticides, etc.).

A system weakened by the impacts of climate change

These weakened systems become highly sensitive to extreme climate events such as drought or heavy rains. Yet, in many regions, current climate change and its effects are increasingly visible: rainfall variability is increasing every year, disruption of seasonal patterns, increase in the frequency of extreme events (drought, heavy rains leading to flooding and erosion, extreme temperatures), attacks from parasites and disease, higher average sea level and change in the level of water surfaces. Climate and ecological conditions are becoming a lot more unpredictable, increasing the vulnerability of farmers and especially the poorest among them.

Over the coming years and decades, and even if global warming is controlled and the average increase in temperature is stabilized at 1.5°C to 2°C – which is far from being guaranteed – the effects of climate change will be heightened in tropical wet regions.

Reducing farmers' vulnerability to climate change and its effects is a major challenge. It necessitates strengthening farmers' capacity to adapt, especially via more resilient agricultural production systems. Although today we are not able to specifically define climatic impacts or the impacts of mitigation and adaptation measures applied at local level, it is nevertheless crucial to explore alternative approaches and document their techniques as specifically as possible.

The major challenges of fighting against deforestation

Deforestation related to agriculture accounts for approximately 11% of global warming. Although the rate of deforestation decreased by 50% over the last five years, it still remains high. In addition, deforestation mainly affects tropical regions, whereas forested land is tending to increase in temperate regions and to stabilize in subtropical and boreal regions. In all, tree cover decreased by 9%, i.e. 156 million hectares in tropical zones between 2000 and 2012.

Various studies show that, since 1990, the majority of deforestation in tropical regions is related to the development of large farms and agribusiness plantations (palm oil, livestock, soya, etc.). Part of deforestation is also generated by the pressure applied by a farming population in a crisis situation. The latter sets about clearing forest land using the process mentioned above, or with a view to selling wood in order to generate complementary income.

Support for small farms is today a key issue in the fight against deforestation. On the one hand, it is necessary to protect farming families from migration related to land grabbing and the expansion of agribusiness. On the other hand, it is necessary to support them to develop stable agricultural systems that generate income, in order to minimize future deforestation.

Agriculture can also contribute to the fight against climate change by storing carbon in the form of organic matter, both in the soil and in biomass. In this way, reforestation in agricultural production systems can be envisaged, especially in tropical wet regions offering the conditions necessary for rapid growth of tree vegetation. Soil content of organic matter is often very low in these regions and agricultural production systems adapted to suit this context can enable considerable growth in the rate of organic matter, and therefore of farming land.

Farming populations subjected to food and nutritional insecurity

The food and nutritional security of farming populations in tropical wet regions generally depends on their capacity to produce food in sufficient quantity that is nutritionally balanced and healthy (free from pathogens and toxic products). Yet, it is among rural populations that rates of food insecurity and malnutrition are highest.

Given the characteristics of the world market (high price volatility), long term food security for populations in tropical wet zones depends largely on the capacity of the regions and countries in question to produce their own food, with a view to feeding rural and urban populations. However, the rate of dependency on food imports in many countries – especially in Africa – is tending to increase and the situation could further deteriorate due to demographic growth and the challenges agriculture must rise to today. Consequently, increasing agricultural production is important for food security in countries in tropical wet regions.

It is necessary to promote the development of agricultural production systems that make it possible to sustainably:

- restore degraded ecosystems (in particular soil fertility and biodiversity);
- manage ecosystems and their fertility, adapting this management to climate change;
- go beyond the limits and negative effects of agricultural models generated by the green revolution;
- improve and stabilize levels of production, food and nutritional security, and income for farming families;
- increase available agricultural production for the entire population in the countries concerned, and therefore their food security in the medium term;
- contribute to the fight against climate change, both by stopping the process of deforestation and increasing carbon storage in the form of organic matter.

Agroecology, a response at the intersection of major issues

Multiple objectives

Agroecology is a type of agriculture that aims to simultaneously respond to various objectives, which means that no single one of these objectives must be sacrificed for the benefit of the others. These objectives are:

1. obtain diverse, quality agricultural and food products, in sufficient quantities and in a relatively stable (and therefore predictable) manner over time. Stability requires the capacity of agriculture to adapt to climatic events and health crises;
2. improve and reproduce the productive potentialities of the ecosystem cultivated;
3. maximal autonomy in terms of non-renewable resources;
4. no contamination of the environment (soil and sub-soil, water, atmosphere, biodiversity, state of fauna and flora) or populations. Agroecology can also contribute to recycling contaminating elements;
5. contribute to the fight against climate change.

The first objective is a sort of raison d'être of agricultural activity, fully integrating the diversity and quality of products (nutritional, taste and health quality).

Objectives 2 and 3 are the positive effects generated by agriculture (positive externalities) in domains where, on the contrary, "industrial" agriculture very often produces negative effects (degradation of the productive potentialities of the ecosystem, consumption of non-renewable resources, contamination of the environment and populations, contribution to global warming).

Objectives 4 and 5 are not necessarily made explicit by farmers, but agroecological practices can contribute to these in a general manner.

Let us add that agroecology covers other dimensions that exceed the scope of agricultural production, such as:

- the entire food system (preservation, marketing, processing, distribution and consumption of agricultural and food products);
- cultural (reappropriation of traditional techniques and local know-how, solidarity, etc.), social (organization of farmers to promote agroecology and draw optimum value from its products, establishment of direct links with consumers, etc.) and political (defence of rights and of the role of farmers, food sovereignty, etc.) dimensions.

Four fundamental principles of agroecology

At agricultural production level, agroecology is based on four fundamental principles:

– mobilization of potentialities of ecosystems cultivated in terms of use of natural external resources;
– inter-relationships between components of the ecosystems cultivated;
– enhancement of biodiversity;
– reproduction and improvement of the productive potential of the ecosystem cultivated.

1. Mobilization of potentialities of ecosystems cultivated

This principle can be divided into various stages of harnessing, retaining, storing and reducing losses of natural resources external to the ecosystem cultivated. Several types of resources can be identified:

Unlimited and directly accessible resources:

– solar energy and atmospheric carbon fixed in the form of organic matter during the photosynthesis process;
– atmospheric nitrogen for protein synthesis, via leguminous crops with the capacity to fix nitrogen thanks to interaction with microorganisms at root level.

Resources that are practically unlimited but difficult to access, especially mineral elements located deep in the bedrock.

Limited resources, such as rain water and water from rivers and the sub-soil. Agroecology places particular focus on storing these and reducing their loss in the form of evapotranspiration, infiltration or run-off.

Numerous agroecological practices aim to increase harnessing of natural resources, and reduce losses: maximal harnessing of solar energy and carbon dioxide with combined crops and succession of various production cycles on the same plot during the year: use of leguminous crops (harnessing of nitrogen), use of trees and crops that are deep-rooted (harnessing of mineral elements and water, soil protection), ground cover plants (sowing under plant cover) and mulching (reduction of water losses, soil protection), harnessing systems, retention and storage of water, etc.

Alongside this, some inputs can be provided by the local environment, can come from exchanges between farmers or be acquired on the market (natural pesticides, organic manure, etc.).

2. Inter-relationships between components of the ecosystems cultivated

Recycling of biomass within the agricultural production system plays a central role in the enhancement and development of internal flows (organic matter, mineral elements, water) in the ecosystem cultivated, thanks to:

- crop-livestock integration (animal feeding, use of animal manure as fertilizers);
- integration between crop production activities (cultivation of leguminous crops enriching the soil with nitrogen for subsequent crops, trees contributing to organic and mineral fertilization of crops, natural pesticides from plants, etc.);
- integration between animal activities (use of livestock sub-products to feed other animals).

Some agroecological practices facilitate the development of biodiversity, by enhancing the metabolic function of microorganisms and animals in the soil and useful inter-relationships to control disease and parasites (integrated pest management).

Other agroecological practices contribute to changing the microclimate of the farm or its components (trees and hedges protecting crops from wind and excessively high temperatures, organic matter left in the soil to protect it from high temperatures, etc.).

3. Enhancement of biodiversity

Enhancement of the biodiversity of plant and livestock species is one of the principles of agroecology. Use of local genetic material, from the farm or the region (purchase and exchange of seeds) is given priority, as is enhancement of other species (fauna, flora, microorganisms in the soil).

These first three principles of agroecology make it possible to minimize the use of external inputs generated by industry, increase production per unit of surface area, and ensure regularity of production over time and diversity of products obtained. In this way, agroecology places the ecosystem being cultivated at the heart of its approach. It uses its own complexity, contrary to agriculture generated by the green revolution, where the ecosystem becomes a mere physical support to be simplified as much as possible, for example by eliminating all living species other than the plants cultivated and the livestock bred.

4. Reproduction and improvement of the productive potential of the ecosystem cultivated

This principle has implications for the choice of species and agricultural techniques used in each productive cycle (choice of species and techniques that contribute to protecting soils and improving their fertility, etc.). Some techniques aim specifically to protect and improve the ecosystem (soil protection and water management techniques, plantation of trees, etc.).

Agroecology is not new!

The principles of agroecology are not new. Farmers have always included reproduction of the productive potential of ecosystems cultivated in their objectives. Following the crisis of slash-and-burn systems, agricultural production systems have changed. Certain of these are based – and sometimes have been for centuries – on techniques that today could be qualified as agroecological: crop combinations and rotations, use of leguminous crops, integration of trees in ecosystems cultivated (agroforestry), integration between crop farming and livestock farming, biological control techniques, anti-erosive systems, harnessing work, retention and storage of water, use of local genetic resources, etc. But with the development of the green revolution, some of these practices have regressed, or even disappeared.

So the development of agroecology is based largely on enhancement and sharing of traditional know-how. Scientific research has come to play a significant role in:

- better understanding of how the ecosystems cultivated work, agroecology mechanisms and conditions that are favourable for the development of agroecological practices;
- facilitation of innovations aimed at solving the numerous technical problems and improving how agroecological systems work;
- specification and demonstration of the impacts of agroecology in terms of climate change.

So in tropical wet regions, agroecology seems capable of responding to multiple issues:

- restoration of degraded ecosystems;
- development of management of ecosystems and their fertility, making it possible to increase agricultural and food production and decrease its sensitivity to climatic events. Diversification of activities, use of suitable genetic material and reduction of purchase of external inputs contribute to greater stability of production and income year after year;
- sustainable improvement of food and nutritional security of farmers and, more generally, of the regions and countries concerned;
- going beyond the limits and negative effects of agricultural models generated by the green revolution;
- the fight against climate change (control of deforestation and storage of carbon in the form of organic matter in ecosystems cultivated).

Promoting agroecology

The difficulties involved in agroecological transition

Numerous projects across the world are seeking to promote agroecology. However, transition to agroecological systems is far from easy. Adopting and applying these systems generates various difficulties for farmers, in terms of timescale, investment, land security and risk assessment:

– timescale: this transition takes time, especially as there is never a "miracle technical solution" in agroecology. Solutions depend on the specific agroclimatic and socio-economic characteristics of each plot, farm and region. This is why projects promoting agroecology based on a "vertical" approach have not achieved much;
– investment: for farmers, agroecological transition represents an investment (monetary and/or in terms of work) which often has delayed profitability (for example, sometimes it takes several years before soil fertility is regenerated);
– land security: farmers are not always sure to benefit from the investment if they do not have secure, durable access to the land. They are even sure not to benefit from it when collective rights such as common grazing exist and prevent them from protecting the biomass they want to increase or leave in the soil;
– risk assessment: as with any change process, this transition involves taking risks, because results are never guaranteed in advance. These risks seem even greater as giving up certain elements of the green revolution sometimes initially leads to a decrease in production volumes. If farmers are in an economically and socially precarious situation and must face immediate priorities (such as feeding their family), they are unlikely to take such risks. This is why, generally speaking, only agriculture that is not in an extremely precarious situation is likely to engage in agroecological transition.

The necessity for agricultural policies and actions in favour of agroecology

Agroecological transition first and foremost requires agricultural policies and actions that ensure small farms have secure, durable access to natural resources (land, agricultural water) and production capital, as well as a favourable socio-economic environment (stable remunerative prices, access to credit, complementary public investments). So agroecological transition of agriculture should be considered as a dynamic component of more global development. With agroecology, as in the technical field generally, it is necessary, to avoid technicist approaches claiming to transform things with a single technical change.

Specific interventions to promote agroecology

In this context, specific actions can contribute to promoting agroecological practices, whether within development programmes and projects or in the more general framework of agricultural policies.

Technical support for farmers adapted to suit each situation: the ecosystems being cultivated are varied and complex and agroecology is based on drawing optimum value from the specificities of each one. This is why there are no recipes that can be applied everywhere. It is unrealistic to envisage disseminating "technological packages" that could be applied as they are in any situation. Apart from the diversity of ecosystems, socio-economic conditions vary greatly from one region to another, and even from one farm to another, whether in terms of availability of productive resources, levels of know-how or conditions of access to land, credit and markets. This context determines the motivation and possibility of farmers to implement the various practices and choose the most suitable practices.

It is important that actions undertaken favour collective identification of limitations and needs for technical change. Raising awareness on plurality of agroecological practices, support for experimentation, organization of exchanges between farmers (within one region and between regions) and consultation at territorial level make it possible to change collective rules (common grazing rights, etc.), and identification of any technical needs.

Farming field schools can be used to conduct tests in controlled or semi-controlled environments. This enables farmers to observe agroecological techniques and compare them to traditional techniques. Adaptations can be made directly in fields from one year to the next, according to observations made.

Working with "pilot" or "relay" farmers: the techniques considered most favourably by the community can be promoted among "pilot" or "relay" farmers, who in turn accept to test these techniques in their own field. Visits and training are regularly proposed to the rest of the community, both in field schools and in relay farmers' plots. Field schools are often led collectively. The most motivated farmers, who are strongly involved and obtain good results, can be trained further to become facilitators over the long term and ensure wider promotion of innovations.

Systems for access to credit: alongside technical support, it is generally advisable to plan systems for access to credit that are appropriate to the practices implemented (amounts, repayment periods and conditions).

Grants and specific remunerations: targeted grants are sometimes useful to facilitate specific investments in agroecology (plant material, animals, equipment and tools). "Pilot" and "relay" farmers may be motivated by access to credit, seeds and inputs necessary for putting crops in place, or even by allocation of remuneration. However, it is necessary to be extremely careful that these types of grants do not distort the system. This can be the case when a "pilot" or "relay" farmer's interest in the approach is mainly related to the possibility of a grant or a specific remuneration. The latter must be clearly motivated (investment, risk-taking, demonstration of benefit to the community) and have a time limit. If all the other farmers do not have the same conditions, analysis of the long-term profitability of the innovation must be conducted excluding the grant or remuneration. Long term specific remuneration could be envisaged for facilitator farmers. Lastly, more sustainable remuneration of agroecological farmers for the positive effects they generate to the benefit of society at large can be perfectly justified, but it must be said that the majority of tropical countries do not generally have the means to guarantee such remuneration.

Sustainability of input supplies: many agroecological practices require the use of natural inputs from outside the farm: plant material and seeds, biopesticides, food for animals, etc., or specific agricultural material. Their availability after the intervention must be ensured, which may require implementing specific supply chains and mechanisms for exchange of material between farmers.

The existence of income-generating markets: agroecological practices very often include diversification of agricultural activities and therefore of products. If farmers do not consume these products themselves, they must be able to market them, which can require implementing specific market chains. Products generated by agroecological practices – and especially products from organic agriculture – are likely to draw greater value on markets. Appropriate systems can contribute to this: certification systems, processing and packaging activities, and marketing chains at local, national or international level.

Associated research: research programmes associated with promotional actions can be very useful to contribute to responding to needs expressed by farmers, to adapt existing agroecological techniques, solve specific technical problems, or produce references and explain certain results. Farmers' needs in terms of research and support require real developments in terms of training for engineers, technicians and researchers, whose training is generally more focused on "technicist" and "vertical" approaches.

Technical factsheets

Integrated pest and disease management

Soil fertility management

System of rice intensification

Combating soil erosion

Production of quality seeds and plants

Management of natural resources

Intercropping

Functions

Integrated pest management
Income diversification
Land use optimization
Natural resources management

+

- Reduces the incidence of pests and diseases
- Optimizes the use of natural resources (water, minerals, soil, light)
- Produces different crops in the same space
- Valorizes the interactions as well as the complementarity between crops on a single plot
- Limits the risk of loss due to climatic hazards, thanks to different growth habits
- Reduces the risk of lodging
- Provides a better ground cover, both in time and space
- Reduces weed pressure (weed control)

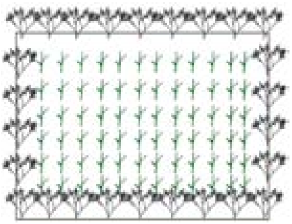
−

- Requires a good knowledge of the different crops and their interactions, especially to avoid any risk of negative biochemical interactions (allelopathy)
- Difficult to mechanize
- Not suited to all crops

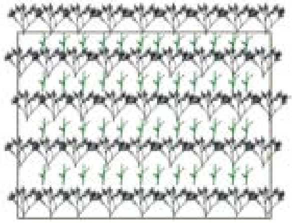
By concentrating a single crop in a given location, even on a small scale, monocultures tend to attract pests toward a single source of food and to favor the propagation of diseases. Moreover, plants all use the very same minerals, depleting the soil of these particular elements while leaving other unutilized.

On the other hand, intercropping aim at producing various crops simultaneously on a single plot in order to maximize their interactions, optimize the use of resources (water, minerals, light) and diversify the products, thus reducing the risk of bad harvest. However, not all crops are suited to be intercropped together, some associations being detrimental, where one species dominates a more fragile one or due to incompatibility of growth habits and requirements.

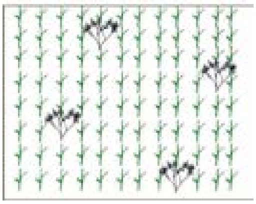
Crops can be planted in alternate rows (row intercropping), or one at the center with the other along the perimeter of the plot. It is also possible to disseminate a few plants of a specific species throughout the plot, alongside the main crop, as it is the case with trap cropping for instance (see factsheet no. 2).



Intercropping on the perimeter of the plot.



Row intercropping.



Trap cropping with disseminated trap crop.

An example of a time-tested combination is the intercropping of grains with legumes, the latter fixing atmospheric nitrogen in the soil, benefiting the grains that require an abundance of it for their growth.

Some associations based on different "physical" characteristics can also be made:

– some plants can act as a stake for climbers such as yam or pole beans;
– other plants can cast shade on shade loving crops;
– some plants fix phosphorous through their mycorrhizal association, making it available to the main crop, etc.

Generally speaking, the total yield per hectare increases when plants are intercropped rather than grown in separated monocultures.

Intercropping Basic principles

When choosing crops to be grown in combination, one should ensure they have the following characteristics:

- a complementary root system; one deep and the other superficial;
- a complementary habit and need for light;
- they shouldn't compete for water and nutrients;
- they shouldn't show any negative biochemical interactions (allelopathy) and should ideally be mutually beneficial.

It is also advised to combine plants with different repelling and attracting ability, or confusing insects with their fragrance, in order to create a conducive environment for beneficial insects to multiply and thrive while deterring pests (see technical factsheets no. 2 and no. 4). The roots of some plants can also deter pests by secreting repulsive molecules.

Every type of crops has particular advantages. For instance, plants belonging to the Liliaceae family such as garlic, shallots, chives or leeks are known to deter many pests and to protect the main crop from certain fungal diseases. As for it, marigold is very efficient against root nematodes. Hence, it is important to know what are the main problems faced in term of pests and diseases so as to choose wisely which plants to associate in an intercropping system

When planting crops with a tall canopy, it is important to cover the ground with shorter plants in order to minimize erosion and maximize the use of space.

Examples of appropriate and inappropriate crop associations.

Crop	Compatible	Incompatible
Wheat	Beans, cucumbers, lettuce, melons, peas, potatoes, pumpkins, sunflowers	Tomatoes
Beans	Broccoli, cabbage, carrots, cauliflower, celery, wheat, cucumbers, eggplant, peas, potatoes, radishes, tomatoes, strawberries, pumpkins	Garlic, onions, chili, sunflowers
Cabbage	Beans, celery, cucumbers, lettuce, onions, potatoes, dill, kale thyme, sage, spinach	Broccoli, cauliflower, strawberries, tomatoes
Eggplant	Basil, beans, lettuce, peas, potatoes, spinach	
Onions	Beetroot, broccoli, cabbage, lettuce, chilies, potatoes, spinach, tomatoes	Beans, peas, sage
Cauliflower	Beans, beetroot, celery, cucumbers, sage, thyme	Broccoli, cabbage, strawberries, tomatoes
Cucumbers	Beans, broccoli, cabbage, cauliflower, wheat, lettuce, peas, radishes, sunflowers	Melons, potatoes

Agroforestry is the practice of associating tree with annual crops in a same plot and meets the same objectives as the intercropping of annual crops but on a longer time scale (see factsheet no.19).

Due to their importance in human diet, Solanaceae (night shades) are grown on a very large scale. Nevertheless, it is essential to avoid cultivating them in the same field year after year and refrain from growing it on the entirety of the land, so as to be able to alternate with other families and prevent diseases and pests to settle in (see crop rotation factsheet no. 6).

Examples of intercropping combinations

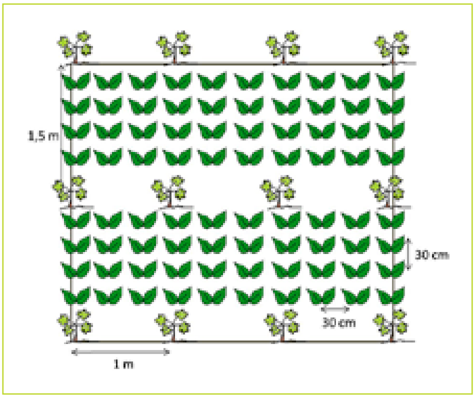
In the following section, five systems are described in further details:

- (1) Cassava/peanuts intercropping.
- (2) Intercropping of *Cajanus cajan* (pigeon pea) with various main crops.
- Vegetable intercropping with (main crop): (3) tomatoes, (4) eggplant, (5) cabbage.

Cassava/peanuts intercropping

25 to 30 cm long cassava cuttings are planted at 1,5m x 1m spacing. Peanuts are then planted between the cassava rows at 30 cm x 30 cm spacing, sowing 1 or 2 seeds per seed hole.

Such an association offers multiple benefits:



- peanuts, being a legume, bring cassava the nitrogen required for its proper growth (by fixing atmospheric nitrogen in the soil);
- peanuts can be harvested after 3 months, while it takes cassava 1 or 2 years to mature, allowing two harvests in the same year, at different times, thus diversifying sources of income;
- thanks to its growth habit and its sowing density, peanuts protect the soil from erosion and help controlling weeds. After three months, at harvesting time, the plot is perfectly clean, reducing the amount of labor needed for weeding.

It is equally possible to associate cassava and peanuts with *Acacia auriculiformis* and/or *Acacia mangium*, in order to extend the system in time by adding a long duration crop (see factsheet no.19 on agroforestry for further details).

Cassava/peanuts intercropping, D.Violas,GRET, DRC,2015.

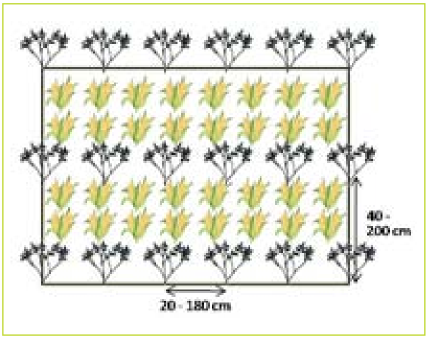
Cassava, peanuts and acacia intercropping, J. Scholle, GRET, DRC, 2014.

Cajanus cajan (pigeon pea), cassava, hog-peanut, sorghum, millet, cotton, maize intercropping.

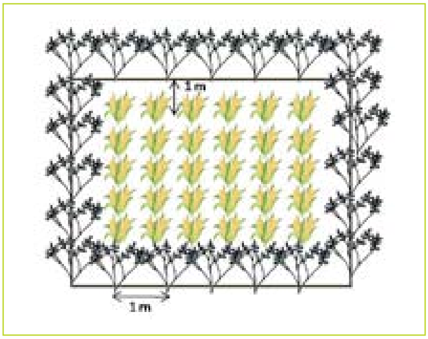
Pigeon pea (*Cajanus cajan*) can either be planted along the perimeter of the plot or in row-intercropping with a variety of other species. Sow 2 to 3 seeds per seed hole at 4 to 5 cm depth. Spacing will vary greatly according to farmers' objectives and environmental limitations. Generally speaking, spacing may vary from 20 to 180 cm x 40 to 200 cm when used in row-intercropping, allowing for a variety of options, and 1 m x 1 m when planted along the perimeter of the plot.

Cajanus and sorghum, S. Fayon, GRET, Myanmar, 2014.

Cajanus planted on plot's perimeter, D. Violas, GRET, DRC, 2015.



or



This association offers multiple benefits:

- pigeon pea, being a legume, fixes nitrogen in the soil, providing for the need of the main crop in this particular mineral;
- when planted around the edge of the plot, it acts as a windbreak, protecting the main crop from lodging;
- it provides quality fodder, edible seeds for human consumption, firewood and can be used as a trap crop for certain pests.

See factsheet no. 2 on integrated pest management using trap crops.

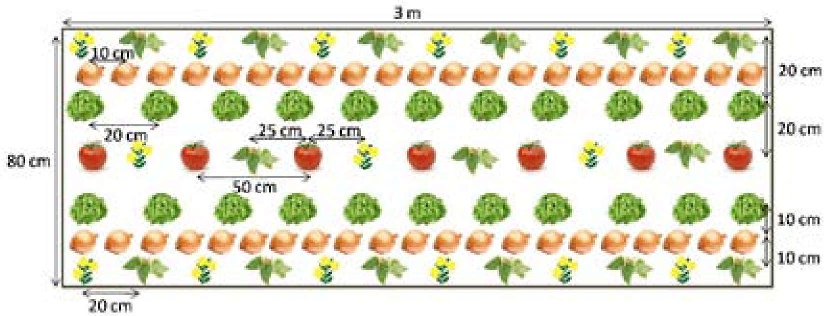
Intercropping vegetables

Generally, when intercropping vegetables, crops are established according to the average of the inter-row spacing normally used for each of the crops grown separately. For instance, when intercropping carrots with onions (in order to control their respective fly), consider each crop's usual inter-row spacing – 30 cm for onions and 40 cm for carrots – and divide by two. Hence, when intercropped, carrots and onions should be planted in alternate rows 35 cm apart ((40+30)/2).

The following illustrations show the precise inter-row and intra-row spacing for some vegetable intercropping combinations.

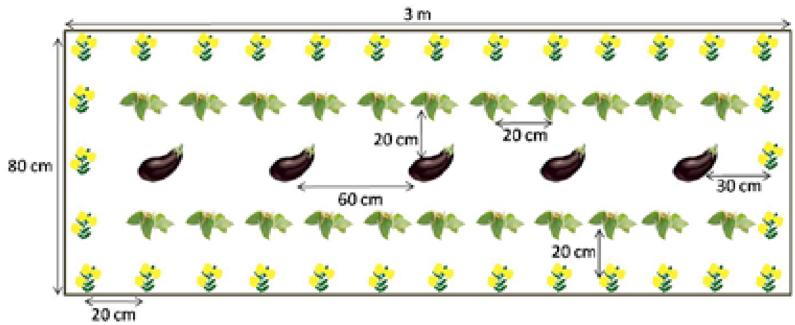
› Case no. 1: tomato intercropped with lettuce, onions, marigold and Thai basil

In the case of an 80 cm wide and 3 m long bed, tomatoes are planted at the center of the bed at 50 cm in-row spacing. Marigolds and Thai basil are then planted alternately alongside the edge of the bed at 20 cm in-row spacing, as well as between the tomato plants. One row of lettuce is then sown on each side of the tomato row, 20 cm away from it, at 20 cm in-row spacing. Finally, onions are sown between the lettuce and the Thai basil/marigold rows, 10 cm away from each, at 10 cm in-row spacing.



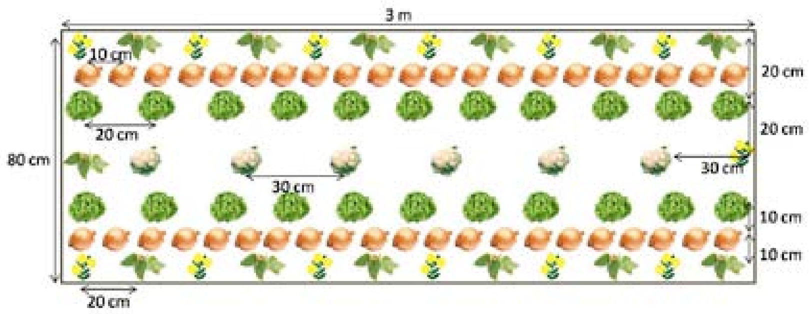
› Case no. 2: eggplant intercropped with Thai basil and marigold

In the case of an 80 cm wide and 3 m long bed, eggplants are planted at the center of the bed, at 60 cm in-row spacing. Marigolds are then planted alongside the edge of the bed, at 20 cm in-row spacing. Finally, Thai basil is planted 20 cm away from both the eggplant and the marigold rows, at 20 cm in-row spacing.



› Case no. 3: cabbage intercropped with lettuce, onions, Thai basil and marigolds

In the case of an 80 cm wide and 3 m long bed, cabbages are planted at the center of the bed at 30 cm in-row spacing. Marigolds and Thai basil are then planted alternately along the edge of the bed, at 20 cm in-row spacing. Lettuce is sown on each side of the cabbage row, 20 cm away from it, at 20 cm in-row spacing. Finally, onions are sown between the lettuce and marigold rows, 10 cm away from each, at 10 cm in-row spacing.



To learn further

Mission on agro-ecological pest and diseases control, S. Fayon, Cambodge, CIRD, Gret, 2014.

L'agroécologie en pratiques, Agrisud international, 2010, 188 p. www.agrisud.org.

Les associations de culture, Terre et Humanisme, Fiche pédagogique n° 5, 2 p. http://terre-humanisme.org.

Présentation très résumée des cultures associées dans les agricultures africaines, Valentin Beauval, 2009, 5 p. www.resogm.org.

Trap cropping and "push-pull" farming systems

Function	Integrated pest management

+

- Preventive control against pest infestation and propagation
- Low implementation cost
- Harmless to the environment
- Low labor and working time requirement

−

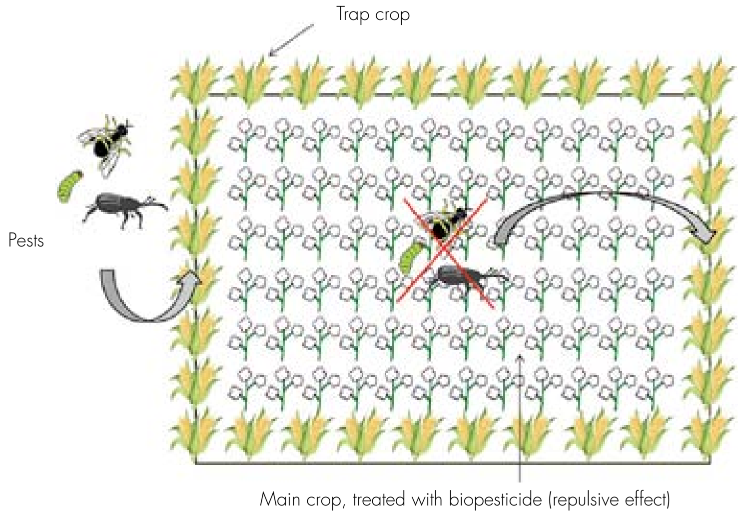
- Requires regular monitoring
- Requires very good knowledge of pests and their predators as well as their ecology
- Requires thorough planning prior to implementation

These techniques aim at **biologically controlling** pests by intercropping trap plants or repulsive plants with the main crops. These plants have the ability **to attract pests**, mostly insects, thus **diverting them from the main crops** and limiting damage while minimizing the use of chemical inputs.

Combining trap crops and repulsive plants: the "push-pull" effect

This technique is most efficient when associating two types of plants:

– repulsive (*push*) plants, usually row-intercropped with the main crop to deter pests;
– trap (*pull*) plants, attracting pests away from cultivated areas, most often planted along the edge of the field.



The repulsive effect can be obtained by intercropping repulsive plants with the main crop or by treating it with biopesticides, such as neem extract (see factsheet no. 5 on biopesticides).

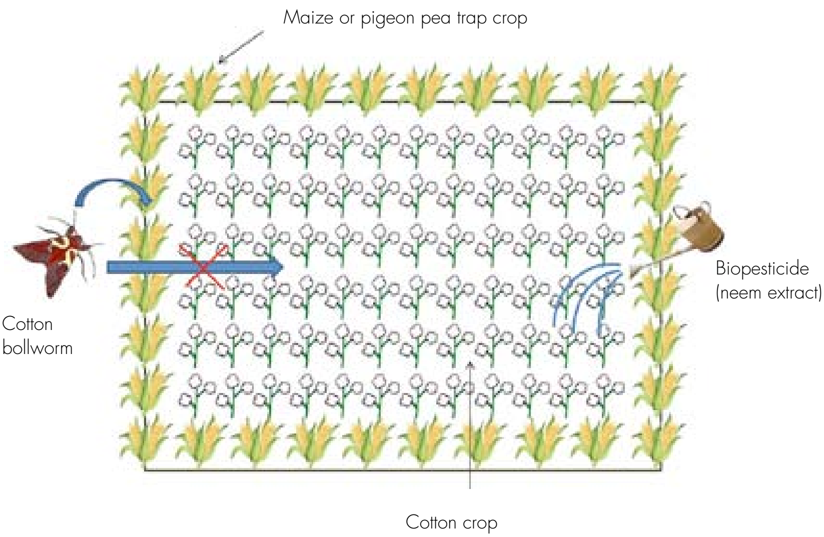
Trap crops divert pests from the main crops and, according to species, might additionally hinder larvae development, inhibit feeding, etc. thus reducing pest population in the field.

Some plants repulsive to pests also attract some of the beneficial insects integrated pest management seeks to encourage (see factsheet no. 4 on integrated pest management using beneficial insects).

Examples of "push-pull" crop combinations

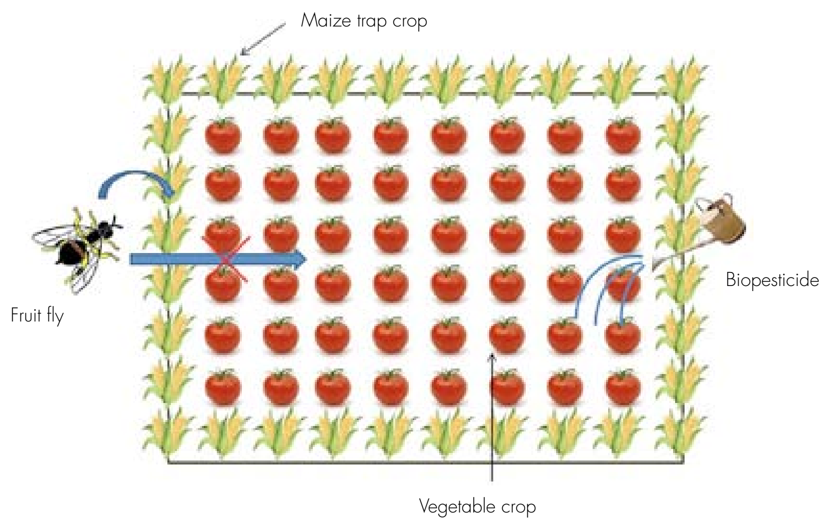
Maize or Pigeon pea (*Cajanus cajan*) intercropped with cotton against cotton bollworm

Maize or *Cajanus cajan* (see plant fact-sheet no. 5) is planted along the perimeter of the field. The Cotton crop is planted at the center of the plot and treated with biopesticides, such as neem extract, to deter cotton bollworms that then get established in the maize or *Cajanus cajan* located on the perimeter, preventing bollworm damage to the cotton crop.



Corn planted on the perimeter of the vegetable plot for fruit fly control

Plant maize along the perimeter of the vegetable plot against fruit fly belonging to the *Tephritidae* family such as *Bactrocera cucurbitae*, *Dacus ciliatus* or *Dacus demmerezi*. The repulsive effect can be obtained either by treating vegetables with biopesticide or by intercropping them with repulsive plants (see factsheet no. 1 on intercropping).

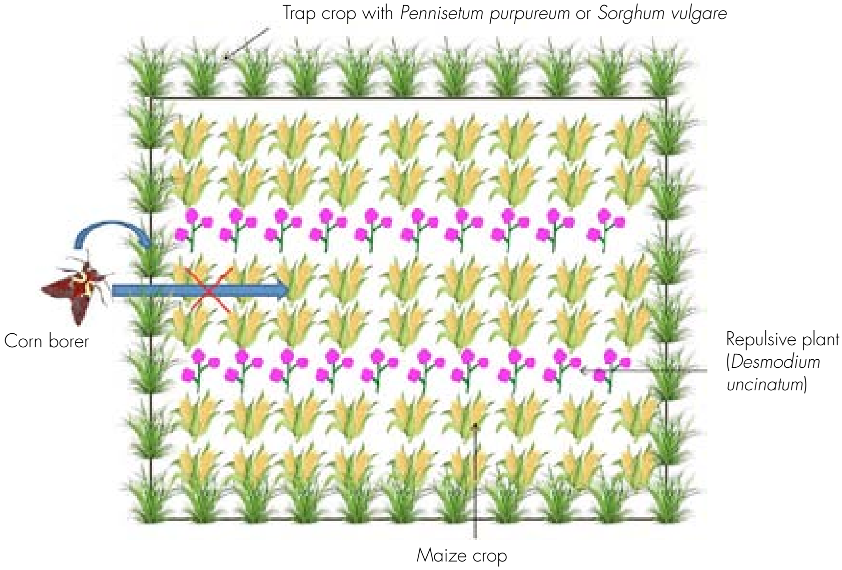


Fruit flies spend 90% of their time away from the fruit or vegetable crops, only visiting them to lay their eggs. Establishing crops that can be used as a refuge along the perimeter of the plot prevents the flies from laying their eggs on the vegetables. It is possible to prevent proliferation by applying a biopesticide on the trap crop, thus avoiding treating the main crop.

Not only does maize trap fruit flies, it also attracts beneficial organisms such as hoverflies. If one wants to encourage their establishment, it is important not to use biopesticides on the trap crop. The particular strategy adopted will depend on the locally occurring species of pests and beneficial insects.

Desmodium uncinatum in row intercropping with *Pennisetum purpureum* or *Sorghum vulgare sudanense* along plot's perimeter against European corn borer

At the center of the plot, plant maize intercropped with *Desmodium unicatum* (silverleaf desmodium) for its repulsive effect against European corn borer, combined with *Pennisetum purpureum* (elephant grass) or *Sorghum vulgare* (sorghum) planted along the perimeter for their trapping ability. Both of these plants inhibit larvae development, thus making the use of biopesticide unnecessary to prevent infestation.



Monitoring of pest populations remains essential and contaminated fruits or vegetables should be removed from the field and destroyed to prevent proliferation.

To learn further

Des plants de maïs pour piéger les mouches des légumes, J.-P. Deguine, S. Quilici, B. Reynaud, Cirad, Réunion, 2012. http://www.cirad.fr.

Combiner plantes pièges et plantes répulsives : stratégie « push-pull », Julien Halska, Marc Moraine, Inra, Réseau mixte technologie, systèmes de cultures innovants, 2011. http://agropeps.clermont.cemagref.fr.

Implanter des cultures pièges à bio-agresseurs, Julien Halska Jacques Girard Adeline Michel. Réseau mixte technologie, systèmes de cultures innovants, 2011. http://agropeps.clermont.cemagref.fr.

Banana weevil trap

Function	Integrated pest management

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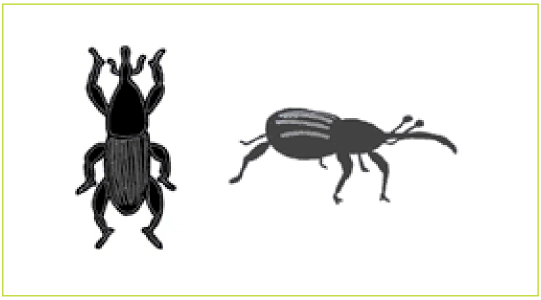
- Preventive control against pest propagation and infestation
- Low cost
- Harmless to the environment

−

- Requires regular monitoring
- Not sufficient to overcome important infestation on its own; has to be combined with other integrated pest management techniques.

Problems related to banana weevil borer



Banana weevil borer (*Cosmopolites sordidus*) is one of the most important pests in banana plantations. Damages are mainly inflicted by the weevil larvae who feed on the banana corm.

This pest causes the following problems:

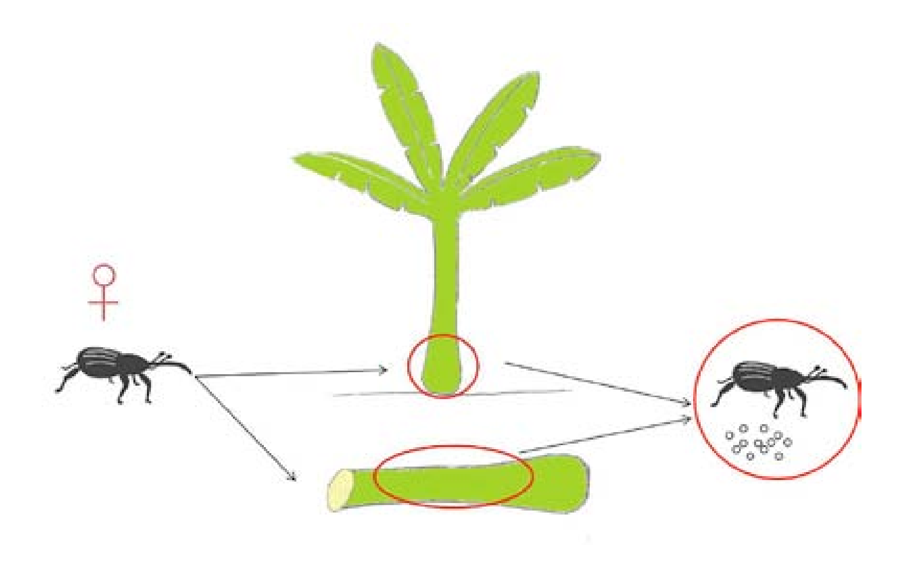
– stunted banana bunches;
– weaken stems; affected banana trees break very easily and are highly prone to lodging.

Weevil borer attack is identified by observing the following indicators:

– splitting of the leaf sheath at the base of the banana stem (tear in the stem tissue);
– presence of furrows dug into the stem and the corm, filled with brown sawdust like material (larvae's dejection).

Banana weevil borers' life cycle

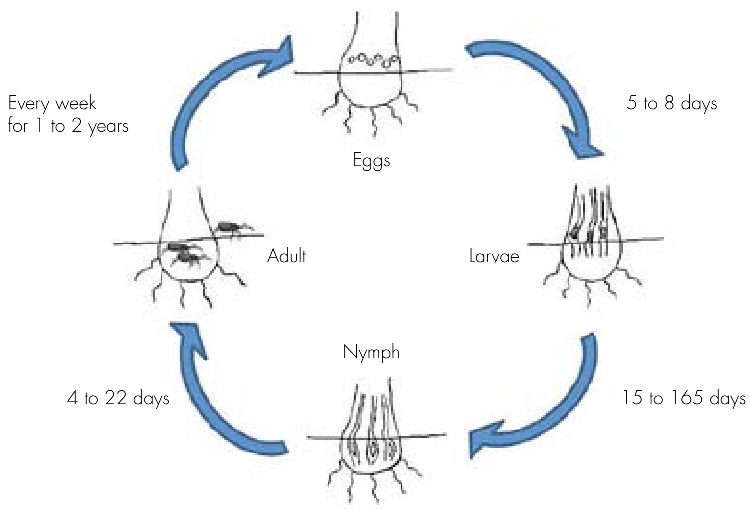
Step 1: Female weevils lay eggs in banana corms



Females dig holes in the banana corm, at the base of the stem, just above ground level, and settle in. They can also colonize fallen stem left lying on the ground during harvest. Each female lays 50 to 100 eggs a year.

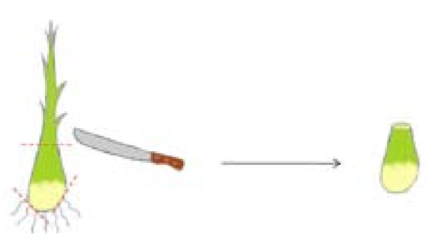
Step 2: Eggs hatch and weevil larvae develop in the banana corm

The time required for banana weevil borers to develop into full adults (larvae then nymph) is highly variable.



How to control banana weevil borers?

Cleaning of banana suckers

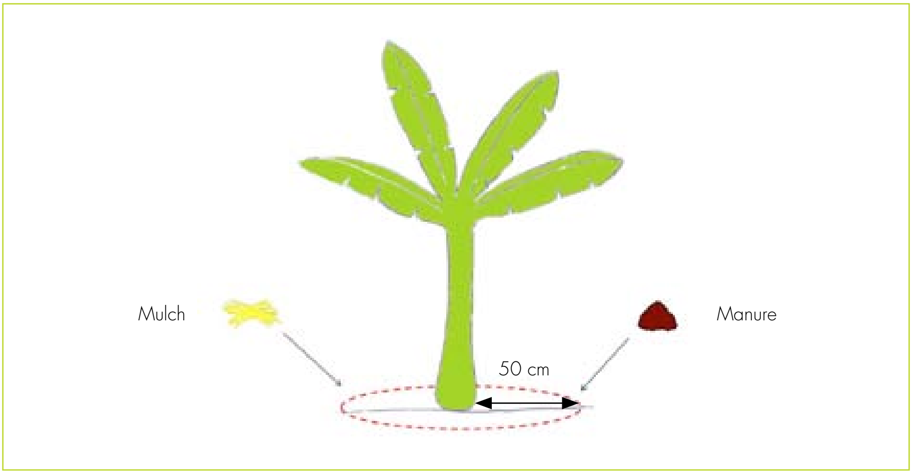


Banana weevil borers seldom fly and only travel short distances. Hence, in new banana plantations, propagation mainly occurs by means of infested banana suckers originating from former plantations. Therefore, it is essential to carefully clean the suckers before transplanting them, by removing the leaves and roots and exposing the corm's (identified by its white color). Then, it is important to plant them immediately.

Strengthening of the crop

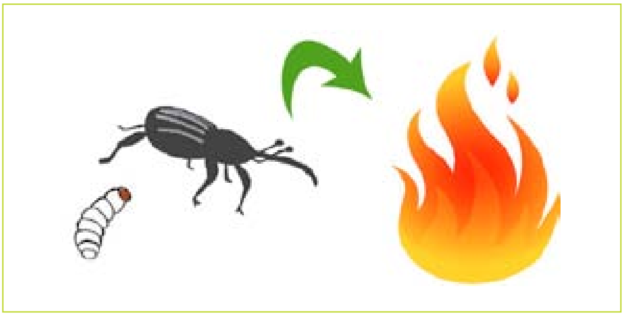
At the start of every season, mulch and organic manure enable soil moisture retention and provide banana plants with nutrients, making them more resistant to pest attack, including banana weevil borers.

Banana weevil borers like moist and relatively cool places, optimal development occurring at 25°C. If mulch is used, they are attracted by this favorable environment and nest in it, hence sparing the banana trees. Mulch should be applied 50 cm away from the trunks to prevent weevil moving to the trees. To prevent banana roots from growing on the surface, manure should also be applied 50 cm from the plant.



Monitoring population development

During the whole cultivation cycle, it is important to monitor weevil population in the banana plantation. Visible larvae and adults should be collected and burnt.

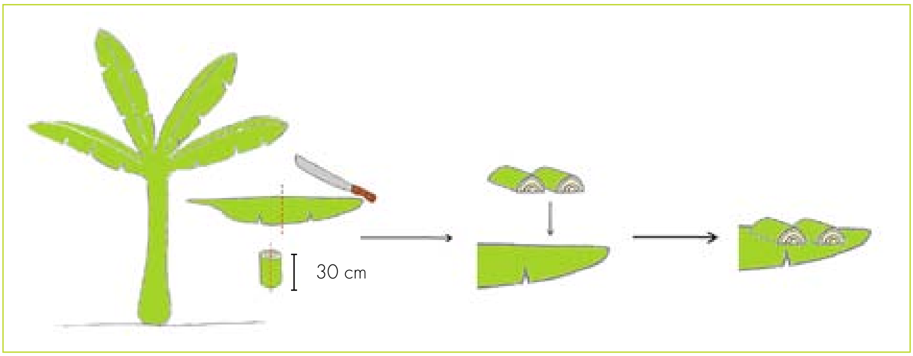


After harvesting banana bunches, fallen stems should always be cut in small pieces, leaf sheaths after leaf sheaths, and spread to be sundried in order to destroy weevil eggs and larvae as well as to make sure they don't act as a refuge for new banana weevil borers. The cut pieces should be left 50 cm away from the mother plant.

If many tunnels can be seen, it means the plant is infested and should be destroyed (by feeding it to cattle for instance).

Banana weevil borer trap confection

Cut banana stems in 30 cm long pieces and split them lengthwise in half. Place the pieces upside down on a banana leaf.

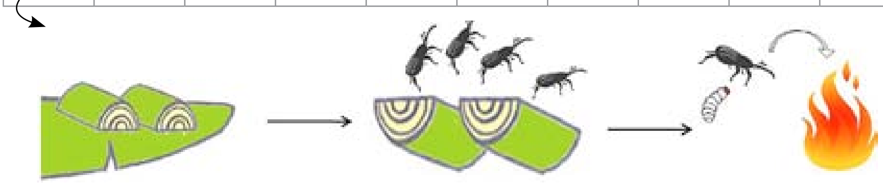


The smell of freshly cut banana stem attracts weevils toward the trap.

The traps have to be dispersed throughout the entire plantation. Weevil's population often being very unevenly distributed, do not hesitate relocating traps catching only few pests toward more heavily infested areas.

Check traps every second day. Collect the weevils found in the traps and destroy them.

D1	D2	D3	D4	D5	D6	D7	D8	D9	D...
X		X		X		X		X	



Traps remain efficient for two weeks during rainy season and one week during dry season.

When pheromones are readily available on the market, pheromone trap can also be used as they are equally efficient in controlling banana weevil borer.

To learn further

Lutter contre les charançons du bananier, projet Videos for Farmers, Access Agriculture, vidéo 11'30. www.accessagriculture.org.

Contrôle du charançon du bananier, in *Manuel du planteur de banane de Guadeloupe et Martinique*, Institut technique tropical IT2, Banane de Guadeloupe & Martinique, 3 p. www.it2.fr/documentation/manuel-du-planteur-fr.

La lutte contre le charançon du bananier, Cosmopolites sordidus (Germar), Institut agronomique néo-calédonien, 2006, Protection phytosanitaire des cultures fruitières en Nouvelle-Calédonie, Fiche 3.7, 2 p. www.formagri.nc.

Controlling pests with beneficial insects

Function Integrated pest management

+

- Helps to control pest infestation and propagation
- Low implementation cost
- Harmless to the environment
- Harmless to farmers' health
- Low labor and working time requirement

−

- Requires regular monitoring
- Requires very good knowledge of pests and their predators as well as their ecology
- Must be thought ahead of cultivation and planned in both time and space

What is integrated pest management (IPM)

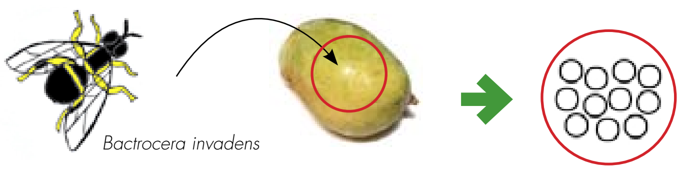
IPM aims at preventing pests and diseases from attacking crops, using cultivation and phytosanitary practices that are **respectful to both the environment and farmers' health** and rely on interactions within the agro-ecosystem. A very good knowledge of the field's environment – especially of occurring pests and their predators (often called **beneficial insects**) – is necessary. It is crucial to implement continuous monitoring in order to control potential pests invasion and crops contamination by diseases.

To manage pests in an integrated way, one can preserve and encourage local beneficial organisms as well as purposely introducing new ones. However, newly introduced organisms have the potential of becoming invasive and disrupt local ecosystems, making it of limited interest.

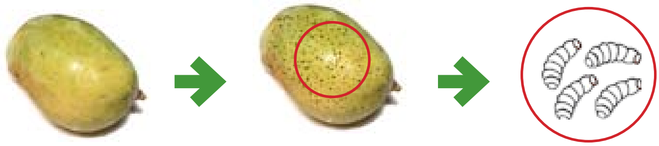
In the following factsheet, one specific technique used in integrated pest management is described: the use of predatory insects to control pests. It is however important to combine various techniques, some preventive and some curative, to succeed in managing both pests and beneficial insect populations.

Example: Weaver ants (*Oecophylla smaragdina* and *longinoda*) against fruit flies and other diptera

Fruit flies, *Tephritidae* and *Bactrocera invadens* infest and lay their eggs in the fruits of trees such as mango, citrus and cashew (principally but not limited to).



Black dots appear on the surface of infested fruits and larvae development causes the fruits to rot.



Fruits become improper for consumption.

The most efficient technique to control these flies is the use of weaver ants, *Oecophylla longinoda* or *smaragdina*.

Weaver ants live on fruit trees where they nest by "weaving" leaves together with silk thread produced by their larvae.

They hunt both at leaf canopy and ground level and are efficient on various levels:

- they catch fruit fly larvae;
- they produce chemical signals that deter fruit pests;
- the protect fruit trees from hemiptera (true bugs) and frugivorous bats by defending the trees on which they live.

Weaver ants on a mango tree, Pixabay.

Weaver ants' nest in a mango tree, J. Scholle, GRET, DRC, 2014.

Additionally, the presence of weaver ants improves fruit quality, especially mangoes, by increasing sugar concentration, reducing acidity and improving microbiological quality.

Nonetheless, weaver ants defend their territory fiercely by biting the intruders and, for this reason, are not always welcomed by farmers. The present technique consists mainly in protecting them – rather than chasing or destroying them – or installing colonies when absent from orchards. In West Africa, some orchards host 800 to 1300 nests/ha, constituting 20 to 30 colonies.

The presence of weaver ants does not exempt from carefully removing infested fruits (including the one fallen to the ground) to avoid giving fruit fly larvae the opportunity to develop into full adults and intensify the invasion.

To learn further

Les fourmis tisserandes pour lutter contre les mouches des fruits, SciDevNet, www.scidev.net.

Comment les producteurs de mangues pourraient-ils se passer des fourmis tisserandes, Jean-François Vayssières, Cirad, Bénin, 2013, www.cirad.fr.

Biopesticides

Function Integrated pest management

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- Enables preventive and curative control of pest infestation and propagation
- Uses local organic material
- Has a low production cost
- Is mostly harmless to the environment as the active compounds are often only slightly toxic
- Is not hazardous to farmer's health
- Offers a wide range of treatments, whatever the location, thanks to the abundance of plants presenting interesting properties

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- Requires good knowledge of plants and their properties.
- Is labor demanding: requires numerous applications and constant monitoring
- Is insufficient in some cases, requiring to be complemented with chemical pesticides
- May present weak risk of pollution due to certain plants' toxicity
- Pest control using active compound can lead to pests developing resistance, as it is also the case with chemical products

Biopesticides – also called biological pesticides in opposition to chemical pesticides – are microorganism or plant based products aimed at protecting crops. They are preferred to chemical pesticides mainly for their relative innocuousness to the environment and famers' health and for their low production cost.

List of biopesticides presented in this factsheet:

- Against nematodes: burying of *Chromolaena odorata*
- Against insects:
  - garlic extract
  - neem extract
  - chili extract
  - *Tephrosia vogelii* extract
- Against mites (Acari): palm tree male inflorescence ash
- Against fungal diseases: papaya leaf extract
- Numerous uses of fern based extracts

Nematode control using *Chromolaena odorata* (zaïre, siam weed)

Chromolaena allows controlling nematodes which are microscopic parasites attacking the roots of plants.

Eggplant roots attacked by nematodes, © Scot Nelson.

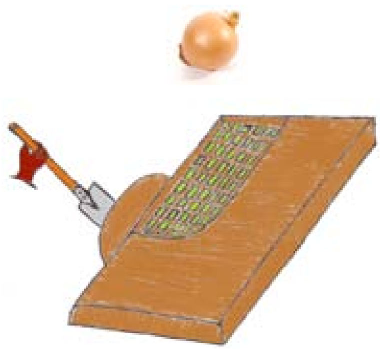
Step 1: preparation

Harvest *Chromolaena odorata* leaves.

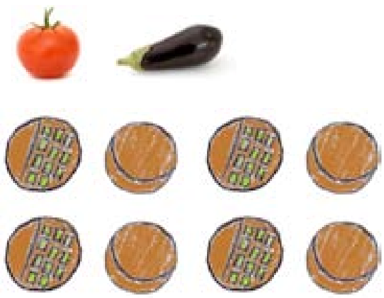
Chop it up.

› Step 2: use

Chopped *Chromolaena* leaves are buried in the soil before planting the crops.



Onion: *Chromolaena* leaves are buried under the whole surface of the bed.



Solenaceae (tomatoes and eggplant): one handful of chopped leaves is buried in each planting hole.

› Step 3: watering

Water the bed with room temperature water for 5 or 6 days after burying the leaves then add manure.

The same technique can be used using *Pueraria phaseoloides* and *Tithonia diversifolia* instead of *Chromolaena odorata*.

Pueraria phaseoloides.

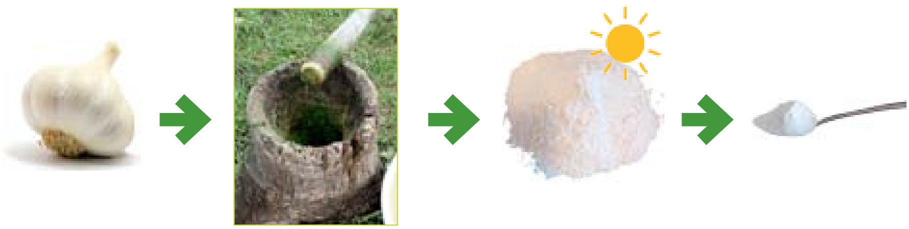
Tithonia diversifolia.

Insect control

Garlic based insecticides

Garlic extract make a useful insecticide, killing aphids, mites and onion flies.

› Step 1: garlic extract preparation

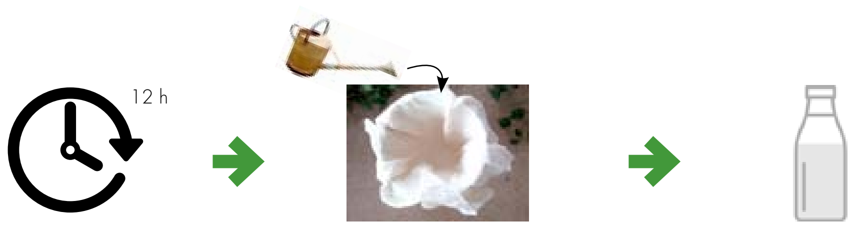


Garlic

Crush in a mortar

Sundry the paste

Soak 2 tablespoons of garlic powder in 10 liters of water for 12 hours.



Strain the solution with a cloth

› Step 2: soapy solution preparation

Soap sticks to surfaces. Adding soap to biopesticides helps them stick longer to plant leaves, hence extending the duration of their protective action.

› Step 3: garlic extract application

Mix 1 liter of garlic solution
with 2 liters of soapy water

Apply 1 liter of the mixed solution for every 10 m^2 by spraying it on crops.

Repeat after 7 days

D1	D2	D3	D4	D5	D6	D7	D8
							

Neem leaf based insecticides (*Azadirachta indica*)

The main interest of neem leaf extract is that it is efficient on numerous pests such as crickets, coleoptera larvae, caterpillars and leafhoppers. Its action works by acting upon their feeding habit, their growth and their reproductive cycle rather than killing them. Indeed, Neem leaf extract makes plants less palatable to insects and inhibits their appetite as well as their capacity to moult and lay eggs. It might take a few days for the effect to become noticeable, hence it is crucial to apply neem solution at the very beginning of an insect attack.

› Step 1: neem leaf extract preparation

Harvest 1 kg of fresh neem leaves.

Discard twigs.

Chop the leaves with a knife.

Crush the leaves in a mortar.

Place 1 kg of crushed leaves wrapped in cloth in a bucket with 5 liters of water (or place the leaves directly in the water and strain at the end).

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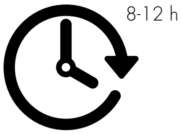

Leave it to soak overnight (8 to 12 h), until water turns light green.

On the following day, press the cloth to extract the solution.

Neem leaf extract is obtained.

› Step 2: Neem leaf based pesticide preparation and application

Cut 2 grams of soap into pieces.

Mix 5 liters of neem leaf extract with 10 liters of water and add the soap.

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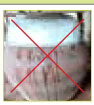
The solution can be kept for 7 days in a dry and shaded place.

D1	D2	D3	D4	D5	D6	D7	D8
							

Spray the solution 2 to 3 times a week, depending on the seriousness of the attack. Regular monitoring of insects population is required.

Tobacco is also a good insecticide. Its leaves can be used by incorporating directly in the preparation of liquid manure for instance (see factsheet no. 9 on liquid manure).

Chili based insecticides

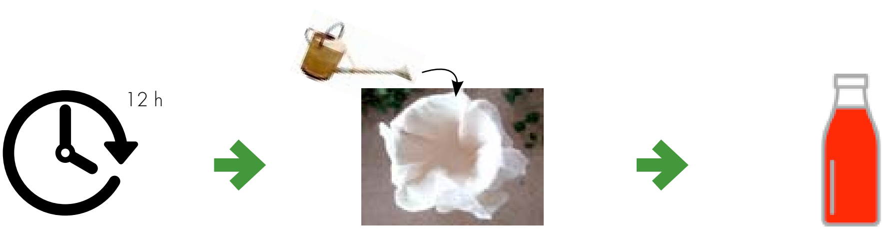
Chili is potent against insects such as white flies, aphids, sucking insects, crickets and grasshoppers.

› Step 1: Chili extract preparation

Dry chilies

Crush in a mortar

Soak 2 tablespoons of chili powder in 10 liters of water for 12 hours.



Strain the solution with a cloth

› Step 2: soapy solution preparation

3 caps of liquid soap

4 liters of water

› Step 3: Chili extract application

Mix 1 liter of chili solution with
2 liters of soapy water.

Apply 1 liter of solution for every 10 m^2 by spraying it on crops.

Repeat after 7 days.

D1	D2	D3	D4	D5	D6	D7	D8
	24h	24h	24h	24h	24h	24h	

Tephrosia vogelii based insecticides

Tephrosia leaf based insecticides are efficient against insects such as larvae, slugs, flies, moths and red spider mites.

Harvest *Tephrosia* leaves.

Crush the leaves in a mortar.

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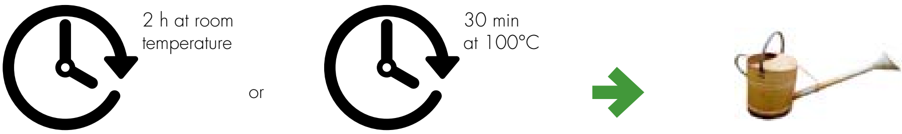
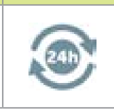
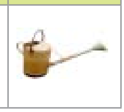
Place 1 kg of crushed leaves wrapped in cloth in a bucket with 5 liters of water (or place the leaves directly in the water and strain at the end).

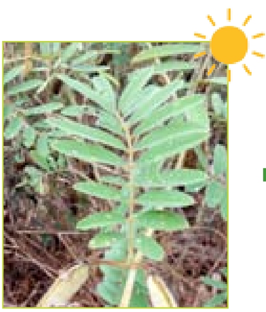
Soak for 2 hours or boil for 30 minutes.



The solution is sprayed on leaves and remains active during 7 days. Passed this limit, the process needs to be repeated.

D1	D2	D3	D4	D5	D6	D7	D8
	 24h	 24h	 24h	 24h	 24h	 24h	

Dry *Tephrosia* leaves can also be used to protect vegetable seeds and pulses stored for human consumption against grain weevil and lesser grain borer.



Harvest and dry *Tephrosia* leaves.

Crush the leaves in a mortar.

Mix 100-200 g of leaf powder with 100 kg of bean seeds.

Seeds and pulses should be cleaned carefully with water before consumption.

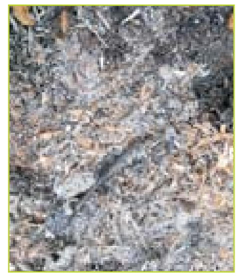
Mites (Acari) control using palm tree male inflorescence ash

Oil palm male inflorescences (*Elaeis guineensis*) – but also inflorescences from other palm trees – are efficient to control mites; in other words, spiders.

› Step 1: preparation

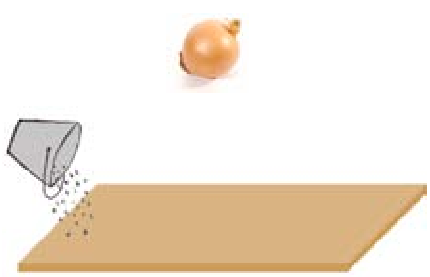
Collect palm tree male inflorescences.

Burn the inflorescences.

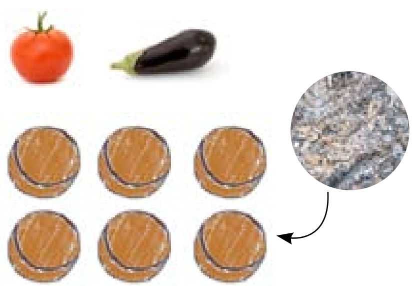


Inflorescence ash.

› Step 2: application



Sprinkle one 10 liters bucket of ash per 10 m^2 on top of the bed.



Put one handful of ash in every planting hole.

Repeat after 2 weeks.

D1	D2	D3	D4	…	D13	D14
	24h	24h	24h	24h	24h	

Fungal disease control using papaya leaf

Papaya leaf extract is used to control microscopic fungi causing necrosis and wilt.

› Step1: papaya leaf extract preparation

Harvest 1 kg of papaya leaves.

Crush the leaves in a mortar.

Soak 1 kg of crushed leaves wrapped in a cloth in a bucket with 1 liter of water for 6 hours (or put the leaves directly in the water and filter at the end).

› Step 2: soapy solution preparation

› Step 3: papaya leaf extract application

Mix 1 liter of papaya leaves extract with 4 liters of soapy water.

Use 1 liter of the solution for 10 m² by spraying it on crops.

Repeat after 7 days.

D1	D2	D3	D4	D5	D6	D7	D8
							

Fern based Fungicide-acaricide-insecticide

There are many species of fern. Mixing several of them allows acting on several pests. Ferns are efficient at controlling mites, fungal diseases and numerous insects all at once.

› Step 1: fern extract preparation

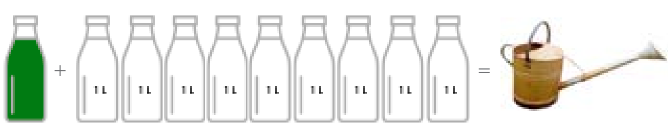
Harvest 1 kg of fern.

Chop the leaves.

Soak 1 kg of chopped fern leaves in 9 liters of water for 10 to 14 days to obtain fern extract (tea).

› Step 2: application

Mix 1 liter of fern extract with 9 liters of water



Use 1 liter of the extract for 10 m² by spraying it on crops.

Repeat after 7 days.

D1	D2	D3	D4	D5	D6	D7	D8
							

To learn further

Mission on agro-ecological pest and diseases control, Stéphane Fayon, Cambodge, CIRD, Gret, 2014.

Improving soil fertility with agroforestry, Laurence Mathieu-Colas, Goulven Le Bahers, Inter Aide, 2009, 8 p. www.interaide.org/pratiques.

Efficacy of *Tagetes minuta* and *Tephrosia vogelii* crude leaf extracts on *Tetranychus urticae* (*Acari: Tetranychidae*) and *Aphis fabae* (*Homoptera: Aphididae*), Sylvia Mmbone *et al.*, *African Journal of Food Science and Technology*, vol. 5 (8), 2014, pp. 168-173. www.interesjournals.org.

Crop rotation

Functions

Soil fertility management
Integrated pest management
Income diversification

+

- Reduces risk of pest and disease attack
- Diversifies income and reduces risks linked to harvest failure
- Valorizes the interaction between the different crops planted in a sequence
- Optimizes the use of resources (water, minerals, soil)
- Provides good ground cover in time
- Controls weeds
- Maintains soil structure

−

- Requires good knowledge of plants and their interactions
- Can increase work load
- Is hard to implement on small surfaces

Crop rotation is the practice of cultivating **different crops successively on a single plot**. The aim is to maximize the use of soil minerals, to avoid the spread of pests and diseases from one year to the other and to diversify production in order to limit the risk of bad harvest. In addition, the constant presence of crops in the field prevents weeds proliferation. Crop rotation is different from intercropping (see factsheet no. 1), as the different crops are not grown simultaneously but in a sequence.

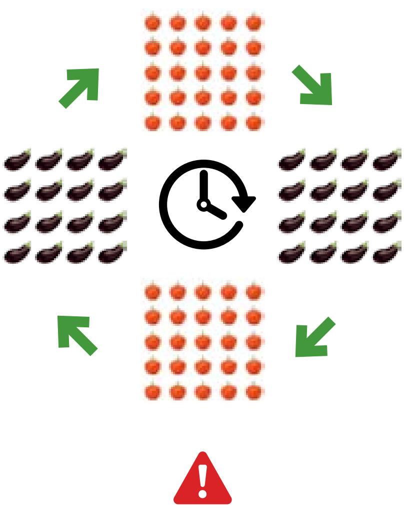
Generally speaking, to efficiently control pests and diseases, the completion of a rotation cycle should take a minimum of a year. Nevertheless, small scale producers farming on small plots can rarely afford such long rotations. Hence, in market gardening, very short rotations (only a few months) are often applied and repeated every year, season after season.

Crop rotation basic principles

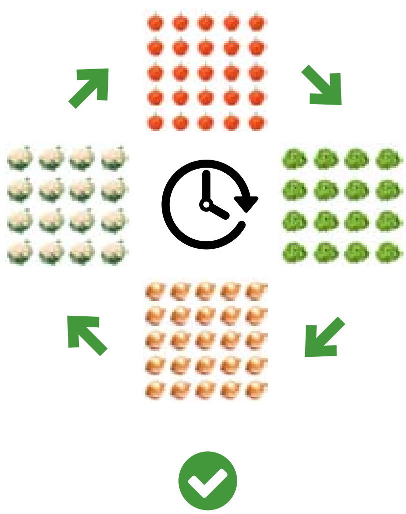
› Do not grow consecutively two crops of the same family in the same place.

This is the first basic principle that should be observed in order to benefit from the effects of crop rotation. Indeed, pests are often specific to a botanical family rather than a unique species. If the same plant is grown in the same place year after year, pest attacks are very likely to increase.

Moreover, different crops use different nutrients, thus rotating them allows avoiding depleting the soil of a particular element.



Successive cultivation of crops belonging to a single family



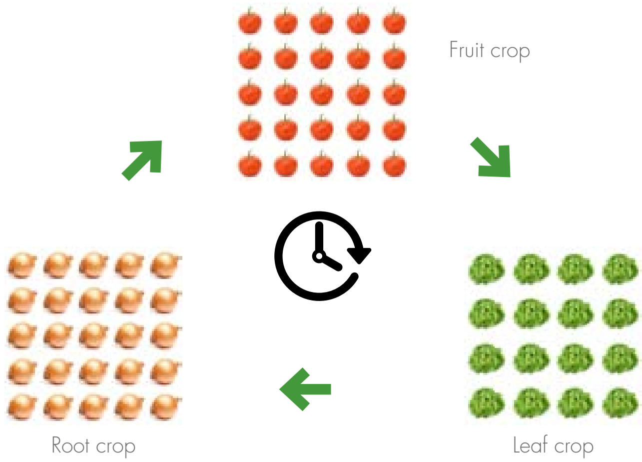
Successive cultivation of crops belonging to different families

Vegetable families' reminder

Family	Crop
Solanacae	Tomatoes, eggplant, chilies, peppers, potatoes…
Cucurbitaceae	Pumpkin, squash, melon, watermelon, cucumbers, zucchini…
Liliaceae	Onions, chives, leaks, asparagus, shallots, garlic…
Fabaceae	Beans, peas, black eyed peas, vetch, clover, lentils, alfalfa…
Brassicaceae	Radishes, turnip, cress, arugula, cabbage, rape…
Chenopodiaceae	Amaranth, beetroot, spinach…
Apiaceae	Carrots, celery, parsley, fennel, coriander…

› Do not successively grow plants from which the same part (leaves, fruits or roots) is consumed.

This aims at maximizing the use of nutrients, as plants use different nutrients to increase the size of their different organs.



› **Wait long enough before repeating growing the same crop on the same plot.**

The time between two cultivations of the same crop on the same plot depends mainly on the available space. Generally speaking, the longer the better. Rotation cycles of 3 to 4 years insure good nutrient use and break pests and diseases development cycles.

Some **legumes** can be inserted in the rotation cycle for their ability to fix atmospheric **nitrogen** in the soil, enriching it for the next crop. **Plants with antiparasitic properties** such as marigold that deter nematodes or radishes, turnips and peanuts that trap them can also be included in the rotation cycle to cleanse the soil.

Not all vegetables are suitable to be grown successively in a rotation. Onions, for instance, don't grow very well after a leguminous crop.

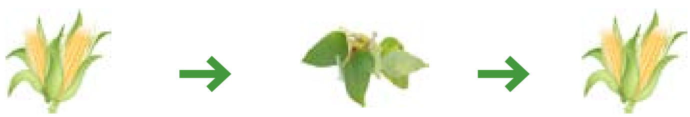
Green manure, ground covers and improved fallow are as many techniques participating to crop rotation (see factsheets no. 10, no. 13 and no. 7).

It is advisable to combine crop rotation with intercropping in order to optimize the use of the plot's natural resources and maximize the output of integrated pests, diseases and weeds management (see factsheet no. 1).

Crop rotation examples

Mucuna/maize rotation

Velvet bean (*Mucuna pruriens*) can either be planted one month after the maize, in order not to compete with it, or after harvest. It is left for 1 to 2 years in the field before replanting maize (see factsheet no. 7 on improved fallow).

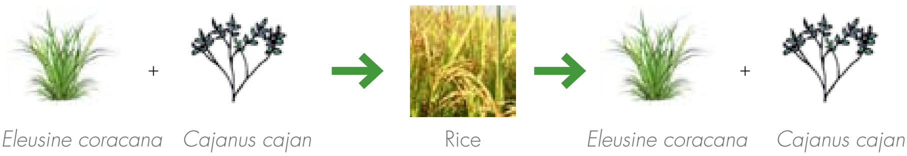


Maize *Mucuna pruriens* Maize

Finger millet/rice rotation

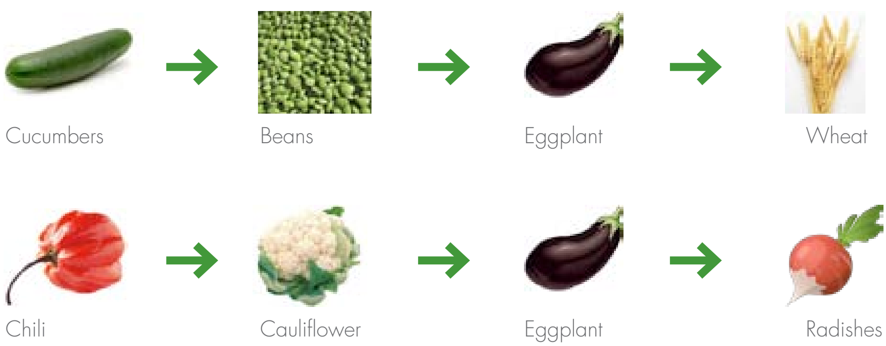
Finger millet (*Eleusine coracana*), combined with a legume such as pigeon pea (*Cajanus cajan*), is an excellent combination to use before cultivating rice, as it restructures the soil – thanks to finger millet's powerful root system – and fertilizes it by fixing nitrogen. Moreover, it also helps in reducing rice blast attacks.

Finger millet is also good before maize.



Rotations in market gardening

Rotations used by Cambodian farmers:



Once the cycle is completed, the rotation starts over again.

To learn further

L'agroécologie en pratiques, Agrisud international, 2010, 188 p. www.agrisud.org.

Agro Ecological Pest Management Program Vegetable, Stéphane Fayon APICI project, Gret, Cambodge, 2015.

Eleusine coracana, in Olivier Husson *et al.*, *Manuel pratique du semis direct à Madagascar*, Cirad, GSDM, 2012, 8 p. Fiches techniques plantes de couverture : graminées annuelles. http://agroecologie.cirad.fr.

Improved fallow

Functions

Soil fertility management
Erosion control
Integrated pest management
Soil structuring
Income diversification

+

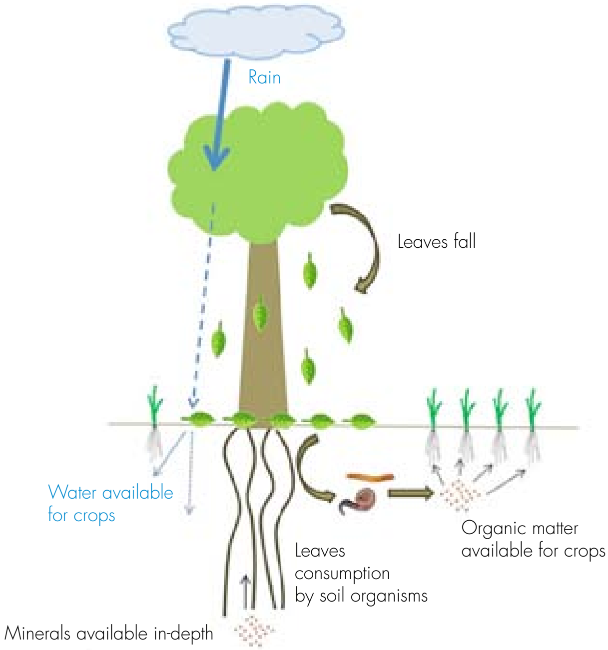
- Enriches the soil with nitrogen through the use of legumes
- Supplements the soil with an abundance of organic matter thanks to the use of fast growing species
- Prevents wind and water erosion
- Produces other products such as firewood, timber, fruits, medicinal plants, etc.
- Makes preparation of the plot easier after the fallow period
- Prevents the main crop's pests and diseases from settling durably in the plot
- Controls weed

−

- Requires labor on an "abandoned" plot

The main goal of improved fallow is **to enrich and restructure the soil** after a field is abandoned and **reduce the time** needed for it to be ready to be cultivated anew.

To establish an improved fallow, one or several species of shrubs, trees or herbaceous plants with soil improving qualities are grown alongside the main crop, as intercrops or relay crops, or planted after harvest. Legumes are especially well suited to the task due to their ability to fix atmospheric nitrogen in the soil.



The deep root system of trees and shrubs allows them to tap nutrients deep in the soil and bring them back to the surface through the leaf litter.

The ground cover provided by these species protects the soil against wind and water erosion after the main crop has been harvested.

Finally, by covering the soil, these plants also limit weed development, making it easier to bring the plot back into production at the end of the fallow period.

The plants chosen can also provide farmers with other products such as fodder, firewood, food, medicines etc.

A minimum period of 12 months is recommended to implement an improved fallow

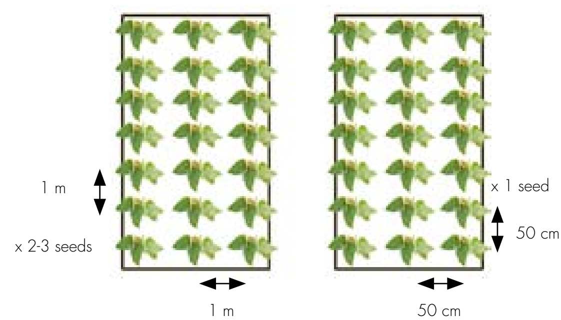
Herbaceous improved fallow

Mucuna pruriens

› Following cassava

After harvesting cassava roots, sow 2 to 3 seeds in the holes left open by the uprooting of the cassava tubers (using the existing 1 m x 1 m spacing).

It is also possible to sow a single seed in seed holes spaced 50 cm x 50 cm apart (or 2 seeds/pocket at 1 m x 50 cm spacing).

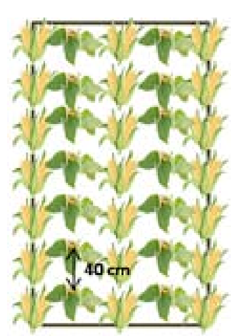


› As a relay crop with maize

Mucuna is planted between the maize rows, one month after the maize, at 40 cm in-row spacing.

Week 1	W 2	W 3	W 4	Week 5	W 6	Week 7
Sowing 				Sowing 		Refill planting 

Mucuna pruriens fallows are perfect for cogon grass (*Cylindrica imperata*) control, thanks to the thick ground cover it provides, preventing other plants from accessing sunlight.



Crotalaria juncea (Sun hemp)

Seeds are broadcasted or, to get the optimal cover, sown in rows at a rate of 30 kg/ha and at 1-2 cm depth. Sun hemp is sown after harvest or at the beginning of rainy season. Monitor germination rate and ensure having a minimum of 15 plants/m^2.

3 to 4 weeks before planting the main crop (when resuming plot's cultivation), Sun hemp has to be mechanically destroyed to ensure proper decomposition.

Crotalaria juncea preventing weeds from growing in the field. Stéphane Fayon, India, 2008.

Fallows using *Crotalaria* (not only *Crotalaria juncea*) allow cleansing the soil from nematodes due to the action of alkaloids produced by the roots of the plant. Also, their erected habit allows them to quickly dominate herbaceous weeds.

The life cycle of *Crotalaria* species does not allow them to meet the recommended 12 months period for improved fallow. Therefore, it is possible to intercrop *crotalarias* with perennial plants such as *Brachiaria brizantha* or other *Brachiaria* species.

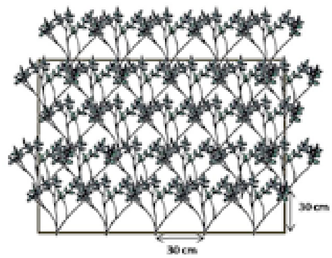
Many plants used as green manure can also be used for improved fallow. The main difference being the period for which the plants are left in the field (see factsheet no.10 on green manure).

Improved fallow using trees and shrubs

Fallows using shrubby species usually last for a 1 to 3 years period, while fallows using tree species last longer, depending on the production requirement of the trees. Such fallows don't allow growing crops between the shrubs or trees.

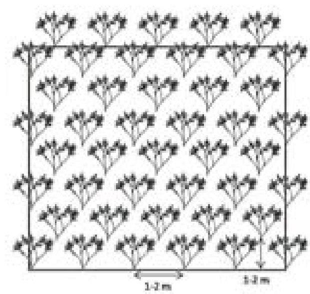
Cajanus cajan (pigeon pea)

The root system of pigeon pea is excellent at loosening the soil. Pigeon pea can be sown after harvesting the main crop, but is also often intercropped with it, or used as a relay crop (sown 2 to 3 weeks after sowing maize for instance). Sow directly in the field at 4 to 5 cm depth, using 30 x 30 cm spacing.



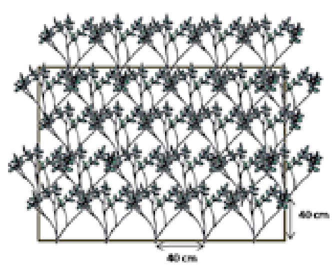
Calliandra calothyrsus

Calliandra calothyrsus can be sown directly in the field, propagated by cuttings or raised in nursery then transplanted. Spacing depends on production objectives. It is interesting to use *Calliandra calothyrsus* for long improved fallow as it can also be used for fodder and honey production. Plants should then be spaced 1 m x 1 m or 2 m x 2 m apart.

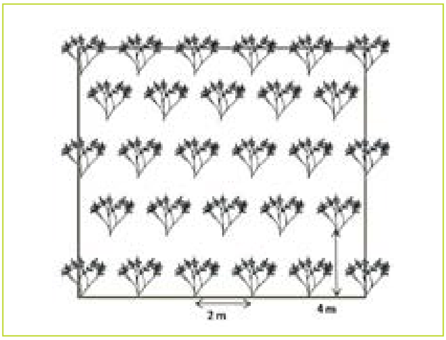


Tephrosia vogelii

Break seeds dormancy by soaking them in 45°C water or in cold water for 24 hours. Sow 2 to 3 seeds/pocket using a 40 cm x 40 cm spacing, directly in the field, in relay with the main crop or after harvest.

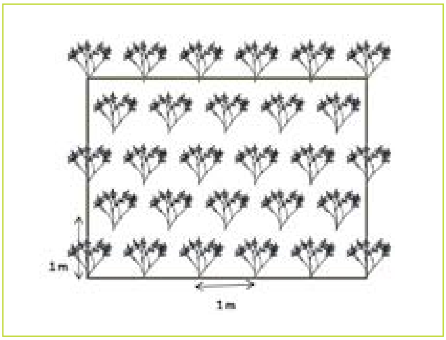


Gliricidia sepium



Within 3 years, the soil of a depleted plot planted with gliricidia can be almost completely restored to its initial geological and physico-chemical qualities. Sow *Gliricidia* seeds or plant cuttings directly in the field at 2 m x 4 m spacing. It is also possible to intercrop *Gliricidia* with an herbaceous cover crop such as *Stylosanthes* to establish a silvopasture system.

Sesbania sesban



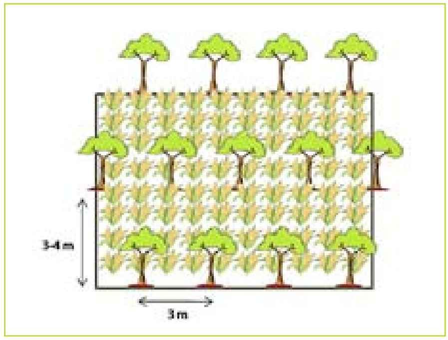
It is advised to prepare bare roots seedling in a nursery rather than sowing directly in the field, as it would prolong the time needed for improve fallow. Also, when direct seeded, plant density is uneven, increasing weeding labor requirement before *Sesbania* gets established. Seedlings can be transplanted 6 to 10 weeks after sowing in nursery, at 1 m x 1 m spacing.

Harvest occurs after 2 years, before rainy season. Trees are cut at ground level and left to dry and drop their leaves on the ground, before cutting the branches and trunks for wood.

Sesbania sesban fallows are perfect to control *Striga*. Indeed, *Sesbania* stimulates striga seeds germination while its cover and fast growth kills the weed by blocking sunlight thus decreasing the amount of seeds in the soil.

Acacia auriculiformis

Plant seedlings raised in nursery simultaneously with the main crop in 30 cm x 30 cm x 30 cm planting holes at 3 m x 3 m or 3 m x 4 m spacing to produce honey and wood.



Summary of yield increase from improved fallow

Soil Improving plant	Yield increase from improved fallow
Cajanus cajan	55 to 255% increase in maize yield observed compared to unfertilized maize monoculture
Gliricidia sepium	345% increase in maize yield observed, compared to unfertilized maize monoculture
Mucuna pruriens	250% (or more) increase in maize yield observed, compared to unfertilized maize monoculture
Sesbania sesban	161% (or more) increase in maize yield observed, compared to unfertilized maize monoculture
Tephrosia vogelii	232% increase in maize yield observed, compared to unfertilized maize monoculture
Acacia auriculiformis	Hard to evaluate due to the length of the improved fallow period
Calliandra calothyrsus	Hard to evaluate as *Calliandra* can also be used for long fallow periods

NB: The result on yield of improved fallow using trees or shrubs is greater than when using herbaceous plants, mainly thanks to their deeper root system having a greater structuring effect and bringing nutrients localized deep in the soil back to the surface.

To learn further

Climate Smart Agriculture, A review of current practice of agroforestry and conservation agriculture in Malawi and Zambia, Arslan A., Kaczan D., Lipper L., Esa Working Paper, FAO, 2013, 62 p. www.fao.org.

Les crotalaires, *Manuel du planteur de banane de Guadeloupe et Martinique*, Éric de Lucy, TinoDambas (dir.), Institut technique tropical IT2, LPG, 6 p. www.it2.fr/documentation/manuel-du-planteur-fr/

La jachère à *Gliricidia sepium* associé à *Stylosanthes hamata*, *Marché des innovations et technologies améliorées*, WAAPP/PPAAO, MITA, Coraf. http://mita.coraf.org.

Évaluation de l'effet fertilisant de *Mucuna utilis L.* face à deux doses de NPK (17-17-17) sur la croissance et la production de la variété samaru du maïs (*Zea mays L.*) dans les conditions opti-males, W. Mokuba, R.V. Kizungu, K. Lumpungu, *Congo Sciences*, vol. 1, n° 1, nov. 2013, pp. 23-30. www.congosciences.cd.

Compost

Function Soil fertility management

+

- Produces quality fertilizer
- Adds value to on-site biomass and crop residue
- Has a low fabrication cost
- Reduces or even eliminates the need for chemical inputs
- Increases the quality of agricultural products
- Is harmless to farmers health, unlike chemical inputs
- Improves soil structure
- Improves soil water holding capacity
- Facilitates root penetration into the soil
- Has a long lasting effect due to slow release of nutrients
- Strengthens plants, making them more resistant to diseases

−

- Requires significant labor to turn the compost and, if needed, build a shelter during rainy season
- Crops' need for compost has to be anticipated, as the composting process requires time, and compost production should be planned ahead
- Transporting compost to the field can be challenging if the composting location is located far away (requires a cart)
- Manure can be hard to source if livestock husbandry is not practiced in the area
- The fabrication cost of a shelter for rainy season can be high if local materials are not used
- Requires skill to control the fermentation process

Compost produced in a bin
by a Cambodian farmer supported by GRET
as part of APICI project, 2011.

Compost heap method, Siam Reap research
station, GRET, Cambodia, 2015.

Compost aims at feeding crops, efficiently replacing the need for chemical fertilizers. In addition, it also strengthens plants and helps to prevent diseases. It is also free of weed seeds and pathogens as the high temperatures generated during the fermentation process kill the seeds and microorganisms initially present in the composting materials.

What is compost?

Compost is the end product of the controlled decomposition of plants (leaves, straw, hay, crop residue, kitchen waste) and animal products (bones, egg shell, manure). Decomposition is the result of microbial activity developing in a warm, moist and aerated environment. Good compost is brown in color and doesn't smell. To produce such compost, conditions have to be monitored in order to create an appropriate environment for the decomposition of the materials.

Preparing compost material

To make compost, the following ingredients are needed:

› Fresh organic matter

Leaves, stems, vines.

Banana trunk.

Naturally occurring species such as *Chromolaena odorata*, *Mucuna pruriens*, *Pueraria phaseoloides* or legume crop residues such as *Cajanus cajan* or *Vigna unguiculata* enhance compost fertility.

› Dry organic matter

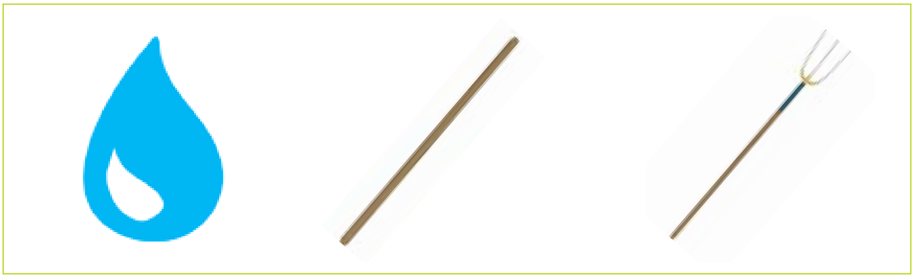
Rice straw residues left after harvest.

› Fertile soil, well rotten manure or excrements mixed with soil

Manure, Sothea Sok, GRET, Cambodia 2015.

Humus, Sothea Sok, GRET, Cambodia 2015.

› Some water, a stick, a pitch fork or any other tool allowing turning the compost

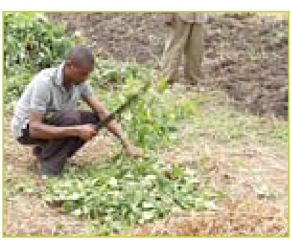


Building the compost heap

In some countries, it might be necessary to build a shelter during rainy season. The shape and appearance can vary greatly from one place to the other and it might be built with local materials or not. Here, only the composting process will be described.

Dig a hole 10 cm deep, 1.5 m wide and 2 m long at least: the length of the heap depends on the amount of materials available.

Collect and chop dry and fresh organic matter.



The compost heap is built by alternating layers of the different materials.


Start by adding coarse materials (banana trunk for instance) at the bottom of the hole to improve aeration.


Add a layer of straw, roughly, 20 cm thick.


Water carefully. The straw should be moist, not soaked.


Add a layer of manure or fertile soil, roughly 5 cm thick.


Water the new layer the same way as the previous one.


Add a layer of fresh organic matter, approximately 15 cm thick.

Water the new layer as previously

Repeat the same steps again, starting over from the straw layer (not the coarse materials).

Repeat 2 to 3 times or even more…


… until obtaining a heap 1.5 m tall if available materials are sufficient.


Cover with straw or palm fronds to protect the heap if no shelter is available.


Plant the stick vertically at the centre of the heap to be used as a thermometer.

Every 10 days or so, pull the stick out and grab the buried end. If it is warm, the fermentation process is going on and the materials are decomposing well. Once the heap is cold, the compost is ready to use.

Turning the heap

The heap should be turned every 10 days or so, after it has reached maximum heat and starts cooling down.

While turning the heap:

- Invert the layers: the top layers should end up at the bottom of the heap and the bottom one on top;
- Materials located on the edge of the heap should be buried in;
- Water the new layers when they are 30 cm thick.

Once turned, the compost should look just as it did before (it should form a heap) and fermentation should resume within a few days (temperature should rise).

After 1 or 2 months, the compost is stable, brown in color and doesn't smell.

Compost use

The compost obtained is stable and can be stored given it is protected from bad weather.

Nutrients contained in compost can leach out if exposed to rain. Therefore, it is important to protect the heap from bad weather.

Incorporate compost directly into the soil before or during cultivation. If compost is abundant, apply on the whole field's surface or, when it is scarce, only at the base of the plants.

Liquid manure

Function	Soil fertility management

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- Produces quality fertilizer
- Makes use of various locally available plants, according to desired effect
- Valorizes naturally occurring plant resources
- Low production cost (if drum is available)
- Reduces or even eliminates chemical inputs through the use of pesticidal plants
- Increases the quality of agricultural products
- Harmless to farmers health and environment, unlike chemical inputs
- Low labor requirement
- Easy to apply (watering can)
- Improves soil structure when combined with mulch (accelerates mulch decomposition)

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- Production has to be planned ahead for liquid manure to be available when needed by crops
- Requires appropriate skills to avoid burning the crops when applying
- Manure can be hard to source if no livestock are raised in the surroundings
- Watertight containers of appropriate size are not always locally available at low cost

Compost aims at feeding crops, efficiently replacing the need for chemical fertilizers. It also has the ability to strengthen plants and helps to prevent diseases. It is free of weed seeds and pathogen as the high temperatures generated during the fermentation process kill the seeds and microorganisms initially present.

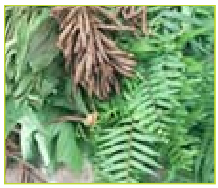
Unlike solid compost (see factsheet no. 8), liquid manure doesn't require much work as there is no need for regular turning, but it cannot be used for basal application and doesn't affect soil structure. Rather, it is used as a top dressing: to supply plant nutrients to the crops during their growth.

Preparation of required material

To make liquid manure, the following items are needed:


One 100 l drum
(or earthenware jar).

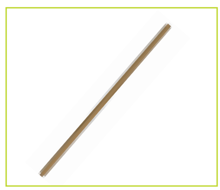

Some water.


10 kg of mixed
fresh leaves.


1 jute bag.

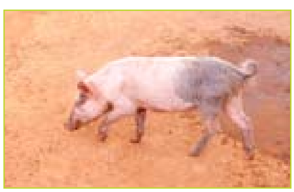
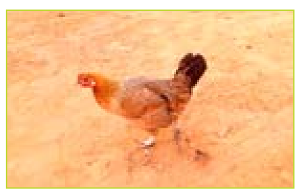

One big stone.

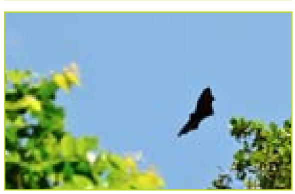

6 kg of manure.


One stick.

Appropriate types of manure

Dung of the following animals can be used to make liquid manure.



Appropriate type of fresh leaves

In addition to providing some organic matter, the plants used should also provide the minerals required by the crops for their growth. If chosen carefully, they can also be used to control pests and diseases. Hereunder are a few examples:

› Nematicide and provides nitrogen

Chromolaena odorata (Zaïre, siam weed).

› Insecticide

Nicotina tabacum (tobacco).

› Fertilization

Leucaena leucocephala.

Moringa oleifera.

Pueraria phaseoloides.

Liquid manure preparation

› Step 1: filling up the jute bag

Place 10 kg of mixed leaves and 6 kg of manure in the jute bag

› Step 2: fill up the 100 l drum with water

Step 3: place the jute bag in the drum

The bag must be closed and maintained fully immersed at the bottom of the drum with a stone.

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Step 4: partially close the drum

As the mix needs to breath, the bin should not be air tight. Nevertheless, to prevent flies and foul smell – and as a safety measure – the drum should be closed, either by placing a mat or a cloth on top of it, or by partially screwing-down the lid.

Step 5: maceration

Two days after step 4, stir the mix for 5 min with a stick and, if required, add some water for the bag to be fully immersed.

Repeat once a week.

D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
Step 4 	24h	Stir 	24h	24h	24h	24h	24h	24h	Stir 

Using liquid manure

Liquid manure is ready after macerating for 3 to 6 weeks, depending notably on ambient temperature. The finished product can be store for 1 month in a cool and shaded place.

Month 1				Month 2				Month 3		
W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11
Confection										
			Maturation							
				Use and storage						

To apply liquid manure, a watering can should be used.

For vegetable production, it should first be applied immediately after transplanting the seedlings, then regularly throughout the whole growing cycle.

Applying liquid manure, Justine Scholle, GRET, DRC, 2015.

Green manure

Functions

Soil fertility management
Soil structuring

+

- Increases soil fertility by providing nutrients (especially nitrogen) and organic matter, benefiting crop growth
- Prevents wind and water erosion once the main crop has been harvested
- Restructures the soil by improving porosity and facilitates water infiltration into the soil
- Increases soil's water holding capacity
- Prevents disease propagation in the field (crop rotation)
- Offers an alternative to the use of chemical inputs
- Harmless to both the environment and farmers' health
- Does not require complex agronomical knowledge or high technicality

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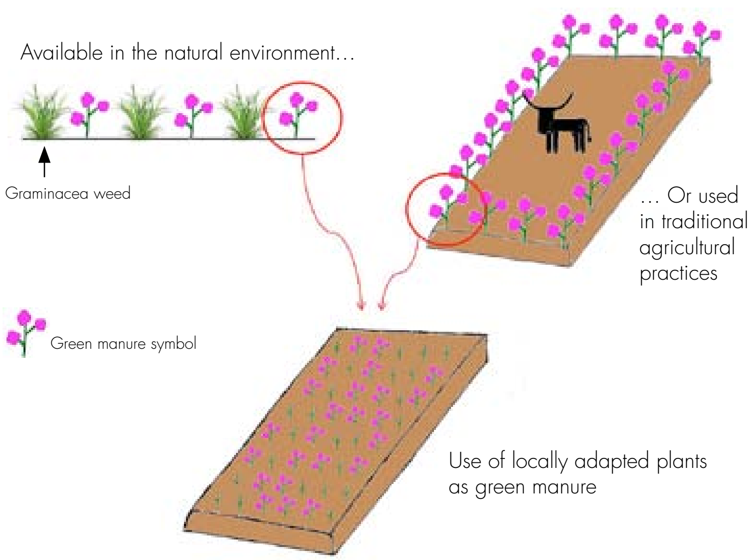
- Requires sourcing quality seeds for the plants used as green manure
- Animals must be refrained from grazing the green manure crop
- Irrigation is required when residual moisture or precipitations are insufficient
- Turning the green manure crop requires additional labor
- Implies a 40 to 60 days interval between two crops, depending on the plant used for green manure

Green manure aims at:

– enriching the soil, by using legumes that fix atmospheric nitrogen for instance;
– adding organic matter, by turning into the soil plant biomass that breaks down into humus;
– structuring the soil;
– eradicating certain weeds by turning the soil;
– controlling weeds through direct competition for light, nutrients and space.

Choosing green manure plants

The two first things to consider are the **adaptability** of the crop to the specific climatic zone and the **availability** of quality seeds. Indigenous varieties are always the most adapted to local environments, but various crops naturalized throughout the entire humid tropics also possess interesting quality. One should identify what plants are available locally and, among them, which one the farmers are familiar with.



Growth cycle: plants used for green manure preferably have a rapid growth. Nevertheless, the duration of their life cycle varies from one plant species to the other: some have short cycles, other medium or long.

The species chosen will depend on the available duration for the fallow period between two crops.

Examples

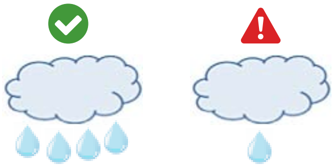
Farmers possessing small plots of land have to continuously produce on the same field, having very little fallow periods between two crops. In such cases, using *Vigna unguiculata* – a species reaching maturity within 30 days – will be appropriate, given the field is not flooded.

On the contrary, if the available period between two crops is longer, species with a medium growth cycle such as *sesbania* and *crotalaria* are recommended. Their cycle lasts approximately 45 days but, these plants being photoperiodic, their vegetative growth is encouraged by long days while flowering is induced by short days.

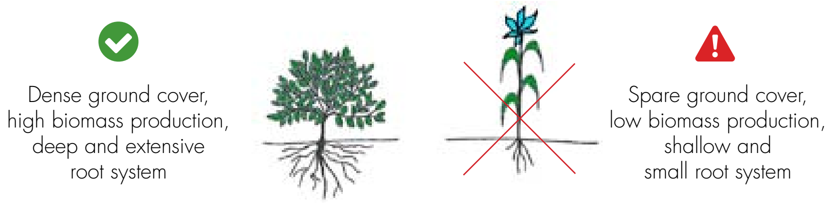
Finally, for farmers who can afford a few months of fallow, long duration crops such as *Mucuna pruriens* can be used.

The cultivation techniques for each of these plants are described further in the factsheet.

Climate: direct seeding under vegetative cover, including green manure, are only efficient in area with enough moisture, as biomass production is high and organic matter decomposes rapidly. On the contrary, in semi-arid and arid areas, biomass production is low, given no irrigation is provided, and its degradation is much too slow to be efficient.



Plant morphology: plants forming a dense ground cover as well as having deep and extensive root systems should be preferred.



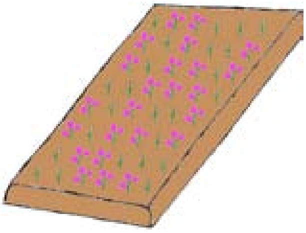
Inputs from different green manure plants

Below are the inputs of a few plants commonly used as green manure. The list is not exhaustive.

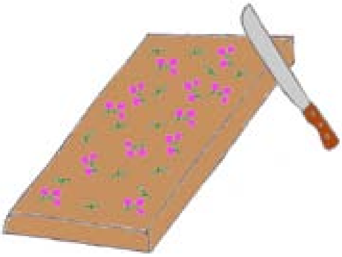
Green manure crop	Days before turning in	Seeding rate (kg/ha)	Organic matter fresh weight (t/ha)	Organic matter dry weight (t/ha)	Quantity of nitrogen fixed (kg/ha)
Azolla pinnata	After drainage of the field in flooded rice cultivaton	7 to 8		2.50	50 kg in 35 days, 90 kg in 2 months
Canavalia ensiformis	70 to 110	62.50	29.80	6.45	70 to 80
Crotalaria juncea	45 to 90	30	25 to 35	5.75	100 à 120
Indigofera hirsuta (d'autres sont utilisables aussi)	100 to 120		40	9.7	80 to 90
Mucuna pruriens	150 to 180	22 to 50	20-30		80 to 100
Sesbania					
rostrata	45	31 to 40	17.00	2.30	140
Sesbania bispinosa	45 to 50	50 to 90	25		80
Vigna radiata	40 to 65	44 to 50	25.00	4.30	55
Vigna unguiculata	30 to 60	50 to 90	25.00	3-5	50 to 100
Vigna mungo	40				60
Vigna umbellata	45				90

General technical itinerary

Step 1: green manure is considered mature when 50% of the plants are blooming. It is at this stage that they fix the most nitrogen in the soil. The 50% value is a general indication and cutting might actually happen at different stages according to specific crop calendars constraints. Indeed, these plants being photoperiodic, the flowering will be induced sooner or later according to day length, thus not always matching perfectly farmers' particular needs.

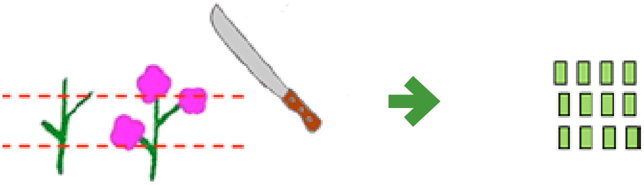


Step 2: cut green manure after 1 to 3 months (depending on the growth cycle of the plants)



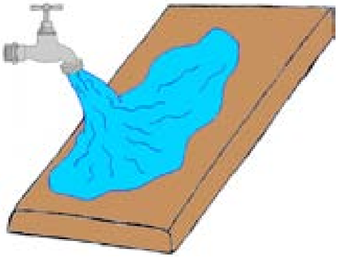
Since the plants used as green manure are turned in the soil at flowering stage, it is not possible to collect their seeds. In order to produce seeds, it is recommended to plan for a specific plot.

Step 3: chop the plants (if tall species) to accelerate decomposition.



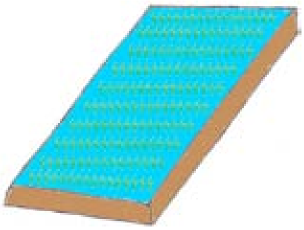
Step 4: turn green manure and plow.

Step 5: according to climate, and only for rice cultivation, flood the field.



Step 6:

– for rice: transplant rice seedlings two weeks after turning the green manure (7 days can be sufficient if the farmers cannot afford waiting that long);
– for vegetable growing, plant 7 to 10 days after turning.



The increase in yield is greater when the cash crop is planted shortly after turning the green manure plants (less than 7 days) into the soil. On the other hand, it might be harder to work the plot or to plant the vegetable crop, except when using *Vigna* species as they break down very fast.

Technical itinerary for rice cultivation

Adapted green manure plants for rice cultivation

› Short duration cycle

Vigna radiata (mungbean), © CIRAD.

Vigna unguiculata (Cowpea, niébé).

Vigna mungo (Black Gram), © Sanjay.

Vigna umbellata (Rice bean), © Krish Dulal.

› Medium duration cycle


Sesbania rostrata (Philippines). Hervé Saint Macary, © CIRAD.


Sesbania bispinosa (acuelata).


Crotalaria juncea.

› Long duration cycle


Indigofera hirsuta, © Alex Popovkin.


Canavalia ensiformis, © Lígia Prado.

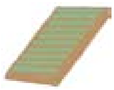
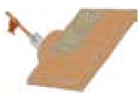
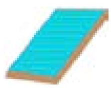
› During rice cultivation


Azolla pinnata.

Crop calendar for different species of green manure plants

› *Vigna radiata* (mungbean, green gram)

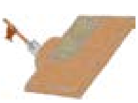
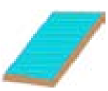
Mungbeans cannot withstand flooding for more than 3 consecutive days, after which they rot and die. Their growth cycle should then occur when the rice field is dry, either during rainy season or after monsoon using residual soil moisture (or beforehand if the complete cycle can happen before monsoon). Also, mungbeans are not very competitive during the early stage of their development and should not be planted during a period when rains are regular as they might be smothered by weeds.

Rice harvest	D1	D2	D3	...	D40	...	D45-50
	Seeding 25 to 45 kg/ha		Germination		Turning (plowing)		Transplantation of rice seedlings
							

- Breaking of dormancy: none.
- Seeding rate: 25 to 45 kg/ha.
- Days to germination: 2 days.
- Turning: 40 days after sowing. Decomposition takes 10 to 15 days.
- Rotation: *Vigna radiata* – rice – rice possible.

› *Vigna unguiculata* (cowpea, black eyed pea)

Similar to *Vigna radiata*, cowpea cannot stand water logging. Therefore the same growing conditions as seen above are necessary for its successful establishment in the field.

D1	...	D5-J9	...	D31-J41	...	D46-J50
Seeding 20 to 50 kg/ha		Germination		Turning		Transplantation of rice seedlings
						

• Breaking of dormancy: none.

• Seeding rate: Seed quantity depends on the objective. If only to produce fodder and green manure, 20kg/ha is sufficient (sown in furrows, at 30 to 60 cm inter row spacing and 10 to 15 cm in-row spacing) while, if grown for human consumption, from 50 kg/ha (if sown in furrows) up to 90 kg/ha (if broadcasted) is recommended.

• Sowing depth: 3 to 5 cm.

• Days to germination: 4 to 8.

• Turning: 40 days after sowing.

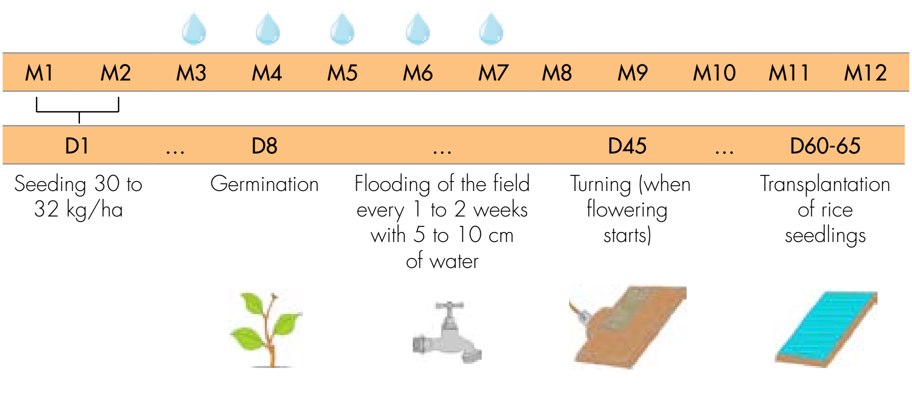
• Rotation *Vigna unguiculata* – rice – rice possible.

Vignas have the advantage of having a very short growth cycle. Nevertheless, because of their low tolerance to excessive moisture, in the case of flooded rice cultivation, other species of green manure will be preferred if time permits.

› *Sesbania rostrata* and *bispinosa (Sesbania aculeata)*

If mature plants tolerate water logging, young seedlings don't. Hence sowing should take place 1 to 2 month prior to rainy season.

It can be complicated to source good quality Sesbania rostrata seeds. Also, this species can be hard to establish unless all conditions are met.



- Breaking of dormancy: none.
- Seeding rate: 30 to 32 kg/ha.
- Days to germination: 7 days.

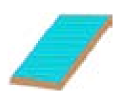
Flood the field to a depth of 5 to 10 cm every 1 to 2 weeks (depending on season). Monitor soil moisture and irrigate accordingly.

The plant is turned into the soil once it reaches a height of 1 to 1.5 m (the stem should be cut into 3 pieces before being turned in the soil).

During growth, buffalos have to be kept away from the field as both *Sesbania bispinosa* and *rostrata* are palatable to them.

Since the plants used as green manure are turned into the soil at flowering stage, it is not possible to collect their seeds. In order to produce seeds, it is advised to plan for a specific plot. For instance, 100 m^2 of *Sesbania bispinosa* or *Crotalaria juncea* yields approximately 6 kg of seeds. Hence, 400 to 500 m^2 are required to produce seeds for 1 hectare of green manure.

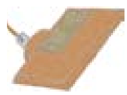
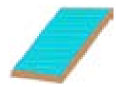
› *Crotalaria juncea* (Sunn Hemp)

D1	...	D3	...	D46-D51	...	D65-D70
Seeding 30 kg/ha		Germination		Turning		Transplantation of rice seedlings
						

- Breaking of dormancy: none.
- Seeding rate: 30 kg/ha (sown at 1 or 2 cm depth).
- Days to germination: 3 days.
- Turning: 45 to 90 days after sowing.

› *Canavalia ensiformis* (Jack bean)

M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12

D1	D2	...	D9	...	D65	D66 … D76 … D81
Breaking of dormancy	Broad-casting (95 to 125 kg/ha)		Germination 		Turning 	Flooding of the field and decomposition 
						Transplantation of rice seedlings 

- Breaking of dormancy: soaking of the seeds overnight.
- Sowing: Broadcasted when seeds are abundant, sown in furrows otherwise.
- Days to germination: 7 days.
- Turning: 64 days after sowing.

Canavalia flowers approximately 45 to 50 days after sowing.

For seed production, sow *Canavalia ensiformis* directly after rice harvest, when the soil is still moist, or sow seeds on the rice field berms, above flood level.

› *Indigofera hirsuta* (other species of *Indigo* may also be used)

Very good green manure crop for long fallow cycles, but seeds can be hard to find and plants might be difficult to establish. Relatively deep rooted. 60 to 120 days cycle depending on the species.

M1		M2		M3		M4

D1	D2	…	D8	…	D120
Rice harvest	Sowing 3 to 5 kg/ha		Germination		Turning


- Breaking of dormancy: Soaking seeds in 80°C water for 5 minutes significantly improves germination rate and fastens germination.
- Sowing rate: 3 to 5 kg (in furrows).
- Days to germination: 7 days (if soaked in hot water).
- Turning: 100 to 120 after sowing.

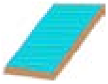
This species can become invasive therefore it is important not to allow the plants to go to seed.

› The case of azolla as green manure in rice cultivation

Unlike other green manure plants, azolla is established during rice cultivation rather than before or after. Indeed, being an alga, azolla requires a constant layer of water and is not suited to cultivation using rice intensification system (see factsheet no. 12 on SRI). On the other hand, in addition to rice, azolla can be combined with pisciculture, acting as a source of food for the fish.

Azolla can be introduced 5 to 10 days after rice transplantation.

D1	…	D5-D10	…	D25-D30	…	After draining the filed
Rice transplantation		Introduction of azolla		Weeding		Turning



Technical itinerary for vegetable production

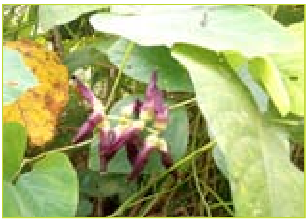
Green manure plants adapted to vegetable production

› Short cycle

Vigna unguiculata (Cowpea, black eyed pea).

Sorghum (sorgho),© Gyrostat.

› Long cycle



Mucuna pruriens (velvet bean).

Green manure growth cycle ahead of vegetable cultivation

Selection of green manure plant and sowing.

Germination.

Growth period (minimum 30 days).

Cut once mature, leaving the roots in the soil, and turn in.

Wait 7 to 10 days for the green manure to start decomposing before planting the vegetable crop.

Sorghum produces an abundance of biomass. For vegetable cultivation, it is good practice to use it once every 3 years, but it should not be allowed to go to seed.

The use of green manure integrates the principles of crop rotation and improved fallow. To understand better these practices and their different aspects, see factsheet no. 6 and no. 7.

To learn further

Pl@ntUse, le wiki sur les plantes utiles et les utilisations de plantes. http://uses.plantnet-project.org/fr.

A Primer on Organic-Based Rice Farming, R.K.Pandey, IRRI, 1991, 201 p.

Essais sur l'emploi des légumineuses comme engrais verts à Java, P.J.S. Cramer, Revue de botanique appliquée et d'agriculture coloniale, 1924, Vol. 4, n° 31, pp. 164-170. www.persee.fr.

Fire-related cues break seed dormancy of six legumes of tropical eucalypt savannas in north-eastern Australia, Pau R. Williams *et al.*, *Austral Ecology*, 2003, vol. 28, n° 5, pp. 507-514. DOI: 10.1046/j.1442-9993.2003.01307.x.

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Document de débriefing de mission, Chapitre sur les engrais verts, Stéphane Fayon, Gret, Apici project, Cambodge, Janvier 2015.

Document de débriefing de mission, Chapitre sur la riziculture, Stéphane Fayon, Gret, Phasein project, Myanmar, Septembre 2013.

Document de formation : techniques de gestion de la fertilité du sol, Stéphane Fayon, Annadana Soil and Seed Savers, Inde, 2005.

Mixed crop-livestock farming

Functions
Soil fertility management
Income diversification
Erosion control

+

- Valorizes animal dejections to enhance soil fertility
- Valorizes crop residues used as fodder
- Simultaneously intensifies agricultural and livestock production
- Produces animal energy in the case of animal-drawn cultivation
- Limits erosion by the use of ground cover plants for pasture and trees for fodder production

–

- Can lead to competition for the allocation of land between agriculture and livestock, sometimes difficult to solve
- Is difficult to implement in areas where animal husbandry is not, or seldom, practiced

Village coop (left) and rotten chicken manure ready to be used (right) for vegetable production, DRC, D. Violas et J. Scholle, 2013 et 2015.

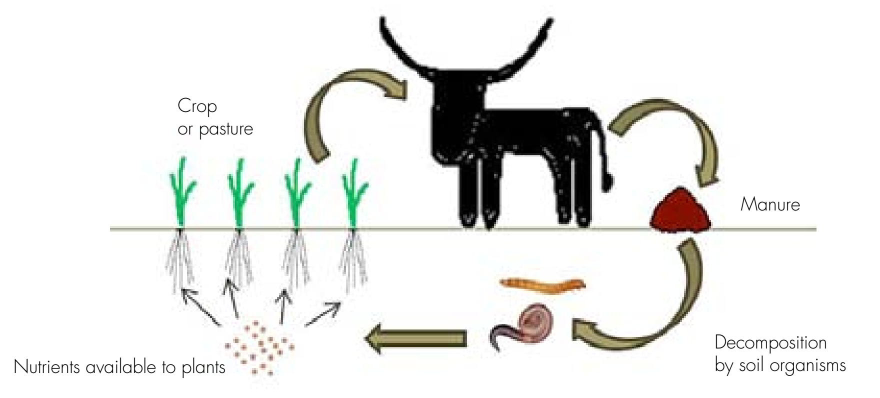
Agriculture and livestock farming often find themselves competing, especially for access to land, fields or pastures, leading to actual conflicts between farmers and breeders in some tropical countries. Yet, agriculture and animal husbandry are complementary in ecosystem management and a farm able to take advantage of the interactions between the two can successfully manage soil fertility sustainably, diversify activities and increase overall productivity.

Why integrating crops and livestock?

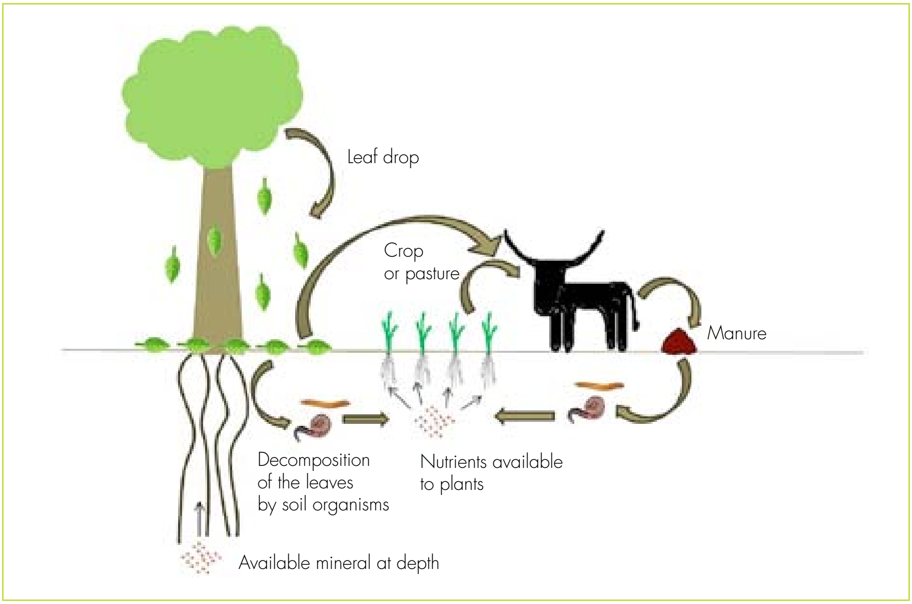
The aim of crop and livestock integration is to encourage the interactions between both components of the system in order to increase farm productivity. In a nutshell, this is achieved through:

– valorization of crop residues to feed livestock;
– valorization of animal dejections to fertilize the soil and feed the plants.

This agropastoral system allows **recycling** soil nutrients, thus managing fertility sustainably.



There are numerous ways to integrate crop and animal farming, depending mainly on local socio-economical conditions. It is also possible to integrate animal husbandry with agroforestry, or even to combine the three in a system.



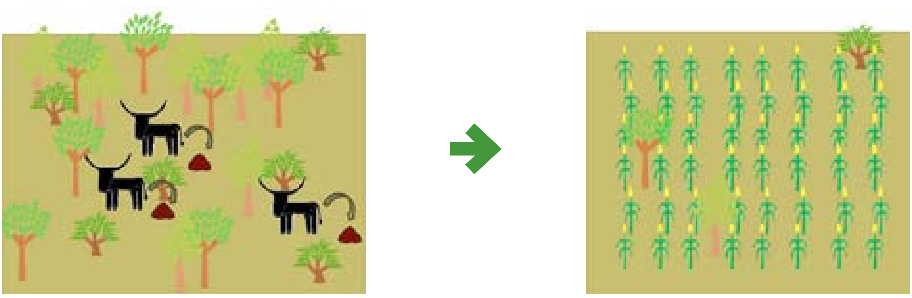
Agro-silvo-pastoral systems, integrating crops, trees and animal husbandry are more complex and more efficient at cycling nutrients. Trees can provide cattle with fodder and their leaves bring nutrients back to the soil surface once they fall, making it available to crops.

Examples of crop-animal integration

Integration possibilities are countless, hence only a few will be described further.

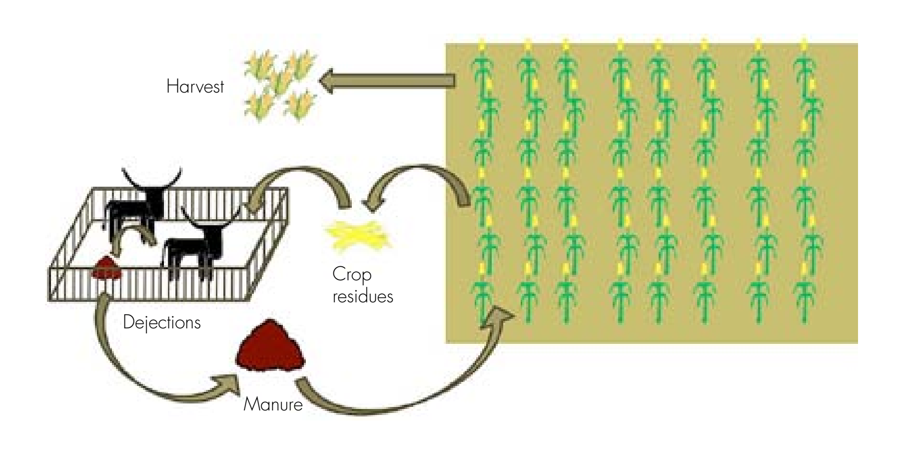
Enclosing of livestock on fields prior to cultivation

When the field is not used all year round, it is possible to pen livestock on the plot, a few days or weeks before cultivation. Cattle graze the grass that has grown during the fallow period and their dejections are dropped on the field, with the advantage of not having to carry the manure to the field.



Valorization of manure for crop production and use of crop residues as fodder

Animals are penned in the village and famers feed them every day. It requires more labor compared to straying but allows controlling food rations, hence rapidly increasing animals weight. Animals can be fed with crop residues, kitchen scraps or grass collected in the surroundings. Dejections are stored to produce manure that, once well rotted, will be brought to the field to fertilize the crops. Market gardeners often use this method.

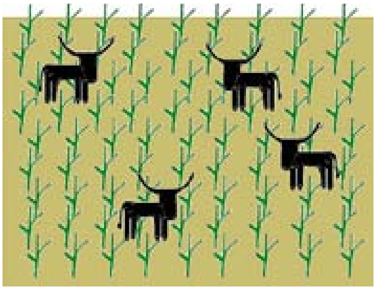


To increase quantity and improve quality of manure, the animal shelter should:

– be well sealed for the dejections to remain inside;
– have a roof to prevent manure from being leached;
– be designed in such a way to facilitate manure removal.

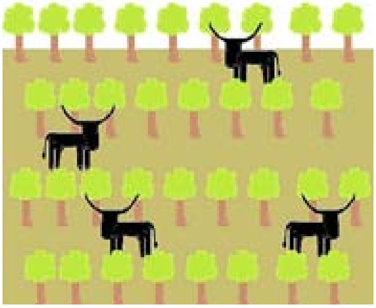
Manure is also used to make compost, increasing the quality of organic fertilization as well as providing a greater quantity of fertilizer by the addition of organic matter available in the surroundings. (See factsheet no. 8 on compost and factsheet no. 9 on liquid manure).

Fertilizing and restructuring plants used for pasture or fodder bank



Numerous fertilizing plants – especially legumes – and restructuring plants can be used as they are palatable to livestock. Farmers can use them to establish pastures or fodder banks. Amongst plants worth mentioning are species like *Mucuna pruriens* (see plant fact-sheet no. 14), *Brachiaria brizantha*, a herbaceous plant that also restructures the soil (see plant fact-sheet no. 4), *Sthylosanthes guianensis* that grows well on poor soils, plants from the *Pennisetum* and *Desmodium* genus or vetch and clovers that grow on more fertile soils and produce better quality fodder, etc. (see factsheet no.13 on living mulch and factsheet no. 6 on crop rotation for further details).

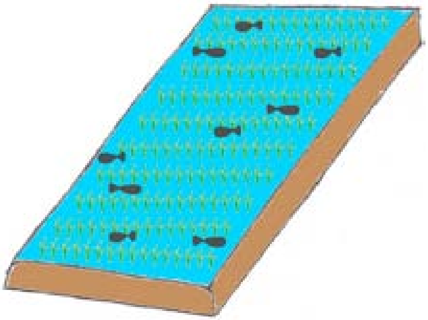
Numerous trees and shrubs also have fertilizing and restructuring properties while being palatable to livestock. Worth mentioning are notably *Gliricidia sepium*, *Cajanus cajan*, *Leucaena leucocephala*, *Calliandra calothyrsus*, *Sesbania sesban*, etc.



These pastures can be established as part of an improved fallows system, (see factsheet no. 7), using their fertilizing and restructuring properties to put the plot back under cultivation at a later stage or, when animal husbandry is prioritized, they can be used exclusively to feed cattle.

Integrated rice-fish farming

In flooded rice cultivation, it is possible to introduce fish in the field alongside the rice crop. When the field is drained out to harvest the rice, fishes are collected. It should be noticed that the arrangements required to accommodate the fish reduce the amount of available space for rice. Nevertheless, on a per hectare basis, integrating rice and fish lead to greater yields than when grown separately.



Fish seeding is achieved either by catching wild fish in the surroundings or by introducing commercial species.

To learn further

Conduite des systèmes de culture sur couverts végétaux et affouragement des vaches laitières : guide pour les Hautes Terres de Madagascar, Cirad, GSDM, Tafa, Fifamanor, ARP et Sicalait Madagascar, 2008, 90 p. http://umr-selmet.cirad.fr.

Rizipisciculture, in *Manuel pour le développement de la pisciculture à Madagascar*, Ministère de l'Élevage et des Ressources halieutiques, Pnud, FAO, Document technique n° 4. www.fao.org.

Systèmes de production riz-poisson en Chine, Parviz Koohafkan, FAO, 2004, 2 p. www.fao.org.

System of rice intensification

Functions

Rice yield increase
Soil fertility management
Water management

+

- Increases yield
- Reduces seed rate
- Saves water
- Limits or even suppresses the need for chemical inputs
- Increases root development as well as tillering capacity
- Reduces time needed for transplantation
- Saves space thanks to the reduced space allocated to rice nursery
- Can be applied to any rice cultivar
- Can be adapted to specific conditions
- Highly appropriate to seed saving due to the transplantation of a single seedling per hill, making selection and roguing easier

−

- Requires good drainage; controlling and managing water level can sometimes be challenging
- Labor intensive
- Difficult to apply on the scale of very large farms
- Sourcing the amount of compost required to fertilize the field can sometimes be challenging

Definition

System of rice intensification (SRI) is a rice cultivation method based on twelve principles aiming at enhancing rice growth and increasing yield. By using SRI, significant increase in production is achieved; more than 100% in the case of small scale farmers and at least 50% on larger scales. This technique can be applied to any rice cultivar. Also, the basic principles can be adapted to the local soil-climatic conditions of any particular rice field.

Harvesting rice from a plot using SRI, Kouk Russei Cheung village, Touch Sokharith, Cambodia, 2013.

SRI methods and principles

Selecting healthy seeds for sowing

› Sorting

– Sorting visually and by winnowing: select full seeds, without stains or malformations.

Rice seeds in a bag prior to visual and winnowing sorting.

– Sorting with water: place the seeds in water with a whole egg (with its shell) and add salt until the egg stands vertically. The egg is a simple way to control optimal salinity to sort the seeds out. Keep only the seeds that sink to the bottom of the container.

› Elimination of fungal diseases

Soak rice seeds in 60 to 65°C water for 10 minutes to prevent the development of fungal diseases.

› Seed protection

Take the seeds out of the warm water and soak them overnight in cold water mixed with crushed neem leaves, in order to protect them from insects (protection lasts for 10 days).

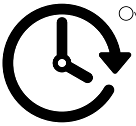
5 kg of rice seeds

=

0,5 à 1 kg of neem leaves

+

+ 3 to 4 liters of water



Over night

› Storage

Keep the seeds in a cotton bag until germination, which takes about two days.

Rice germination.

Rice nursery

› Locating the nursery

Site selection	Justification
Next to a water source	Makes irrigation easier
On a well drained soil	Prevents flooding of the nursery
Sunny	Provides sunlight required for plant growth
Next to the house	Makes monitoring and tending of the nursery easier
Protected from animals	Prevents loss due to stray animals
Well away from the rice field	Prevents pest and disease attacks from the previous rice crop

Nursery soil preparation

Plow the land twice, 7 to 10 days after the first rain. Create raised beds 10 to 15 cm high.

Plowing of the land for nursery preparation, India, Stéphane Fayon.

Nursery soil fertility management

Apply compost at a rate of 0.5 to 1 kg/m².

Add rice straw ash at a rate of 1 to 1.5kg/m² to provide phosphorus and silicate in order to promote leaf development and plant vigor and enhance disease resistance.

Thoroughly turn the fertilizers in the soil.

1 to 1,5 kg ash.

+

0,5 to 1 kg compost.

1 m² nursery bed

Nursery size

There are no general rules when it comes to the size of the nursery, as it depends on the size of the field to be planted and the spacing used between the plants. Generally, farmers who follow carefully SRI guidelines use a 100 m² nursery for 1 ha of paddy.

Approximately 300 to 500 g of seeds are used per every 10 m² of nursery. Hence, for 100 m², 3 to 5 kg of seeds should be sown, more in case the fertility of the land is low. When using 25 cm x 25 cm spacing, 6.5 kg of seeds are required for a nursery measuring at least 125 m².


3 to 6,5 kg of seeds.


100 m² rice nursery.

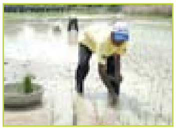
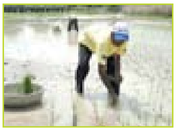
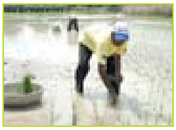

1 ha paddy.

› Nursery establishment calendar

The nursery should be established towards the end of the dry season. It is important to transplant the rice plants as young as possible, when seedlings are 8 to 12 days for short or medium-duration varieties or 15 for the long-duration ones. The general guideline is to transplant seedlings when they have reached two-leaves stage.

Medium and long-duration rice varieties are photoperiodic. If cultivation is delayed, yield will be negatively impacted severely.

Transplanting calendar

Variety	Week 1	Week 2	Week 3	Week 4
Short duration				
Medium duration				
Long duration				

Rice field leveling and drainage

To make water management easier and promote an even distribution of nutrients over the whole surface of the field, it is recommended to level the plot. Leveling is achieved through the use of a rototiller or by animal traction.

Leveling of the field before transplantation.

Selection of the healthiest and most vigorous seedlings

In preparation of transplantation, select tall and healthy seedlings. Avoid those showing symptoms of disease or with stunted growth.

Carefully uproot the seedlings and immediately transplant them in the field in order not to damage them (there should be no more than 30 minutes between uprooting and transplanting).

Selecting young rice seedlings, Muong Laingay, GRET, Cambodia, 2015.

This step is crucial to the success of SRI method. Indeed, ruthless uprooting of the seedlings breaks the roots and impairs tillering capacity. It is hence necessary to uproot seedlings gently, conserving a little bit of soil around the roots, and to transplant them before the emergence of the first tillers in order not to compromise the tillering capacity of the plants. This way, the full potential of the plant is kept intact.

Preparation of seedlings for transplantation

It is advisable to transplant seedlings before they are15 days old to increase the amount of tillers and encourage root development.

Seedlings should be 15 to 20 cm tall and their roots should be 7 to 12 cm long.

Seedlings ready to be transplanted, Touch Sokharith, GRET, Cambodia, 2011.

Transplantation of a single seedling per hill (two at most)

Another of SRI's principle is to give plants enough room to encourage tiller formation. Consequently, a single seedling per hill is sufficient.

Rice transplanted in rows with a single seedling per hill, Touch Sokharith, GRET, Cambodia, 2011.

Careful transplantation of the seedling at shallow depth

Just as when uprooting the seedlings, it is crucial not to damage the young rice plants during transplantation. Plant to a depth of 1-3 cm at most, keeping the roots horizontal.

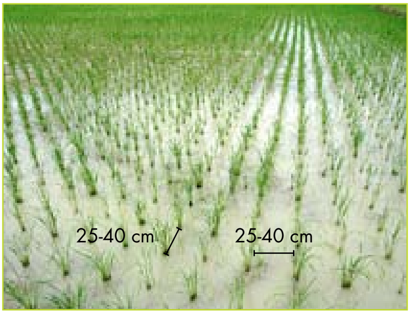
Transplantation following a grid pattern (or at least in rows)

Use a string with knots every 25 or 40 cm (according to the desired spacing between plants). Stretch the string across the rice field and transplant the seedlings following the knots. Then, move the string 25 or 40 cm further, perfectly parallel to the first row.

Monitor proper alignment in both lines and columns to maximize light access and mineral uptake for every plant. Wide spacing following a grid pattern makes passing between rows with the rotary hoe easier.

Transplantation of the seedlings at 25 to 40 cm inter and intra-row spacing

Sufficient space between plants allows each plant to develop fully, produce numerous tillers and bigger panicles.



Transplanting using 40 cm x 40 cm spacing is quicker. It also lowers seed rate. But if soil fertility is anything less than ideal, it is recommended to use a narrower spacing between the plants.

Recommended spacing, Sothea Sok, GRET, Cambodia, 2012.

Introduce water in small amounts, 7 to 20 days after transplantation

Irrigation should aim at keeping the soil humid without flooding it. Water should not be introduced into the field straight after transplantation but rather 7 to 20 days later. Indeed, rice absorbs oxygen through its roots and, consequently, will yield better when it is not flooded and has access to a lot of oxygen.

Fertilizer application

It is possible to apply natural fertilizers (compost for instance) before rice cultivation. This technique may also be combined with the fertilization usually practiced by farmers. It is beneficial to apply 10 to 20 t/ha of compost.

Hoeing

Regular hoeing starting very soon after transplantation (8 to 10 days) is important and should be performed at least 2 to 4 times during cultivation. Hoeing allows the rice not to compete with weeds and thus to benefit fully from sunlight and soil nutrients. In addition, it also aerates the soil, promoting better production.

Cambodian farmer hoeing his rice field, Touch Sokharith, GRET, Cambodia, 2011.

Adapting SRI

The method described earlier is the original and complete SRI method. Nevertheless, SRI can be adapted according to farmers' needs and specific environmental conditions. Indeed, the reality of each particular field doesn't always allow implementation of the original model.

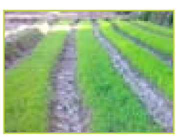
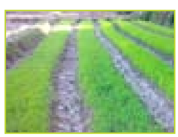
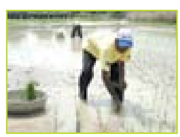
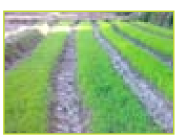
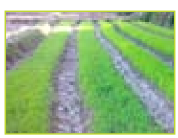
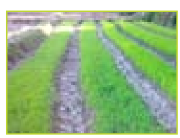
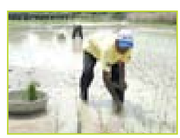
It is possible to use only some of the SRI principles: just by transplanting younger seedlings, providing better aeration to the roots or transplanting the seedlings no more than 30 minutes after uprooting them from the nursery, rice plants will grow and produce better, even when the other principles are not applied.

To adapt the whole method or modify some of its principles only, the following points should be respected:

– transplantation of seedlings **as young as possible** to maximize tiller production;
– minimum plant **density** to maximize access to sunlight and nutrients;
– **weed control** to maximize access to nutrients;
– minimum **water level** to improve root oxygenation.

In practice, this means transplanting seedlings after 20 days in the Irrawaddy Delta in Myanmar or after 15 to 25 days in Cambodia.

The crop calendar is the following:

Variety	Week 1	Week 2	Week 3	Week 4
Short duration				
Medium duration				
Long duration				

We can notice here that the time to transplantation can range from 3 to 4 weeks.

In the same way, regarding seed rate and nursery size, practices can vary according to particular contexts. For instance, in Siem Rep region, Cambodia, farmers use an average of 16 kg of seeds to establish 666 m^2 nurseries providing seedlings for 1 ha of rice field.

16 kg of seeds.

666 m^2 rice nursery.

1 h field.

To learn further

Système de riziculture intensive, Henri de Laulanie, Tefy Saina, Madagascar, 2007, www.tefysaina.org.

Comment faire pour avoir des plants de riz qui croissent mieux et qui produisent plus, Informez-vous et informez les autres, Norman Uphoff, CIIFAD, Tefy Saina, Madagascar, www.tefysaina.org/manuelsri.pdf.

Living mulch

Functions

Erosion control
Soil fertility management
Weed control
Integrated pest management

+

- Limits weed proliferation
- Limits wind and water erosion by covering the soil in between the rows
- Restructures the soil by increasing porosity and facilitating water infiltration
- Provides organic matter to the soil as well as nitrogen in the case of legumes
- Can be used as fodder
- Prevents the establishment of pests and diseases affecting the main crop
- Can produce food for human consumption

−

- May increase labor for the maintenance of the living mulch, in order to prevent it from competing with the main crop
- May require to purchase seeds for the establishment of the living mulch if not available locally
- The fertilizing effect of the living mulch is not immediate
- May require the use of inputs at establishment stage

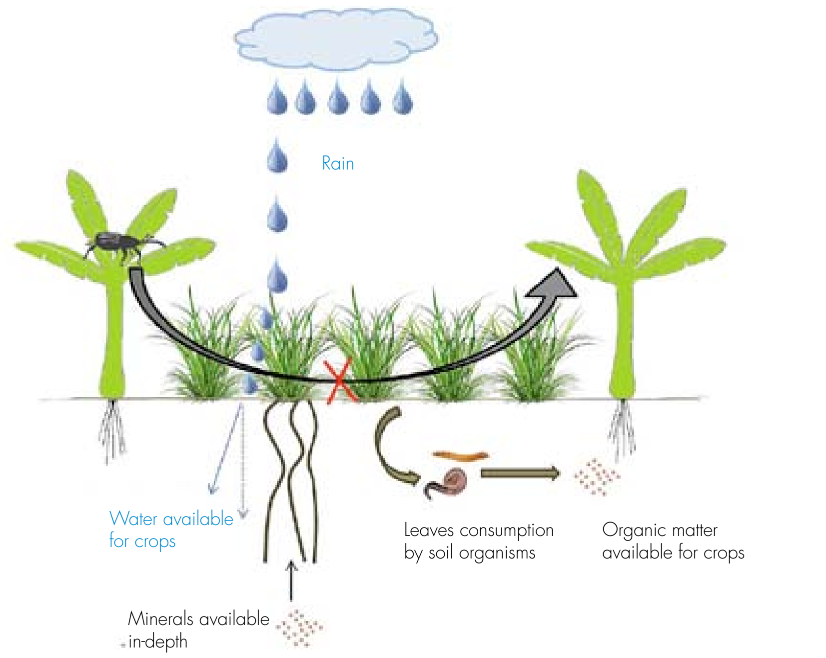
Why using living mulch?

The main aim of living mulch is to protect the soil against wind and water erosion by keeping it permanently covered with a cover crop. As it is the case with intercropping (see factsheet no. 1 on intercropping), it also allows combining different species on the same plot, hence helping to prevent the propagation of diseases to the main crop.

Brachiaria used as living mulch in a banana plantation, GRET, DRC, 2014.

In addition, generally the plants used as living mulch also provide fodder or edible products for human consumption. In the case of legumes, they also enrich the soil by fixing nitrogen that will benefit the main crop.

When their roots are strong and extensive, these plants also loosen and aerate the soil. Finally, the biomass they produce, as well as the remobilization of deep soil minerals they sometimes promote through their root system, enrich the plot and enhance its fertility.



Living mulch belongs to the set of techniques called direct seeding under vegetative cover.

Establishment of *Brachiaria brizantha* as living mulch

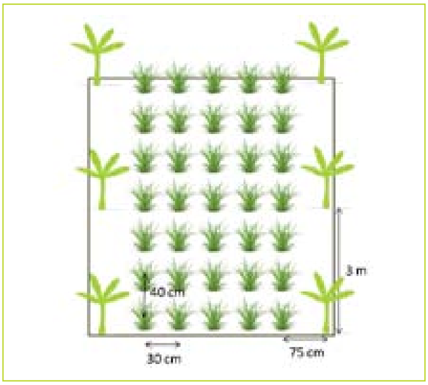
Brachiaria genus comprises numerous species, including *Bracharia brizantha* that is discussed here. All *Bracharias* produce good fodder and plenty of biomass to cover the ground. Generally, they have deep root systems, allowing to remobilize the nutrients at depth and to loosen the soil. In addition, these plants can grow on acidic, compacted and unproductive soils. *Bracharia brizantha* is also drought tolerant and can survive a dry season lasting 5 to 6 months.

Establishment is done by direct seeding, cutting or clump division. Nevertheless, direct seeding leads to much more uneven results compared to the other techniques. For best results, planting should be done at the start of the rainy season but staggered with the main crop to prevent competition.

Combination examples

› **Combination with a pluriannual crop**: the case of *Bracharia* with banana trees

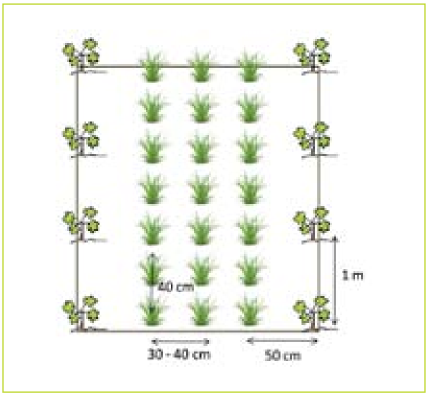
Banana trees are established at 3 m x 3 m spacing. *Bracharia* is then sown at 30 cm inter-row spacing and 40 cm in-row spacing. The first row should be established 75 cm away from the banana trees to prevent competition.



› **Combination with an annual crop**: the case of *Bracharia* with cassava

Cassava is established using 1m x 1m spacing. *Bracharia* is then sown at 30 cm inter-row spacing and 40 cm in-row spacing.

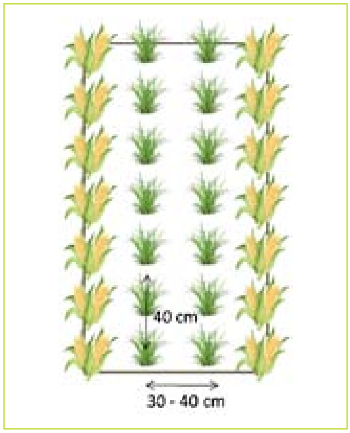
The first row should be established 50 cm away from the cassava plants to prevent competition.



- **Combination with a short duration crop**: The case of *Brachiaria* with maize or okra

  Bracharia is sown at 30 to 40 cm inter-row spacing and 40 cm in-row spacing, 30 to 40 cm away from the main crop.

When transplanting by cutting or root slips, plants can be spaced further away (up to 50 cm) as their growth resume faster. It is equally advised to plant the cuttings or clumps a few weeks after planting the main crops to prevent competition.



Calendar example for *Bracharia* establishment in relay cropping with corn.

Week 1	W2	Week 3	Week 4	Week 5	Week 6	Week. 7	W8	Week 9
Corn seeding		*Bracharia* refill planting		Or *Bracharia* slips/cutting planting		*Bracharia* refill planting		
Okra seeding								*Bracharia* slips/ cutting planting
Rice and *Bracharia* seeding			*Bracharia* refilling or slips/cutting planting		*Bracharia* refill planting			

Numerous other species can be used as living mulch, such as other *Bracharia* species, *Eleusine coracana*, *Pennisetum clandestinum*, *Stylosanthes guianensis*, *Crotalaria spectabilis*, *Crotalaria retusa*, *Vigna unguiculata* (cow pea, also edible), *Arachis hypogaea* (peanuts, also edible), etc.

To learn further

Brachiaria sp. : B. ruziziensis, B. brizantha, B. decumbens, B. humidicola, in Olivier Husson *et al.*, *Manuel pratique du semis direct à Madagascar*, Cirad, GSDM, 2008, 20 p. Fiches techniques plantes de couverture : graminées pérennes. http://agroecologie.cirad.fr.

Brachiaria brizantha, *Agriculture et développement en pays Antandroy : fiches techniques*, Objectif Sud, Madagascar, Gret, GSDM, 2010, 3 p. http://semencesdusud.com.

Mulching

Functions

Erosion control
Weed control
Soil fertility management
Water management

+

- Does not require investment
- Involves low technicality
- Keeps soil moisture (reduces the need for watering)
- Limits weeds
- Slows down surface runoff and allows water infiltration into the soil
- Limits water and wind erosion
- Promotes soil microbiological activity
- Enhances/maintains soil fertility
- Protects soil from high temperatures
- Prevents (slacking) crust formation

−

- Risk of weed infestation if mulch material is not seed free. Make sure to cut mulch material before seeding stage.
- Can provide habitat for certain pests and diseases that benefit from mulch conducive environment
- Risk of contamination if no rotation is applied as parasites from the previous crop can survive in the mulch

Mulching is the practice of covering the soil with **dead plant material** in opposition to living mulches that use soil improving plants left durably in place.

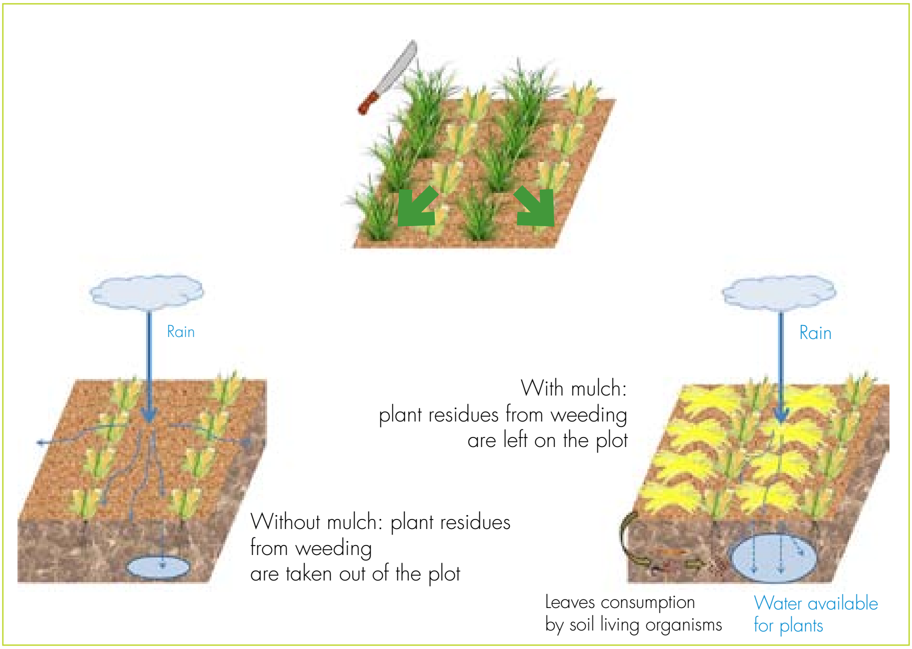
The use of mulch offers numerous benefits:

– prevents erosion by reducing rain-water runoff and improving its infiltration;
– prevents wind erosion by covering the soil and sheltering it from the wind;
– helps storing soil moisture by reducing evaporation;
– protects the soil from intense heat hence promoting root growth and development of microorganisms;
– reduces weed pressure;
– prevents the soil from forming a slacking crust (a layer of hardened soil created by alternating rain and dry spells).

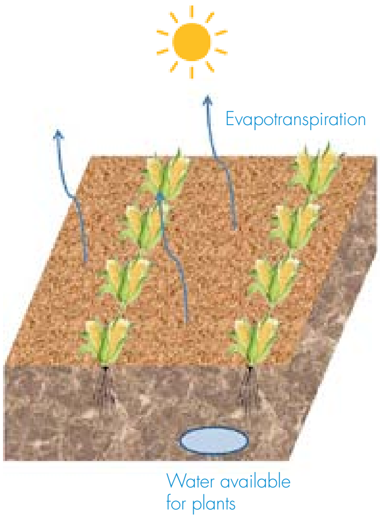
Mulched cassava/*Acacia auriculiformis* plot, Justine Scholle, GRET, DRC, 2014.

A mulch layer a few centimeters thick (4 to 6 t/ha) protects the soil as efficiently as a dense secondary forest with a 30 m high canopy.

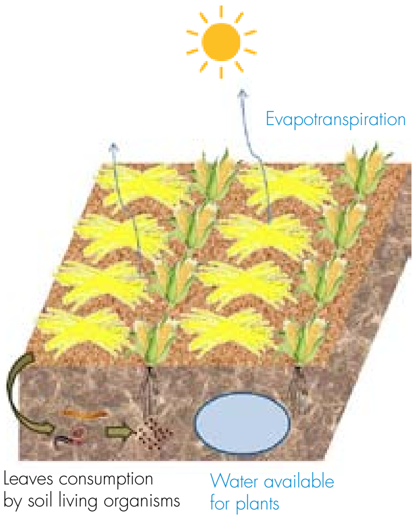
The following diagram shows the effect of mulch on water runoff and infiltration in the soil: the blue dotted arrows indicate water infiltration in the soil and the other arrows indicate surface runoff.



Thanks to the mulch layer, surface runoff is slowed down and rainwater has more time to infiltrate into the soil and replenish aquifers. Limiting surface runoff is also a way to control erosion and, by doing so, to limit loss of fertility. Moreover, mulch protects the soil from sun rays and from their heating effect, reducing evaporation and extending the time water remains available in the soil to be used by crops. Finally, the minerals contained in the mulch material are progressively freed by the action of soil microorganisms degrading the organic matter, benefiting the crops by providing plant nutrients.



Without mulch, under the heat of the sun, the water available in the soil evaporates.



With mulch, the evaporation of soil moisture is reduced.

There are numerous ways of applying mulch:

- when weeding, the weeds are cut and left on the plot as mulch;
- after harvesting, crop residues are left on the empty plot as mulch;
- a soil improving plant is grown and then cut, leaving the residues on the plot as mulch;
- plants from outside the plot are brought in and used to cover the soil.

Maize plot mulched with weeding residues, D. Violas, GRET, DRC, 2015.

Banana plantation mulched with *Brachiaria* and banana tree residues, D. Violas, GRET, DRC, 2015.

Avoid contaminating the plot by bringing in weeds that have already reached the seeding stage.

It is possible to use crop residues such as straw from rice and other grains, weeds like water hyacinth (*Eichhornia crassipes*), *Chromolaena odorata* or *Tithonia diversifolia*, or soil improving plants used in agroforestry systems such as *Calliandra calothyrsus*, *Leucaena leucocephala*, *Tephrosia vogelii* or *Gliricidia sepium*, etc. (see factsheet no. 19 on agroforestry for further details on intercropping using these plants).

Comparison of straw quality from different soil improving plants

Species	Decomposition time (less than 45 days)	Amount of phosphorus provided	Amount of nitrogen provided
Calliandra calothyrsus	+	/	+
Leucaena leucocephala	+	/	+
Tephrosia vogelii	/	+	/
Tithonia diversifolia	+	+	+

Examples of yield increase seen in Malawi and in Zambia

Species	Increase in yield of mulched maize compared to unfertilized maize monoculture
Gliricidia sepium	140%
Leucenea leucocephala	86%
Tithonia diversifolia	216%

When mulch material is scarce, mulch should be concentrated at the base of the plants.

The difference between mulching and living mulch (see factsheet no. 13) lies primarily in the initial objective and the final use of biomass.

Indeed, the biomass produced by living mulches is not necessarily left in the field. The interest of mulching lies in the fact that biomass is left in the field (or imported from outside) to restore fertility and protect the soil.

As mentioned earlier, it is possible to use many types of plants as mulch (including the weeds cut during plot preparation and maintenance). Using mulch involves less complexity, thus requiring less skills and technicality compared to the use of living mulch.

To learn further

Les pratiques antiérosives, in Éric Roose, *Introduction à la gestion conservatoire de l'eau, de la biomasse et de la fertilité des sols (GCES)*, FAO, 1994, Bulletin pédologique de la FAO, n° 70, pp. www.fao.org.

État de la recherche agroforestière au Rwanda, étude bibliographique, période 1987-2003, Léonidas Dusengemungu, Christophe Zaongo, Icraf, Working Paper n° 30, World Agroforestry Centre, 2006, 97 p. www.worldagroforestry.org.

Climate Smart Agriculture, A review of current practice of agroforestry and conservation agriculture in Malawi and Zambia, Arslan A., Kaczan D., Lipper L., Esa Working Paper, FAO, 2013, 62 p. www.fao.org.

Vegetative contour strips

Function Erosion control

+

- Slows down surface runoff, promoting water infiltration into the soil
- Protects the soil from wind and water erosion
- Retains fertility in the plot
- Prevents water lowlands located downslope from getting filled with deposits
- Fertilizes the plot when the strips consist of legumes
- Can also generate useful products (fodder, etc.)

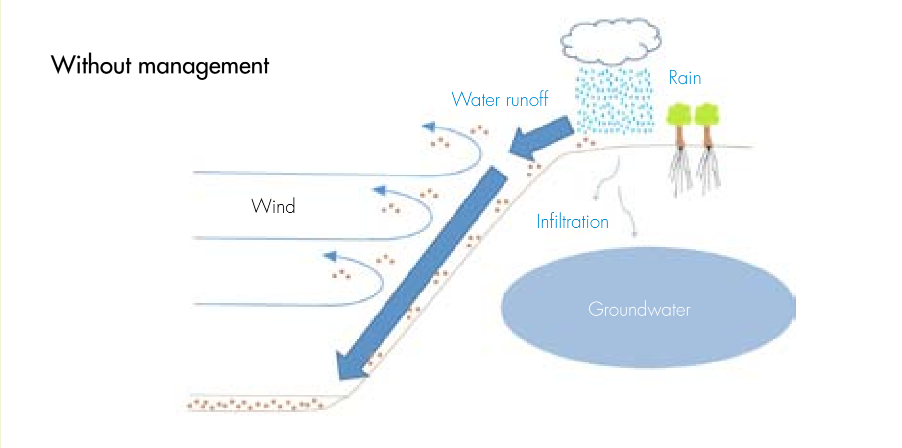
−

- Labor intensive during the establishment phase
- Requires complex skills

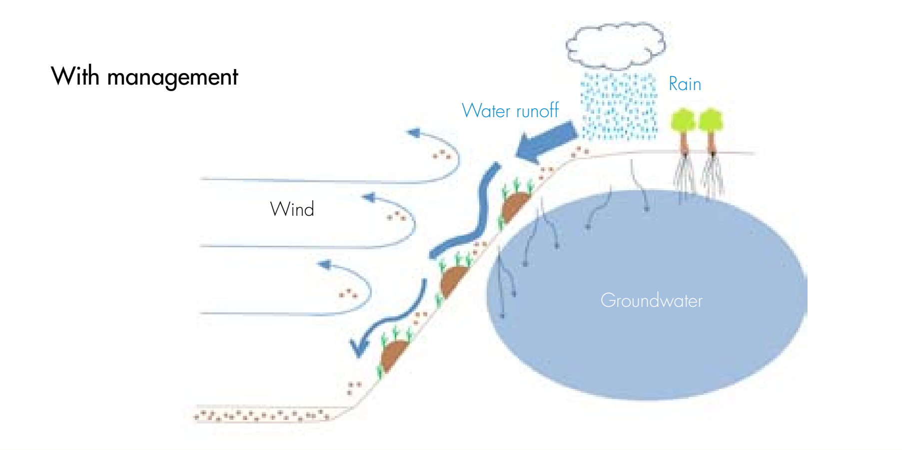
This technique aims at controlling water erosion on sloping land by slowing down surface runoff using vegetative strips planted on contour. The same technique can be implemented using stone barriers or solid gutters but both lack some of the benefits of vegetative strips.

Why managing slopes?

Plants require water and soil minerals for their growth. Yet, when it rains on barren soil the water flows down rapidly, without having the chance to infiltrate, carrying soil fertility (organic matter and minerals) downslope to the lowlands. Hence, aquifers are not replenished and water will not be available to plants at a later stage.



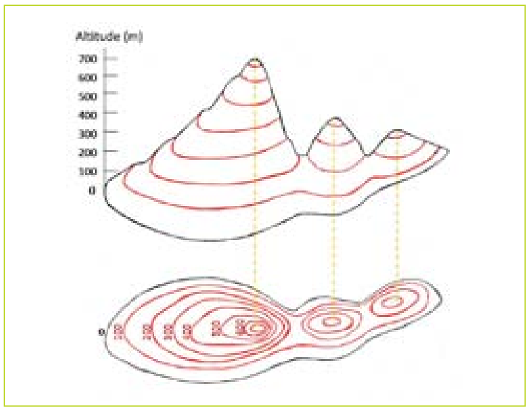
Without management, every cultivated plot is subject to the loss of soil fertility through wind and water erosion. Slopping lands are especially prone to water erosion as a result of the increased speed of water running downslope. Hence, they need to be protected through proper management.



Managing slopes to control water erosion implies implementing means of slowing down water runoff and promoting its infiltration. In order to do so, obstacles are erected across the slope, obstructing surface runoff to give water a chance to seep in the soil and prevent it from carrying away too many soil particles. In order to create such obstacles, vegetative strips can be used; the roots of the plants promote water infiltration, making it available to crops below and their stem trap soil particles, limiting erosion. The ground cover provided by the vegetative strips also protects the soil from wind erosion.

What are contour lines?

A contour line is an imaginary line connecting points of equal elevation. It is perpendicular to the direction of maximum slope. Water flow is perpendicular to contours so to be efficient, all obstacles installed to slow water down have to be established following these contour lines. On the diagram opposite we can see how contour lines run parallel to the horizontal (they are all leveled).



Finding the contour lines on a plot requires using specific tools and methods allowing precisely finding the horizontal level, before marking it with stakes. Crops are then established along these lines.


Rice terraces established on contour, Chin State, Pierre Ferrand, GRET, Myanmar.

This picture illustrates how slope can also be managed using leveled terraces. Nevertheless, establishing terraces is extremely labor intensive and requires complex skills. In scarcely populated areas and where slopes are not too steep, the progressive creation of terraces by means of vegetative contour strips should be favored (passive terracing).

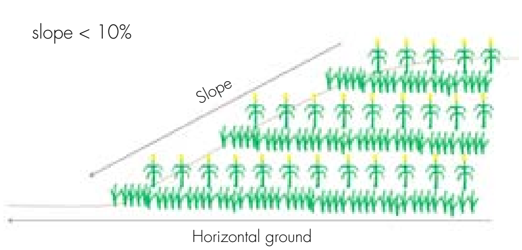
Different slope management methods

Slope management methods vary according to different parameters, including land pressure, slope gradient, manpower, available tools, soil structure, agricultural technical itinerary etc. Nevertheless, some general principles apply to most situations.

All the techniques described in this factsheet are only adapted to slopes not exceeding 25%. On steeper slopes, more significant measures such as terracing are necessary.

When the slope is relatively gentle, vegetative stripes are sufficient to considerably slow surface runoff down. Plants such as vetiver with very dense and deep root systems are especially efficient at performing this task. Vetiver is actually often used on the walls of rice terraces to hold them in place and prevent them from collapsing. It is crucial for the efficiency of the technique to choose plants with a powerful root system.

Vegetative strips for gentle slopes

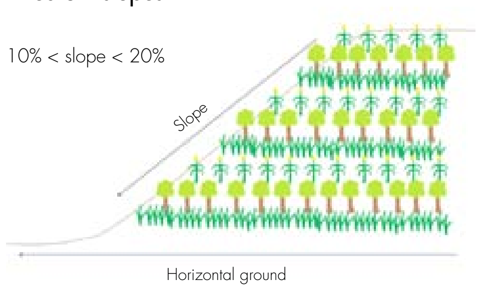


Vegetative strips can reduce surface runoff by 30 to 60% and erosion by 10 to 30%.

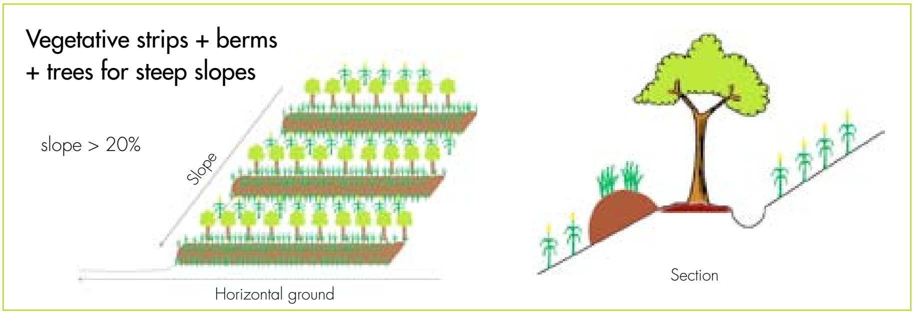
When the slope is slightly steeper, combining trees with herbaceous vegetative strips helps maintain the soil in place and promote water infiltration.

Finally, when the slope is even steeper, it is crucial to establish the vegetative strips on berms. To create the berms, soil is taken along the contour line and piled up downslope of it.

Vegetative strips + trees or semi-perennial plants for medium slopes



When on their own, berms should only be used on gentle slopes. Indeed, if they are not stabilized by the roots of the plants constituting the vegetative strips, they will not remain in place on steep slopes and risk collapsing, causing the formation of erosion gullies. As an indication, berms used on their own reduce erosion by approximately 30% on 1 to 8% slopes.

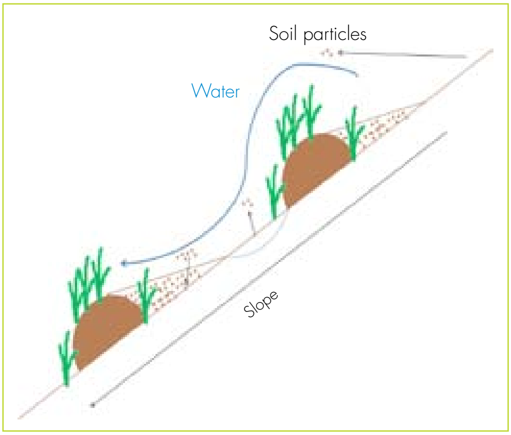


Crops are also established on level, following contour lines, between the vegetative strips.

Digging a ditch up slope from each vegetative strip slows water even more, promoting its infiltration into the soil and protecting the berm. With the same aim, it is also possible to dig a series of trenches downslope from the strips (technique known as contour trenches).

Passive terracing

The obstacles established to slow water down – be it berms, vegetative and tree strips or hardscapes such as stone barriers – allow soil particles carried by surface runoff to deposit at their base. Gradually, the deposit forms relatively flat terraces and the original slope ends up looking somehow like stairs. According to some estimates, deposit thickness increases by 5 to 20 cm yearly.



Method of establishing contour lines

Making an A frame

An A frame is a tool that can be easily built and hardly involves any cost.

Material

- Two 2 m sticks (wood or bamboo).
- One 1.20 m stick.
- Nails, screws or 2 m length of rope to tie the sticks together.
- 1 m length of string.
- One stone.

A frame confection and use training with agroforestry farmers as part of DEFIV project, DRC, GRET, 2014.

Assembling

- Tie the 2 m sticks together by one of their extremities using the nails, screws or rope.
- Attach the 1.20 m stick by its extremities to each of the 2 m sticks at mid height, so it is parallel to the ground. The whole structure should look like an A.
- Make a notch in the middle of the horizontal stick.
- Tie a rope on top of the frame, where both 2 m sticks meet.
- Tie a stone at the extremity of the rope to act as a weight. The stone should be hanging approximately 15 cm below the horizontal stick. The weight should be heavy enough to stretch the string.

Marking the contour lines

Starting from the top of the field, facing the slope, position the A frame upright and mark the position of the A frame's leg located closest from the field boundary with a stake. Use this leg as an axis of pivot.

Position the second leg so as the string with the weight attached falls exactly in front of the notch, in the middle of the horizontal stick, as shown on the diagram below.

The A frame should be slightly inclined up-front in order for the weight to swing freely.

Once the level is found, mark the position of the second leg with a stake.

Turn the A frame 180° using the second leg as a pivot. Position the first leg in order for the string to fall exactly in front of the notch, in the middle of the horizontal sticks. Mark the new position with a stake.

Repeat the procedure all the way to the other boundary. The first contour line is thus marked.

Repeat the process until the whole slope has been covered. The distance between two contour lines depends on the steepness of the slope – the steeper the closer, the gentler the further away I ranging from 3 to 5 m interval.

It is possible to slightly correct the contour lines by moving some of the stakes in order to make them more even (less hilly) and respect approximately the recommended spacing for the crops intended to be established between the vegetative strips.

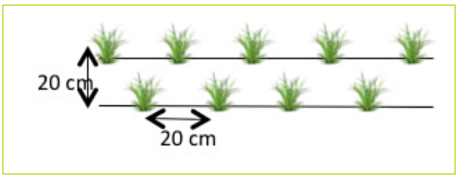
This technique can be implemented on a larger scale using an ox-drawn plow instead of an A-frame, as these animals tend to naturally follow contour lines when moving across slope.

Vetiver vegetative contour strip

Vetiver density depends on the steepness of the slope. For gentle and medium slopes (less than 20%) double rows of vetiver spaced 15 m apart are usually considered sufficient to limit erosion.

For steeper slopes (ranging from 20 to 25%), double rows of vetiver established on berms spaced 9 m apart are required.

– Plant at the beginning of the rainy season, at the same time as cassava or other crops.
– Plant the vetiver in staggered rows at 20 cm in-row and inter-row spacing, as illustrated below.



Vegetative contour strip with young vetiver plants in a cassava field, GRET, DRC, 2015.

– The berm should be 30 to 50 cm tall and is created by taking soil along the contour line and piling it up just below.
A small ditch must be created in front of the berm to help infiltrating and storing water in the soil during the establishment phase, when vetiver is not yet developed enough to fulfill this function.

Legumes with a deep tap root promoting water infiltration at depth as well as graminaceae naturally occurring on fallow lands are excellent plants to use for establishing vegetative contours strips.

To learn further

Érosion hydrique [cours en ligne], in Hafida Zaher, *Conservation des sols et de l'eau*, Agence universitaire de la francophonie, Campus numérique francophone de Rabat, 2010. www.ma.auf.org/erosion.

Les structures de dissipation de l'énergie du ruissellement, in Éric Roose, *Introduction à la gestion conservatoire de l'eau, de la biomasse et de la fertilité des sols (GCES)*, FAO, 1994, Bulletin pédologique de la FAO, n° 70. www.fao.org.

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Seedling production and high yielding cultivation on tables

Functions

Early seedling production
Yield increase and improvement of vegetable production
Integrated pest management

+

- Use of germ free substrate limiting seedling contamination by pathogens
- Good quality substrate (fertile and aerated texture) promoting vigorous seedlings
- Raised tables prevent young seedlings from being attacked by soil dwelling insects and microorganisms
- Protection from rain and water logging
- Allows for early seeding, thus early harvest and economical benefit
- Provides controlled environment for seedling production without using chemical inputs
- The high quantity of seedlings produced allows for replacement of dead or defective plants after transplantation
- Uses low cost local material
- Reduces watering

−

- Table confection is time and labor intensive
- Difficult to apply on large scale
- Can involve a significant increase in production cost if the farmers hire external labor

Propagation table of a Mayanda farmer, supported as part of DEFIV project, J. Scholle, GRET, DRC, 2014.

Propagation tables of a farmer from Chrey Khang Tbong village supported as part of APICI project, Sothea Sock, GRET, Cambodia, 2014.

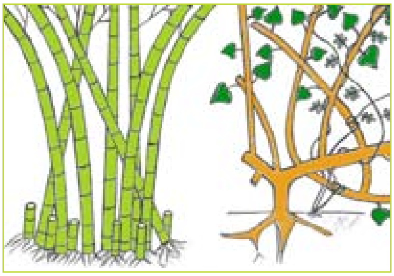
Some vegetables need to be raised in nursery before being transplanted in the field. These are often small seed vegetables such as tomatoes, lettuce, cabbage, eggplants or onions. Propagation tables or benches allow careful monitoring before transplantation. The pathogen free, high quality substrate, ensure healthy plant development.

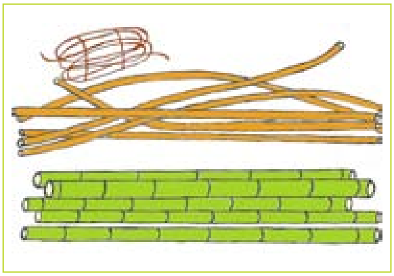
Nursery location

Site selection	Justification
Next to a water source	Makes watering easier
Next to the house	Allows easier monitoring and maintenance of the nursery
Protected from animals	Prevents loss caused by stray animals
Away from the field	Prevents attacks by insects and pathogens from the previous crops

Preparing building material

Material required:

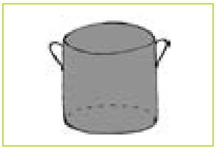




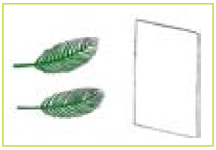
Bamboos, flexible wooden sticks and vines.

A watering can.

A machete or any sharp tool.



A cooking pot.



Small branches or a transparent plastic tarp.

Nursery substrate preparationt

The substrate can be prepared using different methods as long as the final product is rich and has a good structure, in order to promote good germination and vigorous growth. Two substrate recipes are detailed further down.

1/3 sand.

+ 1/3 of good soil.

+ 1/3 well rotted manure or compost.

or

1/4 bokashi or carbonized rice husk (see below).

+ 1/2 of good soil.

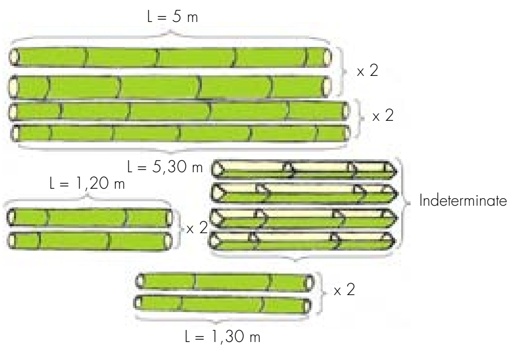
+ 1/4 well rotted manure or compost.

Good soil can be found under trees or in the forest and is mostly black.

To produce CRH (carbonized rice husk or bokashi), burn rice husk for five minutes, then pour enough water to infiltrate the first 2 cm and keep overnight. Rinse two to three times with water to reduce salt concentration.

Assembling the table

Bamboos have to be cut at the following lengths:

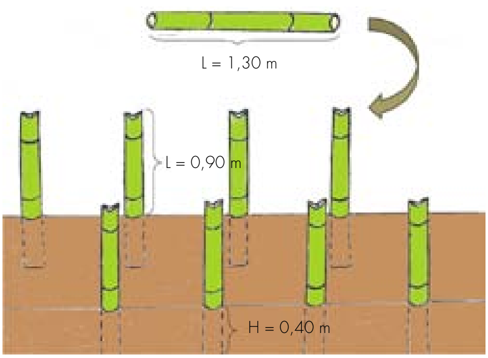


– two 5.50 m sections
– two 5 m sections
– eight 1.30 m sections
– two 1.20 m sections
– a few 1.20 m sections split in 2

Dig eight 40 cm deep holes, spaced 1.70 m apart, forming two parallel lines of 4 holes each.

The lines should be spaced 1.10 to 1.20 m apart.

Plant one 1.30 m bamboo section in each hole to act as the table feet, leaving 90 cm above the ground.



Aménagement de la table

To support the table top, lay the 5.50 m bamboo sections across the table feet, lengthwise.

Form the table top with the 1.20 split sections and tie them with vines

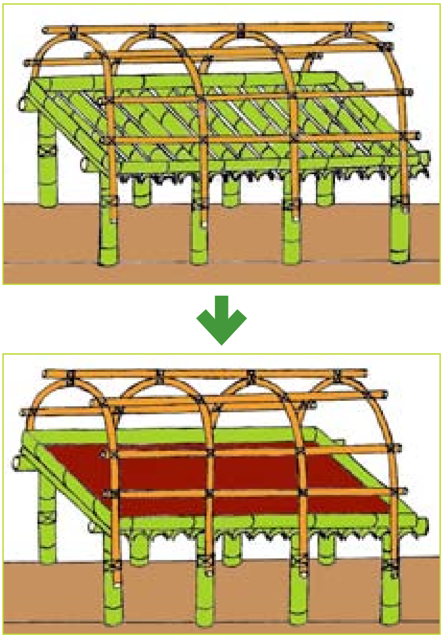
On each end of the table, position:

– one 1.20 section breadth wise

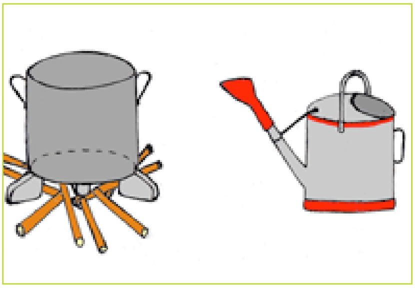
– one 5 m section length wise.

Assemble the shading structure by tying the flexible sticks together with the vines, as shown on the opposite diagram.

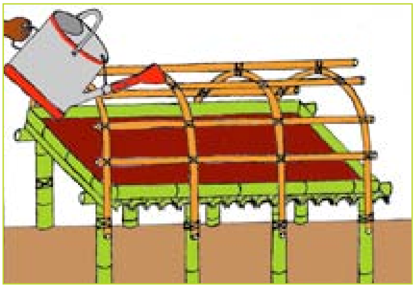
Fill the table up with the nursery substrate until it forms a 5 to 10 cm thick layer.



Preparing and sterilizing the mix

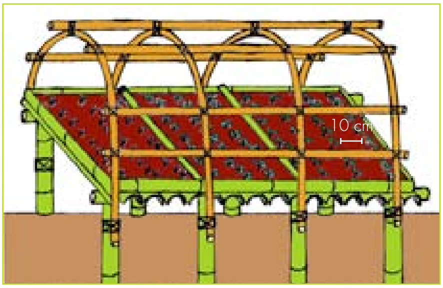


Bring a pot of water to a boil.



Poor the boiling water on the substrate to sterilize it.

Seeding and shading



Wait 48 hours then sow the seeds in the soil mix, in rows across the width.

Seeding depth: Generally speaking, the depth of the seeding furrows should be three time the size of the seed.

Inter-row spacing: Furrows should be spaced 10 cm apart and 2 g of seeds should be sown per row (approximately one beer cap full of seeds).

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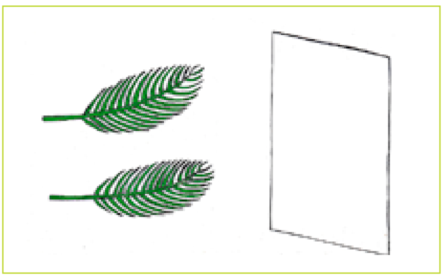
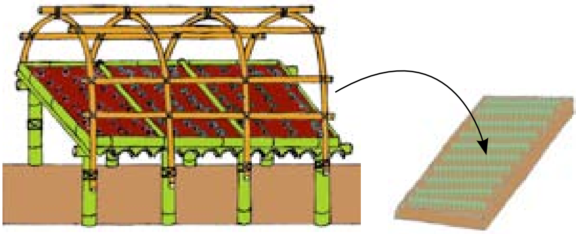


Cover the shading structure with the plastic tarp or branches to protect the seeds from sun, wind and rain.

Mulch can also be applied to limit weed development and keep the substrate moist.

Mulch, Sothea Sok, GRET, Cambodia, 2015.

Transplanting



Only healthy seedlings should be transplanted in the field.

 40 days after seeding. 100 grams = 20 beds.

 20 to 30 days after seeding (2 to 4 leaves stage).

 15 to 21 days after seeding (2 to 4 leaves stage).

 15 to 20 days after seeding (2 to 4 leaves stage).

 5 to 7 days after seeding (2 to 4 leaves stage).

 10 to 15 days after seeding (2 to 4 leaves stage). Apply to all the species from the brassicacea family.

Producing vegetables on tables

In addition to seedling production, it is also possible to accomplish the whole cultivation cycle on tables. Nevertheless, only certain vegetables such as lettuce, cabbage, Chinese cabbage, mustard or onions are suited to this kind of cultivation.

The location, construction and preparation of the substrate are almost identical as for propagation tables, only the table has to be reinforced so as to be able to support the weight of a thicker layer of substrate and full grown vegetables.

Vegetable seedlings are first raised on a propagation table and then transplanted to a subsequent growing table to complete their production.

Cauliflower, onions and lettuce produced on table, APICI project, Stéphane Fayon et Sothea Sok, GRET, 2015.

Crop	Number of days on propagation table	Inter-row spacing and in-row spacing for table production (cm)	Days to harvest
Lettuce	5 to 7	10	25 to 30
Cabbage, mustard	10 to 15	15 to 20	28 to 30

Tree nursery

Function Production of healthy and vigorous saplings

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- Produces healthy and vigorous saplings
- Reduces refilling work compared to direct seeding
- Allows faster plant growth and saving of time thanks to 3 to 6 months of watering prior to rainy season
- Allows the sale of saplings
- Saplings in polybags can be carried to the field without damaging their roots

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- Labor intensive
- Requires good skills and knowledge of the germination cycle of the different species grown
- Requires specialized material

Acacia seedlings J. Scholle, GRET, DRC, 2014.

Dwarf palm tree seedlings, J. Scholle, GRET, DRC, 2014.

Moringa oleifera (foreground) and *Senna spectabilis* seedlings (second plan), J. Scholle, GRET, DRC, 2014.

Due to low or too heterogeneous germination rate, certain trees require being raised in a nursery before being transplanted to the field. The time spent in the nursery allows monitoring the seedlings to be transplanted thus insuring their quality. In the nursery, seedling growth is encouraged by using a healthy and high quality potting mix and by regular watering prior to rainy season (providing 3 to 6 months extra moisture to seedlings). In case of pest or disease attack, it is also easier to monitor the plants in the nursery rather than in the field due to proximity and concentration.

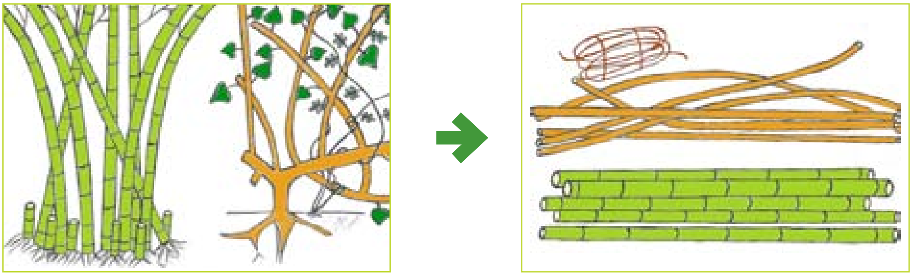
Nursery location

Site selection	Justification
Next to a water source	Makes watering easier
Close to the house	Allows easier monitoring and maintenance of the nursery
Protected from animals	Prevent loss caused by stray animals
Away from planting locations and from citruses	Prevent attacks by insects and parasites from the previous crop
Away from tall trees	Maximize sun light
Not too far from planting or selling location	Makes carrying the seedlings to the field or to potential clients easier

Preparing building material

Assembling the compartments and the shading structure can be expensive if not using local materials. Nevertheless, in most cases all the needed resources are available in the surroundings.

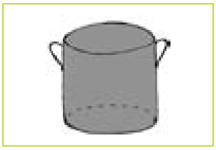
Material required:

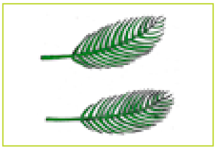


Bamboos, flexible wooden sticks and vines or string.


A watering can.


A machete or any sharp tool.


A cooking pot.


Some small branches.

Soak the bamboos in water for three weeks to remove sugars and limit insect attack later on. Apply a weight so they don't float to the surface. The quantity of bamboo needed will depend on the size of the nursery. To estimate the total length required and to know how much bamboo to cut, refer to the part on compartment construction further down.


Soaking bamboos, J. Scholle, GRET, DRC, 2014.

Land preparation

Start by marking the perimeter of the nursery using stakes or string. The size depends on the desired production capacity; hence, this should be ascertained beforehand. The total space required will depend on the species grown as it determines the size of the planting bags required (see part on compartment construction).


Leveling the location after marking the nursery's perimeter, J. Scholle, GRET, DRC, 2014.

Choose a flat location with a very slight inclination so water doesn't collect during rainy season. Leveling the space might be required if no existing spot meets the desired criteria.

The location should then be weeded, stumps should be uprooted and discarded and a 5 to 10 centimeter layer of soil removed to get rid of weed seeds. Pile up vegetal debris further away to use as compost material later on (see factsheet no. 8).

Weeding, stumps removal and turning of the soil before removal for the preparation of an associative nursery, J. Scholle, GRET, DRC, 2014.

The immediate surroundings of the nursery should be cleaned the same way on a 5 m strip to prevent invasion from nearby insects.

Assembling the compartments and the shading structure

The length and width of the compartments depends on the number of plants produced and the size of the polybags used.

Example: consider a nursery aiming at producing 12,500 seedlings of a species requiring planting bags approximately 7 cm in diameter (*Acacia auriculiformis* or *Senna spectabilis*) and 560 seedlings requiring planting bags approximately 20 cm in diameter (avocado, mango, safou, mangousteen, etc.).

For the 7 cm diameter planting bags, the recommended height of the bags is approximately 20 cm whereas, for the 20 cm diameter bags, it is approximately 25 cm to prevent them from tearing up during transportation and to provide the optimal amount of soil for the plant specific species grown inside.

There are different kinds of planting bags available with different size. The width of "square" potting bags is usually greater than the diameter of the circular ones. It is important to measure the diameter of the bags used before making the compartments, so as to optimize the use of space.

When producing seedlings, it is important to sort them out well. In our example, the small bags should be grouped in compartments containing 1,000 seedlings and the larger one in compartments containing 250 seedlings.

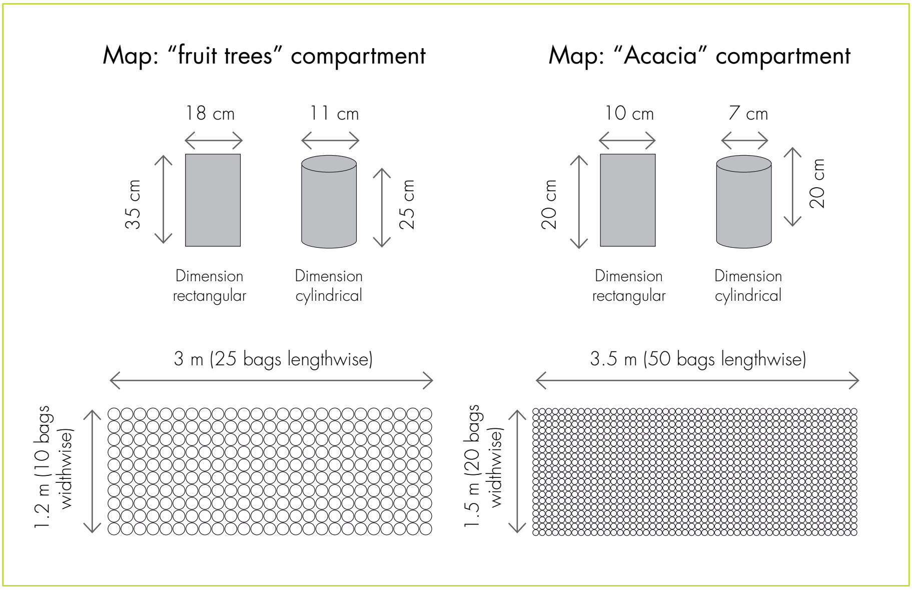


Diagram of possible polybags arrangement as part of DEFIV project, P. Proces, Nature+, 2014.

When calculating the size of the compartments, extra rooms should always be planned to prevent polybags from getting pressed, making their handling and displacing easier during later operations.

It is necessary to leave paths 1 m wide between the compartments, in order to move around easily during watering and maintenance operations.

In the example used here, the nursery measures 25 m x 25 m, including the different compartments, the paths and the 5 m protection strip surrounding it (see diagram on following page). This represents a substantial size nursery and would imply too much setting up and maintenance work for a single person. Sizing of the nursery has to be done not only according to needs, but also according to available labor and land. Also, the 5 m protection strip around the perimeter of the nursery as well as the 5 to 10 cm soil layer to be removed can be modified and adjusted to available resources.

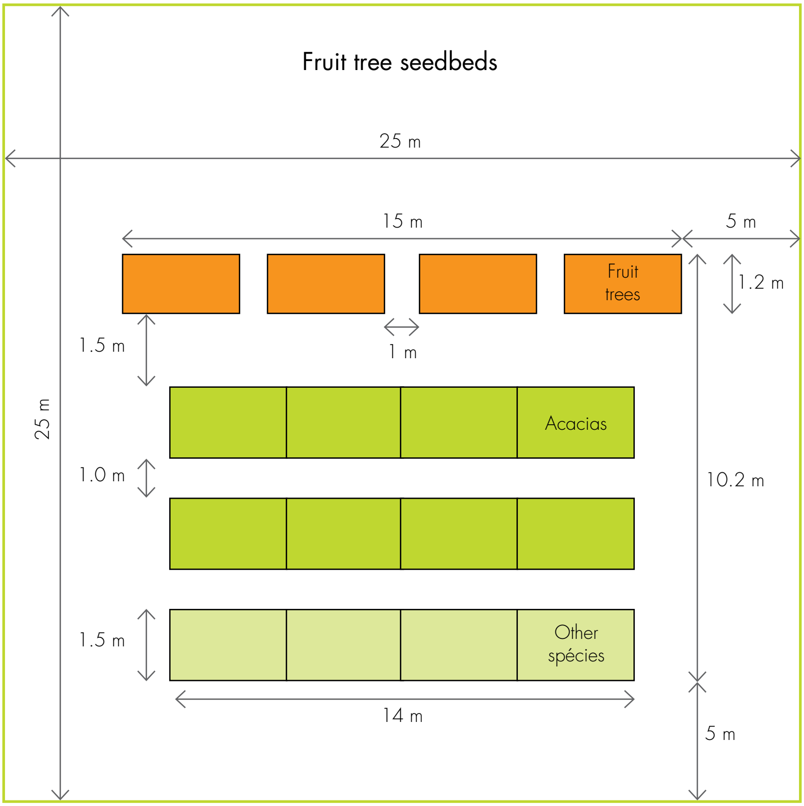


Diagram of possible compartments layout on a nursery site as part of DEFIV project, P. Proces, Nature+, 2014.

Acacia auriculiformis seedbed, Defiv, J. Scholle, GRET, DRC, 2014.

A space can also be planned to create a seedbed in order to germinate the seeds before transplanting them in a planting bag. In such cases, seeding is always done in rows with sufficient in-row and inter-row spacing to avoid overcrowding of the seedlings. The seedlings should then be transplanted at optimal size (see section on maintenance and transplantation).

Once the size of the compartments has been defined, mark their perimeter to ensure a proper rectangular shape and then cut the soaked bamboos at the required dimensions.

Marking of the compartments and cutting of 14 m and 1.5 m long bamboos sections for the installation of 4 adjacent 1000 acacia compartment, J. Scholle, GRET, DRC, 2014.

Position the bamboo sticks on the ground, following the marked compartment boundaries and maintain them in place using wooden stakes.

Bamboos installation and fixing with stakes, J. Scholle, GRET, DRC, 2014.

The assembling of the shading structures is done after the compartments have been installed. Bamboos can also be used for this purpose. Cover the structure with small branches to protect sensitive seedlings from intense sunlight. Shading structures are not necessary for sun loving species such as acacias and sennas but they are important for trees like mango, avocado, safou, orange, mandarin and other fruit trees. Moringa seedlings can also benefit from shade, but care has to be taken not to over water them (when possible, propagation by direct seeding or cuttings is recommended for this species).

Assembling shading structures for fruit trees compartments, J. Scholle, GRET, RDC, 2014.

Shading structures should be tall enough to easily stand underneath and make watering easy. They should be properly anchored in the ground (50 cm deep).

Potting mix preparation

The substrate can be prepared using different methods as long as the final product is rich and has a good structure, in order to promote good germination and vigorous growth. An example of substrate is detailed below.

Mix:

1/3 of sand.

+ 1/3 of good soil

+ 1/3 well rotted manure or compost

Good soil as shown above can be found under trees or in the forest and is generally black in color.

Sieve the different components to discard debris that could hinder root growth and mix them homogenously.

Sieving and mixing of the substrate, J. Scholle, GRET, DRC, 2014.

The substrate can be treated with boiling water if the quantity is not too important, in order to sterilize it.

Potting

Potting is done using polyethylene bags (when available), salvaged water sachets or any other container. They can also be made with banana trunks or leaves. It is crucial to pack the soil to prevent air pockets and ensure proper rooting.

The advantage of polybags is that they are perforated and allow water to runoff, preventing molding due to water logging. The bags should be filled halfway and then packed by dropping them on the ground from a 10 cm height or so. The bottom corners are then pushed in with the fingers; as soil tends not to accumulate in the corners it prevents the formation of hollow pockets that could result in roots aggregating in those spaces.

Bagging for *Acacias auriculiformis* seeding, J. Scholle, GRET, DRC, 2014.

Finally, complete filling up the bag all the way to the top then pack until the bag is hard. Fill up the newly created gap with a little bit of substrate without packing it further.

Classement des sachets dans les bacs avant le semis,
J. Scholle, GRET, RDC, 2014.

The bags should be able to stand on their own if they are packed correctly.

The planting bags should be placed in the compartments prior to seeding to avoid seed displacement when shifting.

Seeding

The seeding calendar for each species depends on the time they need to remain in the nursery before transplantation. Careful planning should be implemented in order for the seedlings to be ready for transplantation at the beginning of the rainy season.

Species	Common name	Time in the nursery
Acacia auriculiformis	Acacia	3 to 4 months
Acacia mangium	Acacia	3 to 4 months
Senna spectabilis	Cassia	3 to 4 months
Moringa oleifera	Moringa	3 months
Mangifera indica	Mango	5 to 6 months
Persea americana	Avocado	5 to 6 months
Citrus sinensis	Orange	5 to 6 months
Citrus limon	Lemon	5 to 6 months
Dacryodes edulis	Safou	5 to 6 months
Garcinia mangostana	Mangousteen	8 months

Seeds are either directly sown in planting bags or started in seedbeds first. While the latter allows not having empty bags and concentrating the care on the germinated seeds only, it also involves stressing the seedlings during transplantation to the planting bags.

Sowing in planting bags requires a lot of work and is recommended only for species having a good germination rate while seedbeds will be preferred for other species.

Certain species require breaking their dormancy to germinate.

Species	Storage time at room temperature	Breaking of dormancy	Time to germination
Acacia auriculiformis	12 months	Soak overnight in hot water (take the water of the fire before soaking)	3 weeks to 1 month
Acacia mangium	12 months	Soak overnight in hot water (take the water of the fire before soaking)	3 weeks to 1 month
Senna spectabilis	2 years	Scar the seeds	3 to 8 days
Moringa	12 months	Remove seed envelop, can be soaked in cold water overnight but not compulsory	5 to 12 days
Mango	3 à 4 weeks	None	2 to 3 weeks
Avocado	2 à 3 weeks	None	3 weeks
Orange	6 months	None	3 weeks
Lemon	6 months	None	3 weeks
Safou	2 to 3 weeks	None	1 month
Mangousteen	1 to 2 weeks	None	20 to 30 days

Water the planting bags or seedbeds before seeding. Moisture can be controlled by inserting 2/3 of the forefinger in the potting mix. If this layer is moist, seeding can be done.

Generally speaking, seeds should be sown at a depth equal to their height and the embryo should be buried. The following table details the proper sowing technique for the different species.

Species	Seeding technique
Acacia auriculiformis	Sow in seedbed or directly in bag (3 seeds/bag) at 1 cm depth
Acacia mangium	Sow in seedbed or directly in bag (3 seeds/bag) at 1 cm depth
Senna spectabilis	Sow 2 seeds/bag at 1 cm depth
Moringa	Sow 2 seeds/bag at 1 cm depth
Mango	Carefully take the seed out of its shell and bury 2/3 of its length, the biggest end facing down
Avocado	Remove the pulp from the seed and sow directly in a bag, covered to the 2/3, the tip of the seed facing up
Orange	Sow in seedbed
Lemon	Sow in seedbed
Safou	Sow seeds horizontally in bags, slightly covered with soil

In the case of seedbeds, seeds are placed in parallel furrows made using a stick.

Acacia seeded in bags (left) in holes made using fingertip. Acacia sown in a seedbed (right) in furrows made by moving a stick slightly inserted into the ground across the bed, J. Scholle, GRET, DRC, 2014.

Once the seeds have been sown, the planting bags or seedbeds should be watered again. Each compartment should be properly labeled with a sign indicating the species and all important information for the monitoring of the nursery (number of bags, date of sowing, etc).

Nursery with labeled compartments indicating planted species, the number of planting bags and the sowing date, J. Scholle, GRET, DRC, 2014.

Care and transplantation

Nursery care involves watering twice a day during dry season – once before 9 am and once after 4 pm – when temperatures are not too high and sun rays not too strong. Also, planting bags as well as the area surrounding the compartments should be kept free of weed to avoid competition for light and soil nutrients and prevent insect and pathogen infestation.

Weeding of *Acacia auriculiformis* bags, J. Scholle, GRET, DRC, 2014.

When the roots of the seedlings start growing out of the bags, they should be carefully pruned using a sharp tool cleaned beforehand. The roots are monitored during the shifting operations required for homogenous seedling growth; the fastest growing ones are placed in the center of the compartment, or even under some shade, while the others are placed on its perimeter to benefit from improved light exposure.

When several seedlings have sprouted in the same bag, the supernumerary ones are transplanted in the empty bags, keeping some soil around their roots not to damage them. When using seedbeds, the seedlings should be transplanted in planting bags approximately one month after germination.

Transplanting citrus from the seedbed into planting bags, J. Scholle, GRET, DRC, 2014.

Once ready, the seedlings can be transplanted in the field as explained in the agroforestry factsheet (sheet no. 19).

Seed production and saving

Functions	Production and conservation of local seeds that can be reproduced the following years

+

- Provides quality seeds to be used the next growing season
- Provides quality seeds without adjunction of chemical inputs
- Allows better adaptation to local growing environment by using local seeds (better disease resistance) and continuous selection
- Saves on production costs by avoiding purchasing seeds every year
- Allows for control and suitability of the selection process

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- Storing seeds for more than a year can be difficult
- Requires proper material and involves extra work to produce the seeds
- Seed production lengthens the time crops stay in the field (requires appropriate maturity index)

Aim of seed production and saving

The aims of producing and saving seeds are the following:

- to produce quality seeds, adapted to growing conditions and environment;
- to have seeds available every growing season, without having to purchase them;
- to value local products and foster farmers' autonomy.

Tomato seed extraction as part of APICI project, GRET, Cambodia, 2013

The practice of seed production and saving contrasts with the use of hybrid seeds which cannot be re-seeded and force farmers into purchasing new seeds every year, thus making them dependant on seed suppliers and weighing on their household budget.

Cucurbitaceae seed production

General information on cucurbitaceae flowers

Cucurbitaceae have unisexual flowers with both male and female flowers on the same plant, thus involving cross pollination between male and female flowers either from the same or different plants. Pollination is made by means of insects.

Cucumber male flower.

Cucumber female flower.

Pumpkin male flower.

Pumpkin female flower.

Insects visit flowers looking for nectar, carrying pollen in the process, thus pollinating female flowers.

Examples of vegetables from the Cucurbitaceae family

Common name	Scientific name
Cucumber	*Cucumis sativus*
Pumpkin	*Cucurbita moschatavar*
Sponge gourd	*Luffa cylindrica*
Ridge gourd	*Luffa acutangula*
Bottle gourd, calabash	*Lagenaria siceraria*
Bitter gourd	*Momordica charantia*
Ash gourd	*Benincasa hispida*
Water melon	*Citrullus lanatus*


Luffa cylondrica.


Lagenaria siceraria.


Luffa acutangula.

Ensuring seed purity

Different cucurbitaceae species can grow side to side without cross pollinating each other as different species cannot cross. On the other hand, to ensure seed purity of seeds from different cultivars belonging to a single species, it is crucial to use one of the following isolation techniques.

– Distance isolation: the different cultivars are grown 1 km (at least) apart.

– Time isolation: different cultivars are grown in sequence, observing a 50 days interval between plantings to ensure staggered flowering.

Nevertheless, it is also possible to grow different cultivars together, in both space and time, while ensuring seed purity (especially for species with big flowers such as pumpkins) by using hand pollination techniques as described further down.

Hand pollination: at dusk, select a male flower ready to open the next day and close it with adhesive tape for the night.

Cut the male flower and remove the sepals to expose the part containing the pollen (anther).

Gently open the female flower, then touch and rub the male flower's anther on the female flower's pistil in order to transfer the pollen.

Female flowers can be identified by the ovary at their base (looking like a small ball, as seen on the picture below).

Use 3 male flowers for 1 female flower to ensure genetic diversity.

Once pollination is accomplished, the female flower has to be closed and sealed with adhesive tape (to prevent further pollination by unwanted cultivars, hence ensuring seed purity) and mark with a red ribbon to identify the fruit for later seed collection.

Fruit selection

Harvest the fruit when fully ripe, that is when the stalk starts drying up.

Cucumber, pumpkin and ash gourd selected for seed production.

Seed extraction

For pumpkin, it is recommended to wait for 2 to 3 weeks after harvest before opening the fruits to extract the seeds. Cut the fruits open in two. In the case of cucumber, ferment the seeds with their pulp in water for 3 days before rinsing with running water.

Seed extraction by hand.

Seeds are manually extracted and cleaned with water to remove the pulp.

Sundry the seeds for 2 hours before placing them to dry in the shade for 10 to 15 days, in a dry and well ventilated place.

Seed drier, Annadana, India, Stéphane Fayon.

Seed storage

Keep seeds in bottles or pots in a dry and shaded place. Storage time before seeds lose their germination capacity varies according to species.

Cucumber seeds can store for 10 years, pumpkin ones for 6 years.

Solanaceae seed production

General information on Solanaceae flowers

Plants from the solanacea family have perfect flowers, which means they have both male and female organs. For this reason, they can either self-pollinate or be pollinated by neighboring plants through insects hopping from flower to flower, carrying pollen in their search for nectar. In fact, for plants belonging to this family, the extent of cross pollination depends mainly on insect activity but also varies according to different species. Cross pollination by means of insects is particularly high for tomatoes as it can reach up to 45%.

Tomato flowers.

Chili flower.

Eggplant flower.

Ensuring seed purity

Different species can grow side by side without crossing. Nevertheless, to ensure purity of different cultivars within a single species, one of the following isolation methods should be applied.

- Physical isolation: plants from different cultivars are isolated under mosquito nets, cages or tunnels. It is also possible to isolate flower clusters rather than whole plants.
- Distance isolation: each cultivar is planted 200 m apart (at least).
- Time isolation: different cultivars are planted at 60 days interval.

Seed production site and pepper under mosquito net, Annadana, India, Stéphane Fayon.

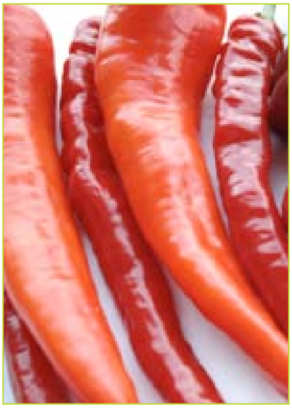
Fruit selection

Tomatoes should be left to fully ripen on plants before harvesting.

Chilies should also be harvested when fully ripe. Generally, chilies are red in color at this stage, but some cultivars are yellow, orange or purple when fully mature.

Like tomatoes and chilies, eggplants should be harvested when fully mature, that is when their skin turns yellow-brown, or their seeds won't be viable.

Tomatoes.



Chilies.

Eggplants.

Seed extraction

Chilies: seeds are manually removed from fully ripe fruits, then placed on a fine mesh in a shaded place and left to dry for 15 days at room temperature. Seeds can be stored for 4 years.

Chili seeds extraction, Annadana, India, Stéphane Fayon.

Tomatoes: cut the fruits in two, press each half tomato in a container to extract the seeds and the juice. Add some water and leave to ferment for 2 to 4 days until molds start forming at the surface. Rinse the seeds with running water and remove debris and damaged seeds to keep only the best specimens. Sundry the seeds for 2 hours then leave them to dry in the shade, at room temperature, for 15 days. Seeds can be stored for 4 to 8 years.

Tomato seed extraction.

Eggplants: eggplant seeds can be removed either by using dry or wet method.

- Dry method: leave fruits to dry on plant before harvesting them, then leave them to sundry for a day before extracting the seeds.
- Wet method: harvest fruits when over ripe for consumption, cut in slices and dislodge the seeds with a bit of water. Place the seeds in a sieve with a fine mesh and rinse with running water. Finally, place the seeds on a cloth or a fine net and leave to dry for 6 to 8 days at room temperature.

Eggplant seeds can be stored for 6 years.

Wet extraction of eggplant seeds, Annadana, India, Stéphane Fayon.

Fabaceae seed production

General information on Fabaceae flowers

Fabaceae species have perfect flowers that have both male and female organs and do not cross pollinate much, as self pollination occurs before the flowers even open.

Ensuring seed purity

Generally, Fabaceae from different species can be grown side by side without crossing. Nevertheless, to keep the purity of different cultivars within a same species, one of the following isolation techniques should be applied.

- distance isolation: plant the different cultivars a few meters apart or separate them using fragrant plant species to distract pollinating insects;
- physical isolation: cover a whole plant or a few flowers with a mosquito net to avoid insect pollination;
- time isolation: plant the different cultivars at 30 days interval to ensure staggered flowering.

Fruit selection

Pods are harvested when fully ripe. In the case of yard long beans, pods are harvested when turning yellow. They are then manually opened or threshed. The seeds inside are already more or less dry and clean.

Selecting yard long bean fruit.

Seed extraction

To make sure seeds are properly dry, bite one seed; if no marks are left on the seed, it means it is dry.

Bean seeds can store for 3 years.

To learn further

Fayon S., *Vegetable Seed Production, Annadana Soil and Seed Savers*, 2012, http://annadana-india.org.

Agroforestry

Functions

Erosion control
Soil fertility management
Natural resource management
Wind protection
Income diversification

+

- Enhances soil fertility
- Promotes water infiltration into the soil
- Improves soil structure
- Limits wind and water erosion
- Improves soil moisture retention
- Produces timber and/or firewood
- Generates numerous products such as fodder, medicinal plants, honey and other non-timber forest products (NTFP)
- Reduces or even suppresses the need for fallow periods
- Protects crops from wind and prevents lodging
- Acts as a refuge for beneficial organisms

−

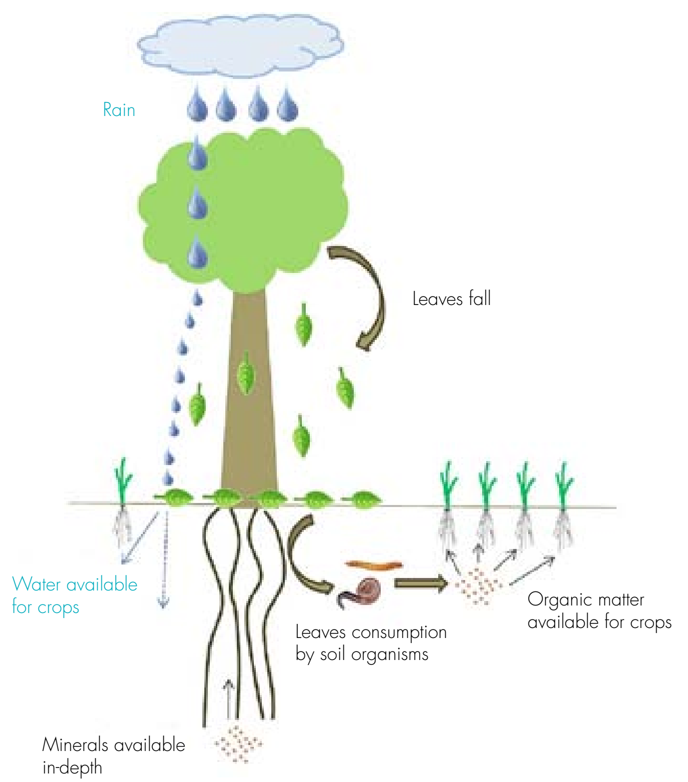
- Species that don't coppice or cannot stand heavy pruning and defoliation only allow row intercropping for the first 1 or 2 years
- Requires consequent time and labor investment for tree establishment when direct seeding in the field is not possible
- Reduces available space for traditional subsistence food
- Can act as a refuge for certain pests

Agroforestry is the practice of combining trees, grown to produce goods and/or services, with crops and/or animal husbandry. There a numerous ways of doing so and particular arrangements vary according to farmers' needs and environmental constraints.

Why planting trees?

Trees offer multiple benefits:

– they provide organic matter and plant nutrients through leaf fall; fallen leaves are decomposed by soil organisms, releasing nutrients and making it available to the crops;
– they slow down surface runoff and promote water infiltration into the soil, benefiting the crops;
– they recycle deep nutrients that are out of the reach of annual crops, thanks to their deep root system;
– they stabilize the soil with their extensive root system.

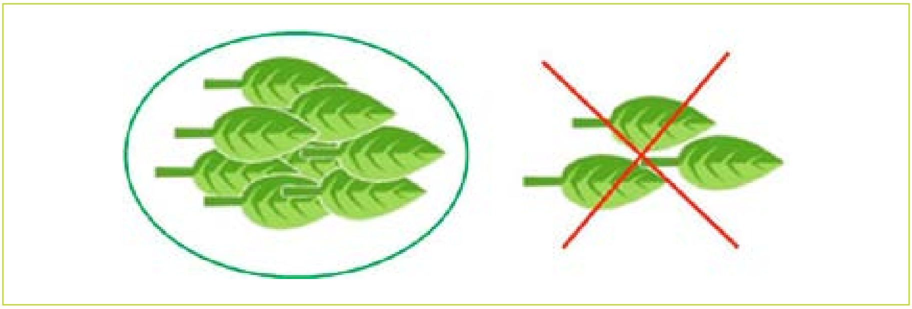


Moreover, trees cast shade on crops that require it for their growth. It also produces wood, sometimes fodder, fruits or ingredients for traditional medicines. It can also act as a refuge for game and insects.

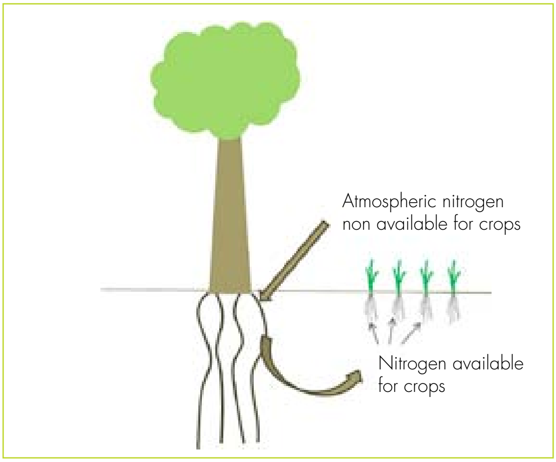
Species selection

The selection of species depends on farmers' objectives and environmental conditions. Nevertheless, in most cases, chosen species should have the following characteristics:

- **Biomass production: selected species should produce an abundance of biomass.**



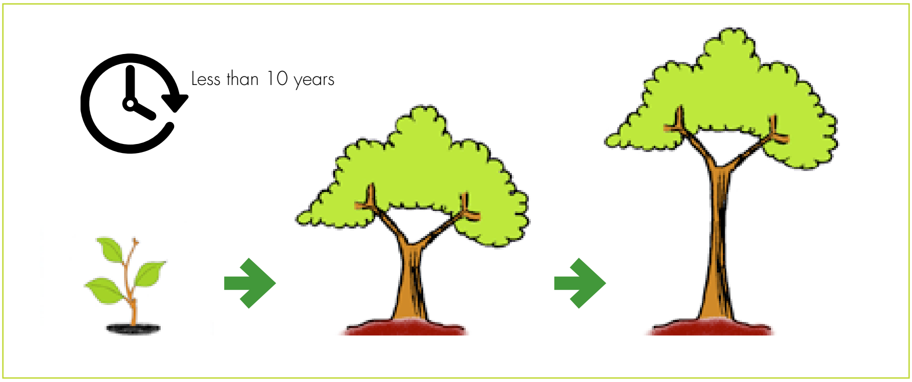
- **Nitrogen fixation:** in most cases, **legumes** are favored for their ability to fix nitrogen into the soil. Nevertheless, they might not always be suitable and the choice of species will vary according to the intended use of the trees; production of goods or fertility restoration.



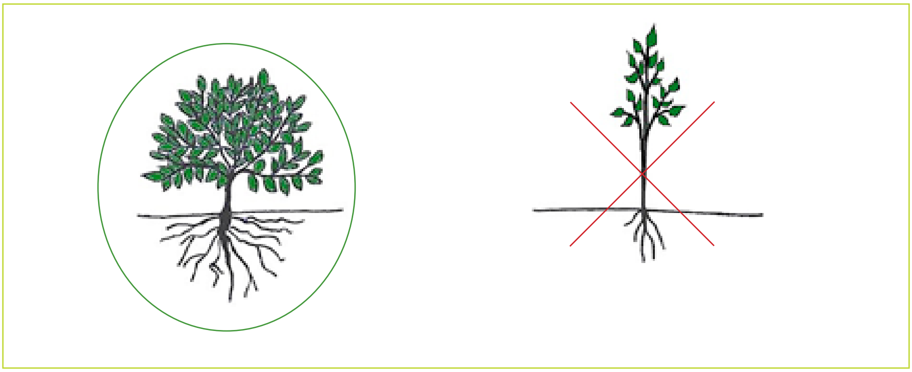
- **Adaptation:** chosen species should be adapted to the particular growing conditions of each site.

	Species 1	Species 2	Species 3
Rainfall	X	✓	✓
Temperature	X	X	✓
Soil	X	X	✓

- **Growth:** selected species should be fast growing. Nevertheless, this might not apply to all cases, depending on the main objective of the trees: soil fertility enhancement or the production of a crop.



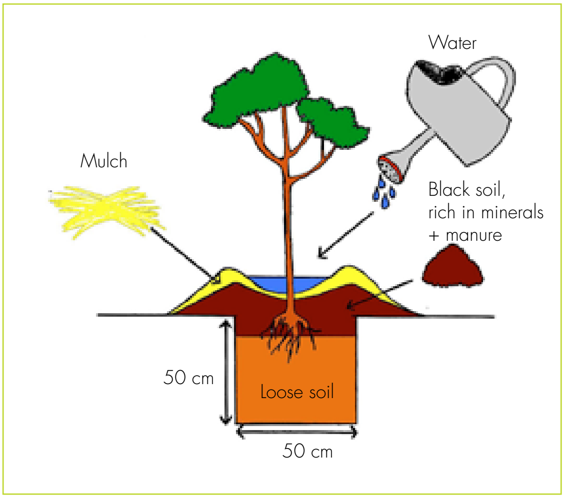
- **Growth habit:** selected species should have a deep and extensive root system as well as a **broad canopy** to efficiently limit erosion.



Tree planting

Trees should be planted at the beginning of the rainy season or else they will need daily watering until the first rains. To promote plant growth, it is recommended to mulch the base of the trees and to provide them with manure.

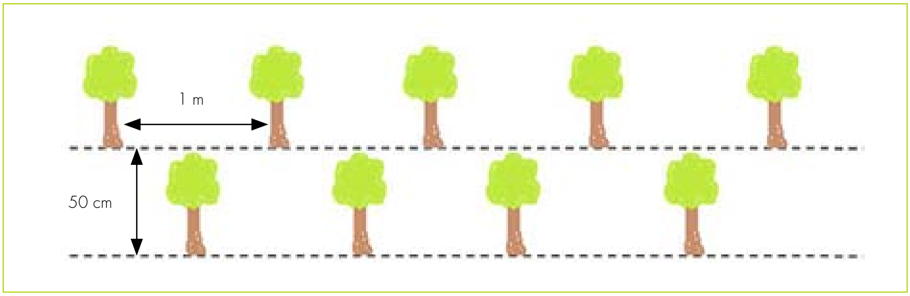
To transplant nursery seedlings in the field, dig 50 x 50 x 50 cm holes for fruit trees or 30 x 30 x 30 cm for forest trees.



Certain tree species can easily be direct-seeded in the field, but transplanting seedlings raised in nursery ensures a more vigorous growth from the early stage. Moreover, direct seeded plants tend to be more heterogeneous. It is also possible to propagate certain trees by cuttings, depending on the species.

Planting trees in double rows rather than single rows is more efficient not only to limit erosion, but also to produce large amount of biomass and offer wind protection. When planted in double rows, trees are staggered as shown in the diagram below.

Generally speaking, hedgerows can be established using two rows of trees at 50 cm inter-row spacing and 1 m in-row spacing. Nevertheless, each species has its own specifications and preferences. Also, spacing and planting patterns will vary with the final use of the trees and wider spacing can be used according to production needs



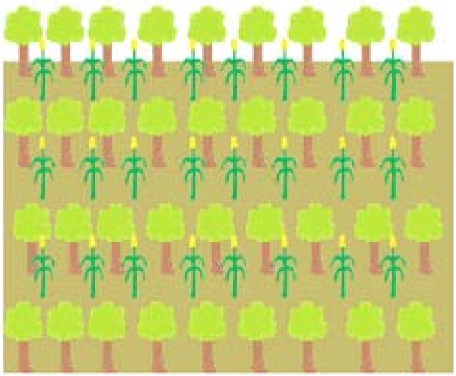
As for herbaceous vegetative strips, there should be no gap within the vegetation of the hedgerow or else the water will collect and flow through the bare spots causing erosion.

Hedgerows should be established following contour lines (see factsheet no. 15 on vegetative contour strips).

Different agroforestry design

Alley cropping

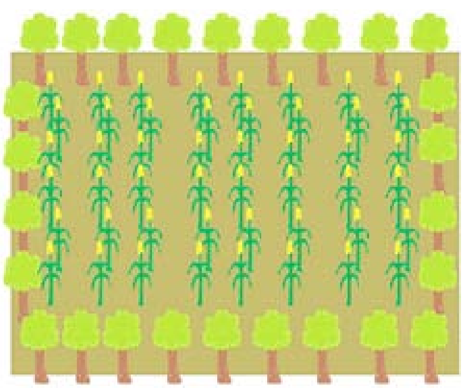
This particular technique aims at producing one or several food crops between rows of trees. It can be managed in different ways:



- trees are the main product and annual crops are grown in between the trees during the first two years following tree establishment, giving way to an orchard or a woodlot after the third year onward;
- annual crops are the main products and are grown between rows of trees that are regularly coppiced, pruned or defoliated.

Perimeter hedgerows (bocage)

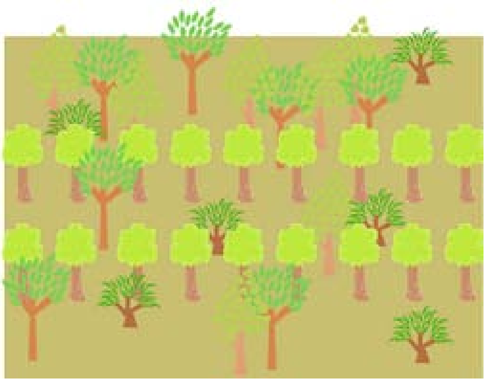
This layout aims at protecting crops from wind (using windbreaks), limiting erosion, fertilizing the soil, delimiting the plot and producing wood and/or fruits on a limited space.



Perimeter hedgerows are a good alternative to alley cropping for small producers as, in this system, the perennial crops don't occupy much land.

Scattered trees in fallow fields or degraded savannas (parkland system)

This layout aims at enriching a fallow field with selected species, either to keep it permanently or to cut it later on (see factsheet no. 7 on improved fallow).



Alley cropping

Agroforestry offers multiple advantages and can accommodate different social and environmental conditions. Indeed, the layout of an agroforestry system depends on farmers' objectives as well as climate, soil quality and field topography.

When trees are used for production, they need to have sufficient space to grow and develop. On the other hand, when they are used for erosion control or soil fertility management, closer spacing should be implemented.

Certain agroforestry techniques require a fallow period during which crops cannot be grown among the trees while others allow continuous cropping.

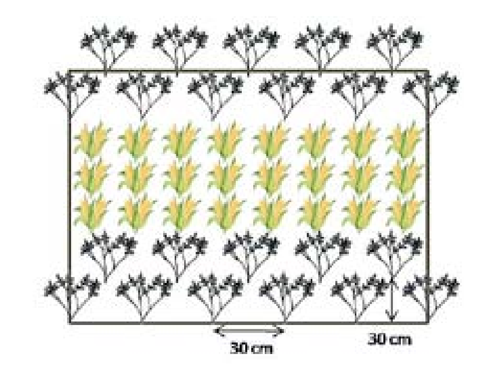
Annual crops combined with coppice or deciduous trees – continuous cultivation without fallow

The ligneous species stay multiple years in the field without hindering the development of annual food crops. On the diagram next page, the latter are represented by maize but any other annual species can be substituted, including combinations of different food crops. This technique also refers to intercropping (see factsheet no. 1).

› *Cajanus cajan*

Numerous planting layouts are possible, following are two examples:

- *Cajanus cajan* is established in single rows planted at 1 m inter-row and 40 cm in-row spacing;
- *Cajanus cajan* is established in staggered double rows planted at 30 cm in-row and inter-row spacing. The double rows are spaced 1 m apart or more.



Sow 2 to 3 seeds per pocket. Seed rate is 60 to 90 g for every 10 row meter. Seeding depth: 4 to 5 cm

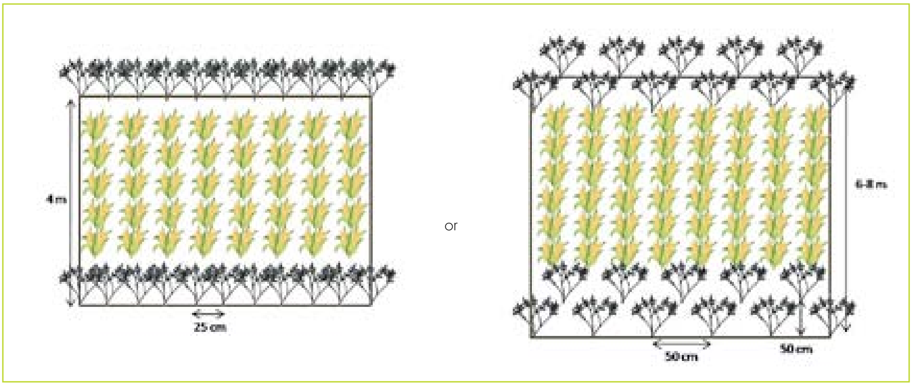
Plants are coppiced 40 cm above ground level at the end of the rainy season. For fodder production, plants are coppiced 80 cm above ground level.

Cajanus cajan rows have to be re-planted every 3 to 5 years.

› *Calliandra calothyrsusn*

If the main role of *Calliandra* is to enhance soil fertility, seedlings should be established in single or double rows at the following spacing:

- single row: 25 cm in-row and 4 m inter-row spacing;
- double row: 50 cm in-row and 6 to 8 m inter-row spacing. Rows should be staggered to reduce erosion and optimize the use of space.



If the main aim is honey or fodder production, trees should be established at 1 m x 1 m or 2 m x 2 m spacing. Nevertheless, at such spacing it is not possible to grow annual crops between the rows following the 2nd or 3rd year (as it is also the case with *Acacia auriculiformis*).

For the two years following establishment, calliandra benefits from the tending of the annual crop growing between the rows, especially hoeing as it limits weed competition. Passed that stage, it can grow on its own without difficulty.

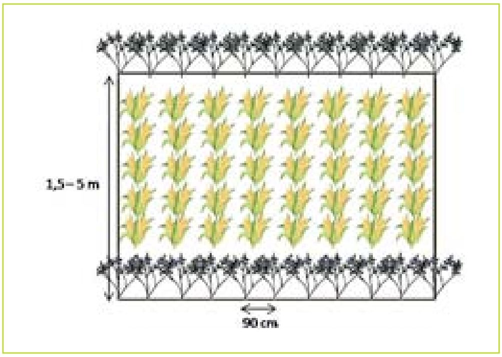
Trees should be coppiced 50 cm above ground level before establishing annual crops.

Calliandra re-grows very fast after coppicing, thus pruning of the lateral branches is necessary one month after establishment of the main crop to limit competition. A second pruning should be done 1 or 2 months later, simultaneously with the weeding of the plot.

This cycle can be repeated for several years, but it is necessary to leave the alleys fallow for 1 or 2 years every 2 to 3 years. *Calliandra* should be reestablished every 3 to 5 years.

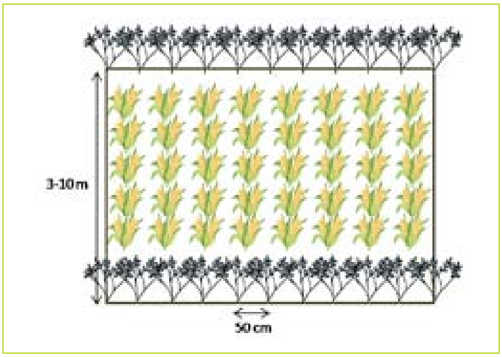
› *Gliricidia sepium*

Cuttings 1.5 to 2 m long and 4 to 10 cm in diameter are planted at 20 cm depth, following a 90 cm in-row and 1.5 to 5 m inter row-spacing. *Gliricidia* can be pruned 2 to 3 times a year.



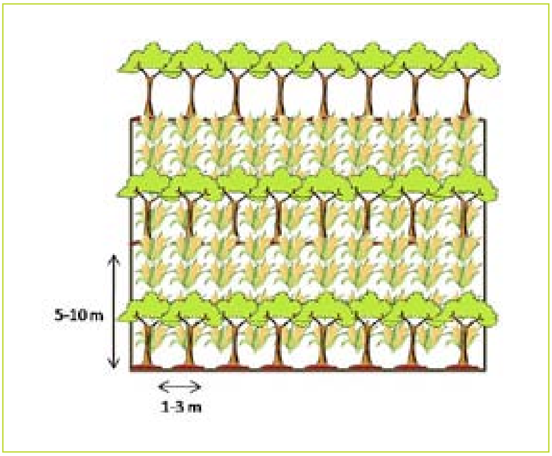
› *Leuceana leucocephala*

Spacing depends on farmers' objectives. For instance, when planted for fodder production, high planting density is recommended. Leuceana rows can be spaced 3 to 10 m in intercropping, using a 50 cm in-row spacing.



Coppicing starts 3 years after planting for firewood and green manure and after approximately 8 years for timber production, which correspond to the biological cycle of the species. For fodder production and for the confection of liquid manure, trees can be pruned on a regular basis.

› *Senna spectabilis*



Senna trees are often established from seedlings transplanted in 30 cm x 30 cm planting holes, but direct seeding by sowing 3 seeds per pocket at 2 cm depth is also possible. Rows should be spaced 5 to 10 m apart while trees within the row should be spaced 1 to 3 m apart.

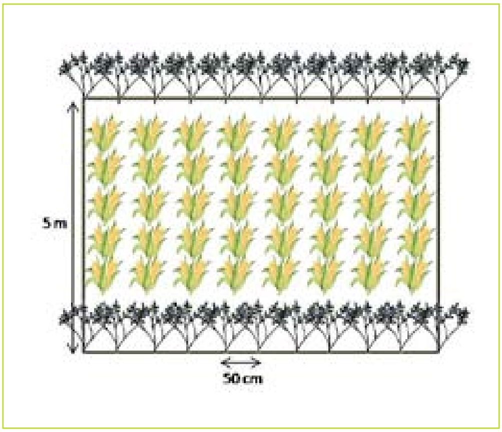
One to four weeding cycles a year are necessary (depending on weed pressure) during the first two years.

Lateral branches can be regularly cut to collect firewood and produce straight trunks that can be used as timber.

› *Sesbania sesban*

When intercropped, *Sesbania sesban* is sown at 0.5 m x 5 m spacing.

For fodder production, *Sesbania sesban* can be coppiced 5 times a year for over 5 years. Plants should be cut 50-75 cm above ground level when they reach 1 to 2 m in height. Growth resumes best when trees are 75 to 100 cm tall and part of the foliage is left untouched.



Delaying coppicing until trees reach 4 m in height, or on the contrary coppicing too early when they are still under 50 cm, can lead to their death.

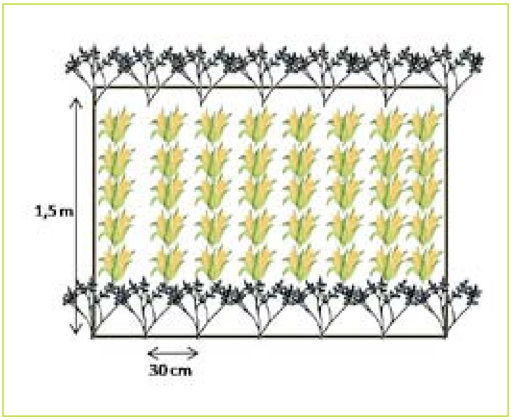
› *Tephrosia vogelii*

In intercropping, *Tephrosia* are sown at 0.3 x 1.5 m spacing.

If direct seeded, seed rate should range from 8 -13 kg/ha.

When sown in furrows, 5 kg/ha of seed is required.

A rule of thumb is to leave the plants to develop for a whole year before coppicing them 50 cm above ground level. Neverthe-less, it is important to make sure trees don't start competing with the main crop during this period.



According to FAO, rows of *Calliandra calothyrsus*, *Leucaena leuco-cephala* or *diversifolia*, or *Cassia spectabilis*, spaced every 5 to 10 m, can produce as much as 3 to 9 t/ha of leaves (making excellent fodder) and 2 to 7 t/ha of firewood a year. Thus, the total biomass produced on a cultivated plot - including crop residues, trees and hedgerows – can exceed the one produced by primary or secondary forests. Nevertheless, in order not to deplete the plot from soil minerals, it is crucial to return enough of the biomass produced to the soil.

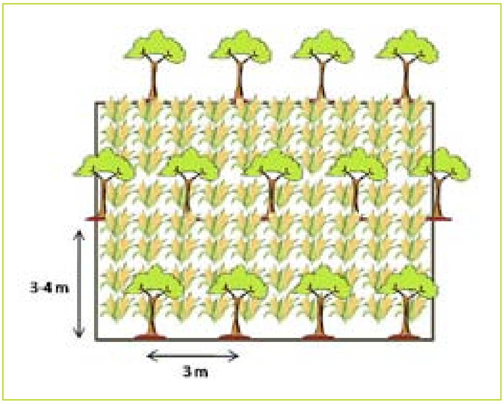
Annual crops combined with trees with a fallow period

In this system, trees should be spaced enough to develop fully for timber or charcoal production or to be used as bee fodder for honey production.

During the two first years, it is possible to grow annual food crops between the tree rows. Nevertheless, after this initial period, intercropping becomes impossible as trees continue developing to their full size, leaving too little sunlight for annual crops to develop. Only once the trees are cut, annual crop cultivation can resume.

› *Acacia auriculiformis* et *acacia mangium*

Acacia auriculiformis, just as *Acacia mangium* to which the same technical itinerary can be applied, does not have the ability to coppice. Consequently, they should only be cut when fully mature as, unlike the species seen earlier, they do not pro-duce valuable products before this stage.



Acacia auriculiformis germination rate being highly variable, it is recommended to raise seedlings in nursery for 3 to 4 months (sowing 3 seeds per planting bag) before transplanting them in the field.

Seedling should be planted at 3 m x 3 m or 3 m x 4 m spacing, depending on whether the aim is to produce as much wood as possible or to intercrop more food crops during the two first years.

During the first two years, the acacia trees benefit from the tending of the food crop intercropped. Passed this stage, weeding becomes unnecessary as the trees generate enough shade to smother weeds such as *Imperata cylindrica*.

The trees are harvested after 4 or 5 years for firewood, 7 years for charcoal, 8 to 10 years for fibers and 12 to 15 years for timber. Harvest starts as early as 2 years after planting for honey production.

Intercropping perennial crops with trees

It is also possible to establish perennial crops with trees, such as vines needing a support to climb on, like pepper or vanilla or trees species requiring shade in the early stage of their growth like cocoa or coffee. It is also possible to intercrop crops such as pineapple with fruit trees.

Numerous tree species can act as stakes and provide shade, benefiting the crops grown in combination. One example already mentioned of combining a perennial crop with trees is the intercropping of pineapples with fruit trees; as most fruit trees are slow growing, it is possible to grow pineapple for several years before trees cast too much shade and hinder their growth.

Pineapples: to establish the pineapples, crowns are planted at 1 m x 1.5 m spacing.

Fruit trees: to guarantee the quality of the fruit trees, using seedlings grown in nursery or grafted plants (see factsheet no. 17 on tree nursery) rather than direct seeding is recommended. Seedlings are planted in 50 cm x 50 cm x 50 cm planting holes, following the recommended spacing for the particular species established (see below for spacing recommendations). Supplying the trees with manure is highly beneficial to their growth.

› Mango (*Mangifera indica*)

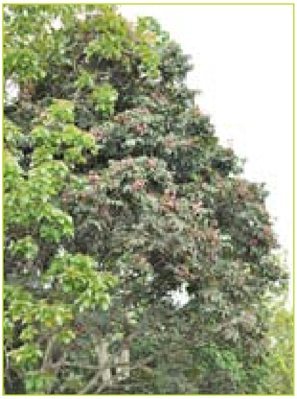
Trees are planted at 10 m x 10 m spacing, in a rich, deep and well drained soil. Mango trees are easily grafted. It is recommended to top the trees 1 m above ground level to give them a ball shape. Maintenance involves 1 to 4 weeding cycles annually during the first 4 to 5 years, depending on weed pressure. Harvest starts on the 5th year.

› Avocado (*Persea americana*)

Trees are planted at 10 m x 10 m spacing, in a rich, deep and well drained soil (sandy), preferably upland on plateaus and slopes. Maintenance involves 1 to 4 weeding cycles annually during the first 4 to 5 years (depending on weed pressure), pruning of the supernumerary branches and ramifications and topping of the trees at 0.5 m above ground level. Harvest starts on the 6th to 8th year.

© RuB.

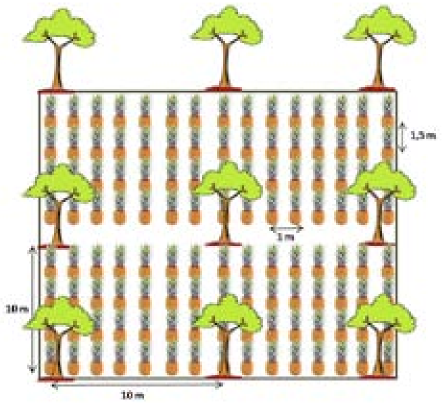
› Safou (*Dacryodes edulis*)



Trees are planted at 10 m x 10 m spacing, in a rich, deep and well drained soil. It is also possible to propagate safou by layering to produce plants that start fruiting earlier than when propagated by seed. Maintenance involves 1 to 4 weeding cycles annually during the first 4 to 5 years, depending on weed pressure. Harvest starts on the 5th year for layered trees and on the 10th year for seedlings.

› Orange (*Citrus sinensis*) and lemon (*Citrus limon*)

Trees are planted at 7 m x 7 m spacing, in a deep and well drained soil. Grafting allows obtaining better fruits. Maintenance involves 1 to 4 weeding cycles annually during the first 4 to 5 years, depending on weed pressure. It is necessary to pinch off the apical bud to give the tree a ball shape. Harvest starts on the 3rd to 5th year.



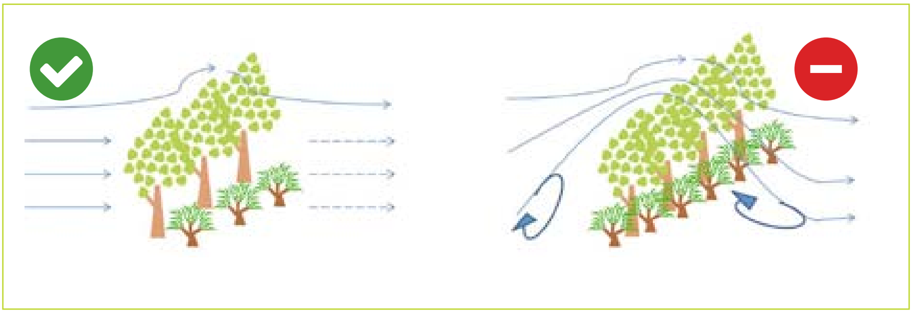
Pineapple/fruit trees intecropping


Lemon tree and orange tree, Pixabay.

Hedgerows

In the case of bocage systems, hedgerows are established along the perimeter of cultivated plots.

To act as windbreaks – as part of lodging control strategy for sensitive crops – trees should be spaced enough to leave some wind to pass through (but not too much). Indeed, if wind is stopped abruptly, it will generate turbulences on the other side next to the hedgerow and cause damage to the crops. Hence, windbreaks should slow wind down **without completely stopping it**.



The species mentioned earlier are suited to the establishment of hedgerows. Numerous other species can also be used such as: trees from the ficus family, *Grevillea robusta*, *Sesbania bispinosa*, *Sesbania grandiflora*, *Casuarina equisetifolia*, trees from the eucalyptus family, *Moringa oleifera*, *Parkia biglobosa*, *Syzygium cumini*, trees from the inga family, etc.

Erosion control

When applying alley cropping on sloping land, tree rows should be spaced at closer intervals (see factsheet no. 15 on contour strips) as erosion is greater than on flat land.

To limit erosion and build soil fertility, tree prunings should be left on the ground as mulch (see factsheet no. 14 on mulching).

Once the leaves have dried up and fallen from the branches, it is possible to collect the latter for firewood while twigs and leaves are left on the ground to protect the soil and enhance its fertility. If required, leaves can also be used as fodder, but doing so implies leaving the soil barren.

To learn further

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Assisted natural regeneration

Functions Natural forestry resources management
Soil fertility management

+

- Speeds up natural forest cover regeneration
- Low labor requirement
- Low skill requirement
- Low implementation cost
- Promotes growth of useful species, therefore producing timber, fodder, medicinal plants, wild fruits etc. and diversifying sources of income
- Preserves biodiversity
- Conserves trees for future use
- Preserves soil fertility and structure

–

- Not very efficient when controlled burning is used to clean the plot (requires excellent protection)
- Requires securing the land (investment for the future)
- Involves protecting the fallow plot from bushfires
- Limits possibilities for mechanization


Cassava plot cultivated with assisted natural regeneration techniques, Cataractes, GRET, RDC, 2014.

Assisted natural regeneration (ANR) aims at promoting the growth of young trees while cultivating food crops, thus preserving forest resources, to produce charcoal and exploit other non-timber forest products.

The objective of preserving trees is both to exploit their products and to preserve soil fertility, as lack of trees causes mineral depletion and hinders healthy plant development.

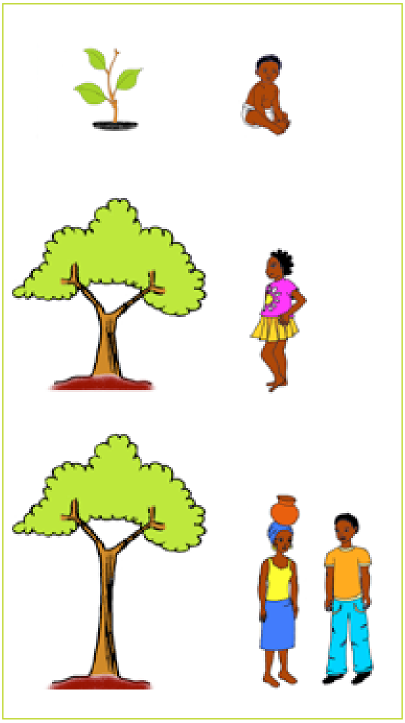
Prerequisite

Fruit trees and forest trees grow slowly. Just like children, they need time to turn into "adults", namely to reach the size where they become exploitable.

Small trees not exceeding 20 to 30 cm are like babies. They need good care to grow and we must be especially careful not to hoe them when cleaning the field. They are so small that they don't disturb the crops.

Ten years later, the seedlings have become small trees and their branches must be pruned if they disturb the cultivated crops.

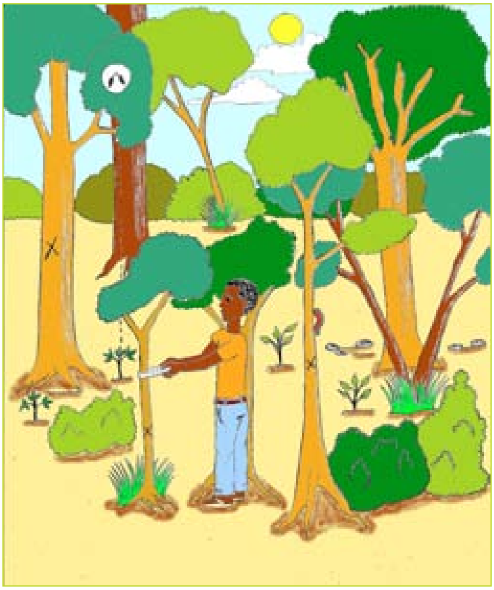
Thirty years later, they have become beautiful trees. Depending on species, they might need a few more years before they can be used for plank or charcoal production. The trees also produce seeds that can germinate and produce new seedlings. This cycle does not disturb the cultivation cycle of crops.



Implementing ANR in a plot

ANR is implemented in two steps: when establishing a new plot and during its maintenance.

Plot establishment



› Before clearing a new plot:

– trees with interesting properties are spotted (wood, medicinal plants, fruits, edible caterpillar refuge, etc.);

– trees to be kept are marked, small and tall alike (80 to 150 trees/ha);

– seed producing trees as well as young seedlings that do not disturb the cultivated crops are also kept (if they are inter-spaced enough), so they can keep growing and reach an exploitable size.

Trees that have not been selected are cut and, if the plot is cleaned using fire (which is not mandatory), the selected ones should be protected by a 2 m wide firebreak.

When maintaining the plot: the maintenance also follows two steps

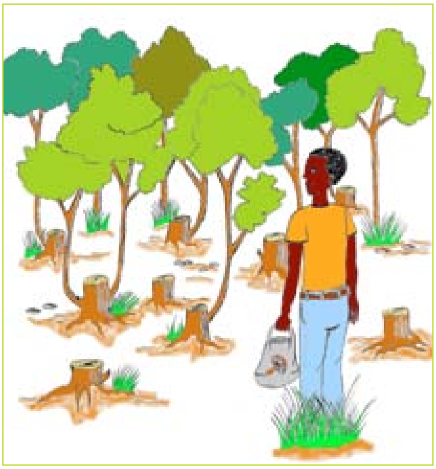
› Hoeing: young seedlings benefit from the care provided to the main crop, especially hoeing, as it prevents weed competition. While hoeing, one or two shoots are kept on each stump (see opposite picture) while the others are cut to reduce competition and allow selected shoots to grow faster.

It is important to make sure the selected trees are disposed in such a way as they do not end up disturbing each other once they reach their full size.

› **Sound exploitation** of branches from the big trees spared, according to species and needs. Bigger trees can be pruned if their foliage disturbs the cultivated crops.

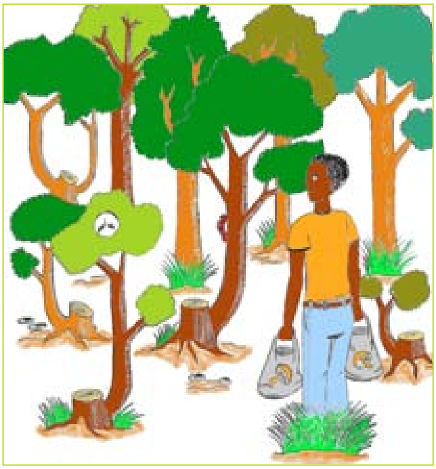
When pruning, cuts should always be done neatly (no breaking or tearing) using clean tools, in order to minimize the risk of disease entering the wound and contaminating the tree.

Thanks to this technique, forest reestablishes faster after a cultivation cycle. Also, trees growing on the plot left fallow are bigger and resources more abundant.



Fallow plot after crop cultivation, without ANR

Trunks are small.
Soil fertility is not rebuilt.
Few mushrooms are found.
Absence of game, caterpillars etc.



Fallow plot after crop cultivation, with ANR

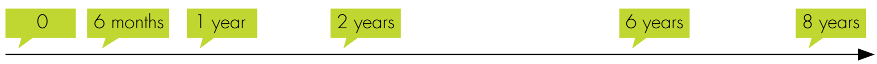
Trunks are big.
Soil fertility is rebuilt.
Mushrooms are abundant.
High occurrence of game, caterpillars etc.

Raising farmers' awareness towards ANR with a game

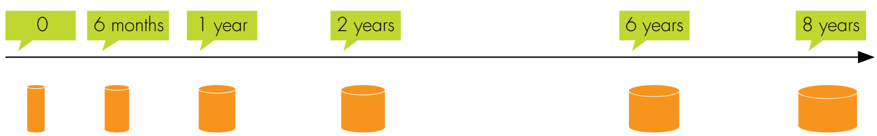
The importance of ANR is not always easy to understand for farmers, as they do not always realize how slowly trees grow and take the full measure of the increasing rarefaction of this resource. In order to address this issue and raise farmers' awareness about ANR, a game has been devised.

If farmers have never heard of ANR before, the facilitator introduces the concept. In case they are familiar with the technique, they should be the one presenting it. Then, they take part in the game as follow.

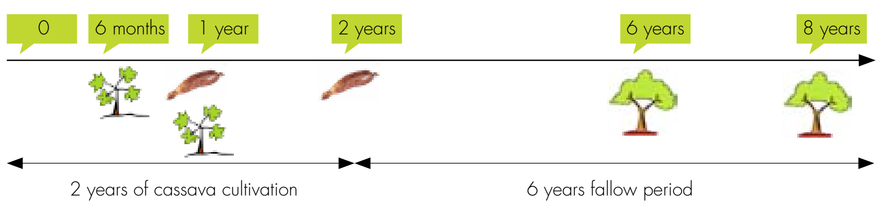
- Time notion: draw a line representing time on the ground and ask women to indicate their children age on it.



- Time notion applied to trees: prior to the game, prepare branches of different diameters (length doesn't matter here) that will be used to represent stumps and seedlings. Participants are then asked to place each branch on the time line in front of its corresponding age. The size of the stem represented is symbolic and do not have to match exactly the age indicated on the time line, what matters is its evolution over time.

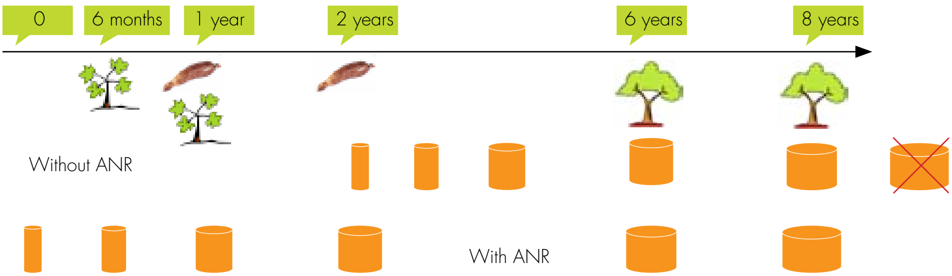


- Cultural cycle without ANR: First, prepare some leaves, seeds, tubers and other items representative of the crops cultivated by the farmers. If charcoal or wooden planks are produced, or if some non-timber forest products (NTFS) are harvested, they should also be represented. The participants are then asked to explain the cultural cycle of a plot and symbolize the different steps on the time line using the items prepared beforehand.



In the case of banana plantations, with a 4 to 5 year cultivation cycle, the ANR benefits will be even more obvious.

- **Cultural cycle with ANR**: it is important for the facilitator to establish a link between the cultural cycle and the tree growth time lines. Participants are asked to place the branches symbolizing trees first with traditional cultural cycle, then with ANR practice.



- **Summary of ANR benefits**: Participants should comment on the difference in the size of the trees at the end of the cultural cycle with or without ANR. Each of them should be able to notice the gain of time as well as the increased size when trees are protected from the very beginning of a plot establishment, hence saving several years and increasing the amount of wood, fruits, fertilization and soil structuring etc.

ANR training as part of Defiv project.. Farmers are placing cassava leaves and tubers between tree stems on the time line, GRET, DRC, 2014.

To learn further

Gérer durablement la ressource bois énergie, Projet Makala, Cirad. http://makala.cirad.fr.

Enhanced firebreaks

Functions

Natural resources management
Protection against bushfire

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- Protects crops and natural resources against wildfire
- Produces valuable agricultural products on an otherwise unproductive space
- Diversifies sources of income

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- Not sufficient on its own. Must be paired with other bushfire management techniques such as controlled burning

Clear demarcation between burnt savanna and an intact agroforestry plot protected by a firebreak (a gap in the vegetation). Nevertheless, the firebreak being very narrow, it could not have protected the plot against a more intense bushfire. GRET, DRC, 2015.

What is a firebreak?

A fire break is a strip cleared of all its vegetation created around a field, a forest or an area of savanna to protect it from wildfire. When rightly done and maintained, this non-vegetated barrier offers efficient protection against bushfire.

Why adding value to firebreaks?

Uncontrolled bushfires, sometime of very high intensity, cause important losses both in agricultural plots and natural environments such as forests and savannas. They destroy several resources such as:

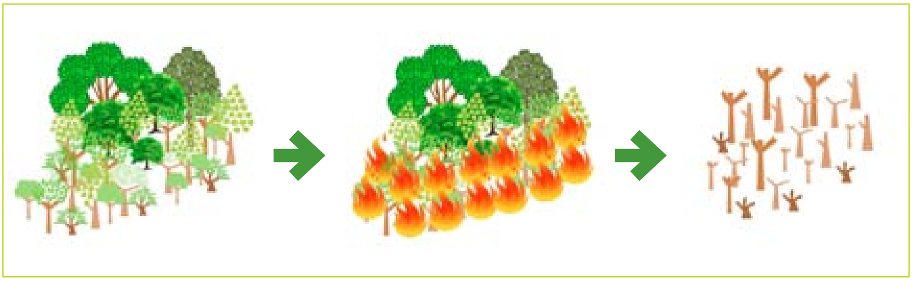
- game habitat;
- trees where bees have their nests and those where edible caterpillars live;
- commercially valuable tree species that can be used for planks or charcoal production;
- wild edible or medicinal plants.

Moreover, the burning of vegetation causes soil to be barren, erode and lose its fertility.

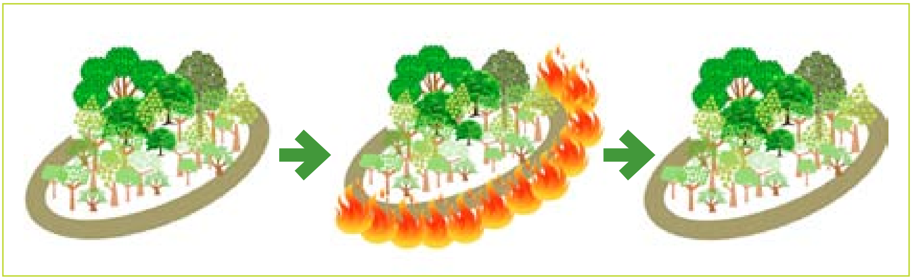
Establishing firebreaks can prevent communities from having to face such heavy losses. But creating such systems is time and labor intensive. Hence, to rapidly make this activity profitable, it is possible to establish a short duration crop (3 months) on the firebreak before the end of the rainy season.

Examples

Natural forest without firebreak

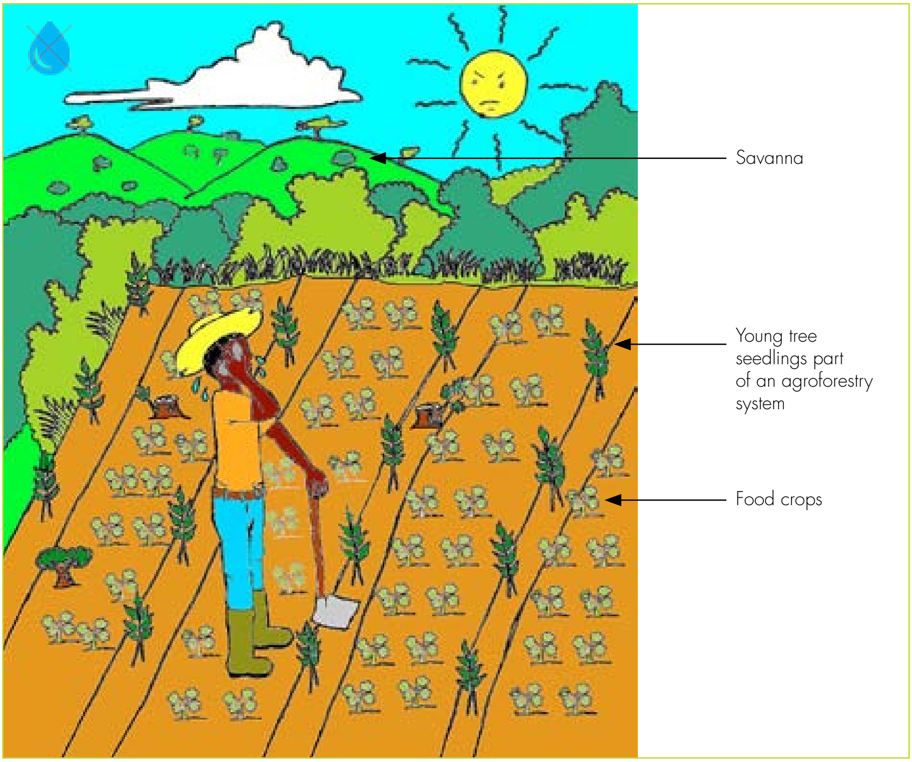


Natural forest with firebreak

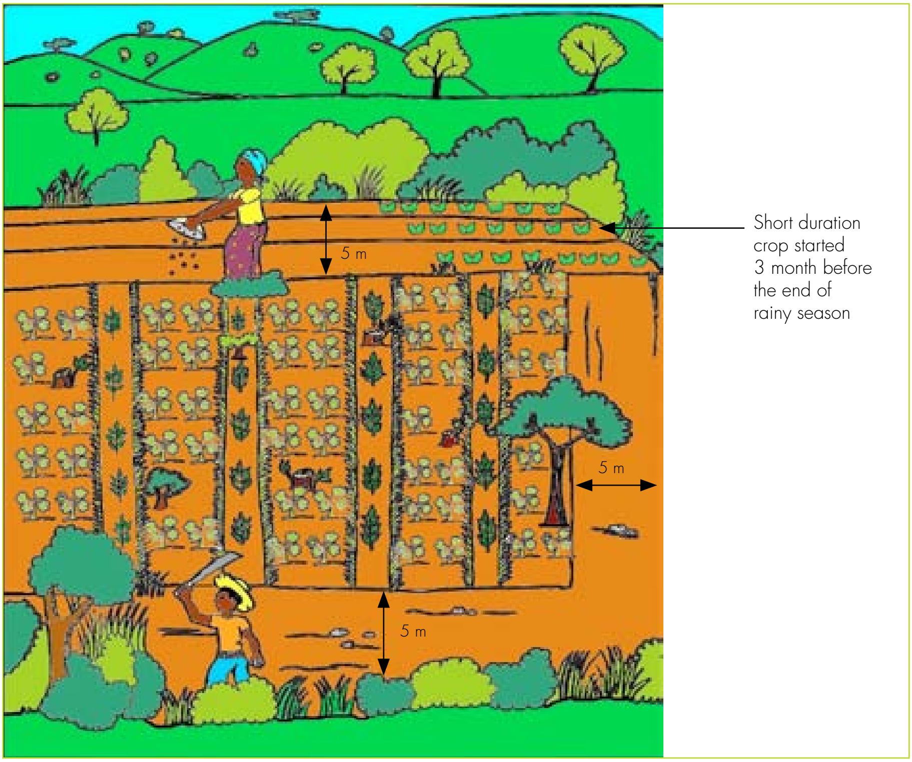


Establishing an enhanced firebreak

Toward the end of the rainy season, rains get sparser and grasses progressively dry up, setting easily on fire and increasing the risk of wildfire as dry season sets in. It is thus necessary to remove grasses from the fields and to establish firebreaks all along their perimeter (firebreaks should be at least 5 m wide on flat lands and more on sloping lands) to prevent bushfire from destroying harvests and trees.



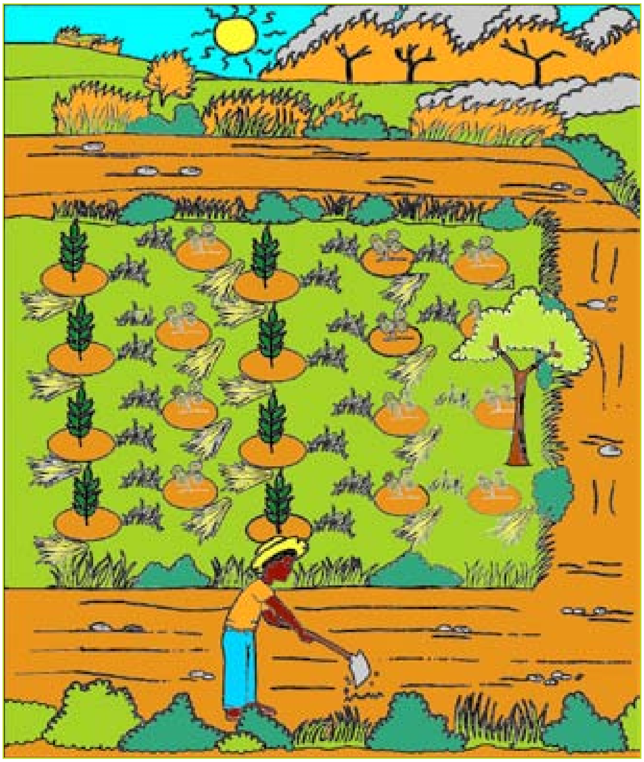
To add value to a firebreak - which primary objective is protection – a short-duration crop is sown on the whole surface of the devegetated strip surrounding the plot, 3 months before the start of the dry season. Harvest will then occur toward the end of the rainy season, leaving the firebreak clear of all vegetation, ready for the dry season.



Maize, peanuts or cowpea (as seen on the picture below) can all be used as short-duration crops.

Enhanced firebreak surrounding a cassava plot (left), with cowpea (*Vigna unguiculata*) sown to add value to the otherwise unproductive space (center), separating it from savanna (right), before the start of dry season, GRET, DRC, 2014.

Once the firebreak is established, it has to be maintained! If not, grasses eventually grow back and facilitate the propagation of fire to the plot. It thus has to be regularly cleaned until the return of the rains. The plot should also be kept clean.



The recommended width for firebreaks is a minimum of 5 m; the wider the firebreak, the higher its chances to stop wildfires. In large areas cultivated under agroforestry systems and where farmers' plots are adjacent, forming large clusters, firebreaks are in the range of 15 to 20 m wide. They are established and maintained communally.

The establishment of firebreaks is absolutely necessary in agroforestry systems, where farmers invest time and money to establish trees over the course of several years. It is indispensable to establish firebreaks around *acacia auriculiformis* plots. Indeed, this species being particularly fire prone, the risk of losing many years of labor to wildfire is great unless protective measures are implemented.

Plants factsheets

Acacia auriculiformis

Botanical information

Vernacular names: acacia, northern black wattle.

Family: Fabaceae.

Morphological description: tree growing to a height of 15 to 30 m with a 50 cm diameter trunk (60 cm in really favorable conditions) and a very dense ramification.

Root system: shallow but dense.

Life cycle: perennial.

Geographical distribution: native to Australia, Indonesia and Papua New-Guinea, naturalized throughout Africa and South America.

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- Fixes nitrogen in the soil
- Produces high quality fuel wood
- Produces timber
- Fast growing
- Melliferous, can be used as bee fodder in beekeeping
- Undemanding plant adapted to many soil types
- Restructures the soil
- Very good source of mulch thanks to slow decomposing leaves
- Low sensitivity to insects

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- Highly fire prone
- Doesn’t coppice well
- Can be invasive in its native range

Description

Fruiting *Acacia auriculiformis*, Justine Scholle, GRET, DRC, 2014.

Acacia auriculiformis is a fast growing tree whose fertilizing properties and wood quality for charcoal production make a popular choice in agroforestry systems throughout the tropics. Leaves are long and pointed, 8 to 20 cm in length and slightly curved with well defined longitudinal veins. The yellow inflorescences produce spiral shaped, flat and strongly curved pods, each containing up to 15 seeds. When fully mature, pods crack open and the small, shiny black seeds are held to the pod by a yellow or orange filament.

Uses

Function	Use	Quality	Benefit
Soil fertilization	Intercropping Hedgerow Mulch Green manure	Very good Medium	Intercropping: 177 kg/ha/year of nitrogen Mulch: 7 to 8 t/ha/year of leaves Green manure: very slow decomposing leaves
Fuel wood	Firewood Charcoal	Very good	High calorific value: 4,500 to 4,900 kcal/kg Produces 10 to 20 m^3/ha/year of wood depending on conditions
Timber	Formwork wood	Good	Produces 10 to 20 m^3/ha/year depending on conditions
Erosion control	Dense root system Windbreak	Good	
Weed control	Supresses *Imperata cylindrica* thanks to the shade and the dense layer of slow decomposing mulch it produce	Very good	
Beekeeping		Very good	

Requirements and adaptability

- **Soil**: performs best in well drained soils and intolerant of heavy soils. Tolerates poor, salty and alkaline soils and can adapt to a wide range of pH (from 3 to 9.5).
- **Temperature**: grows naturally in areas with temperatures ranging from 20 to 30°C but can tolerate light frost.
- **Light**: sun loving tree, tolerates very little shade.
- **Rainfall**: naturally occurs in area with rainfall ranging from 700 to 2,000 mm/year with a 7 months dry season. Tolerant of semi-arid conditions.
- **Altitude**: below 1,000 m a.s.l.

Acacia mangium is very similar to *Acacia auriculiformis* as far as its biophysical limits and uses are concerned. It grows even faster than *Acacia auriculiformis* and produces more mulch. On the other hand, its wood is of lesser quality for fuel wood. Its leaves being broader, it is also more sensitive to lodging. Hybridization between both types of acacia produces better offspring than the parents. Indeed, the hybrid will grow faster than *Acacia auriculiformis* and produce better wood than *Acacia mangium*.

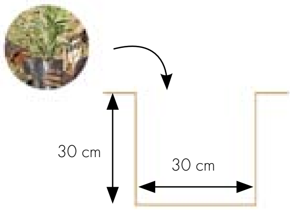
2 years old *Acacia mangium*, Justine Scholle, GRET, DRC, 2014.

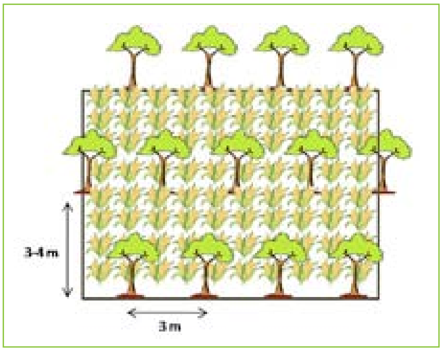
Cultivation techniques

- **Breaking of dormancy**: soak the seeds for 24 hours in hot water (removed from the fire) or for 1 to 2 minutes in boiling water followed by 24 hours in cold water. In the field, the controlled burning of the leaf litter breaks seed dormancy and avoids planting new trees after the first cut.
- **Planting**: it is recommended to use seedlings grown in nursery (see factsheet no. 17).

  Sow 3 seeds per bag at 1 cm depth. Seedlings are ready to be transplanted in the field after 3 to 4 months.

  Dig 30 cm x 30 cm x 30 cm holes to establish the seedlings.





Use a 3 m x 3 m planting pattern if the main objective is wood production and a 3 m x 4 m if the emphasis is on food crops (see factsheet no. 19 on agroforestry and no. 7 on improved fallow).

- Germination: 2 to 3 weeks after sowing. Germination rate: 40 to 80% after treatment.
- Care: requires weeding for the first year following establishment but needs very little care thereafter.
- Harvest: 4 to 5 years following establishment for firewood, 7 years for charcoal, 8 to 10 years for fibers, 12 to 15 for timber. When used as bee fodder, honey production can start as soon as the second year after establishment.
- Intercropping: cassava, maize, peanuts.

Propagation/Seed production

Seeds are small and variable in size. 30,000 to 72,000 seeds/kg.

To learn further

Acacia auriculiformis, in C. Orwa *et al.*, *Agroforestry Database 4.0*, World Agroforestry Centre, 2009, 6 p. www.worldagroforestry.org.

Acacia auriculiformis, *Agriculture et développement en pays Antandroy : fiches techniques*, Objectif Sud, Madagascar, Gret, GSDM, 2010, 2 p. www.semencesdusud.com.

Acacia auriculiformis, Guy Modeste Ganouha, Dominique Louppe, Fiche technique, CNRA, Cirad, 2003, 2 p. http://hal.cirad.fr.

Biomasse, minéralomasse et productivité en plantation d'*Acacia mangium* et *Acacia auriculiformis* au Congo, France Bernhard-Reversat, Daniel Diangana, Martin Tsatsa, *Bois et forêts des tropiques*, n° 238, 1993, pp. 35-44. http://bft.cirad.fr.

Azadirachta indica

Botanical information


© Ton Rulkens.

Vernacular names: margousier, margosier, neem, neem tree.

Family: Meliaceae.

Morphological description: small to medium sized tree, growing to a maximum height of 15 to 30 m.

Root system: deep rooted.

Life cycle: perennial.

Geographical distribution: native to India, Pakistan and Bangladesh, can be found in many places throughout the world.

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- Is widely used as a biopesticide
- Produces edible fruits, flowers and leaves for human and animal consumption
- Provides erosion control
- Can be used in charcoal production
- Provides organic fertilizer
- Is used in traditional medicine
- Can be used for windbreaks

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- Neem extracts can be toxic to aquatic fauna and certain beneficial insects
- At high doses, neem seed oil can be toxic to humans

Description

Neem tree can reach up to 30 m in height although it is generally much smaller. It grows very well in tropical and subtropical climates and can resist long dry spells thanks to its deep root system. Flowers are white to pale yellow. *Azadirachta indica* starts flowering and producing fruits after 4 to 5 years. Nevertheless, it is only after 10 years that the level of production becomes significant enough to allow for commercialization. Neem seed oil has numerous properties but is especially known for its pesticidal qualities (see factsheet no. 5 on biopesticides).

Uses

Function	Use	Quality	Benefit
Human diet	Fruits (fresh or cooked) Young shoots and young flowers (occasionally eaten as vegetable) Edible resin (extracted by incising the bark, high in proteins) Oil (obtained by pressing the seeds)	Good	Fruit production: 20 to 50 kg/tree/year
Fodder	Leaves (bitter, used as fodder during dry season)	Low to medium	25 t/ha Suitable for livestock and poultry
Fuel wood	Charcoal	Very good	
Integrated pest management	Seeds Leaves	Very good	The active compound inhibits insect metamorphosis from larval to adult stage and paralyses their digestive tube
Erosion control	Extensive root system Mulch (leaves and twigs) Windbreak (low branches, efficient in blocking wind)	Good	

Function	Use	Quality	Benefit
Soil fertilization	Neem cakes (seed residues after oil extraction) used as fertilizer Mulch (leaves and twigs)	Good	
Medicinal		Good	

Requirements and adaptability

- **Soil**: can grow in many soil types, ranging from neutral to alkaline, but performs best at pH 6.2 to 7. More adapted than most species to shallow, sandy or rocky soils but intolerant of flooding.
- **Temperature**: tolerates temperature ranging from 4°C to 40°C.
- **Light**: Sun loving.
- **Rainfall**: 400 to 1,200 mm/year.
- **Altitude**: can be found from 0 to 1,500 m a.s.l.

Cultivation

- **Breaking of dormancy**: none.
- **Sowing**: direct seeding (mostly).
- **Germination**: seeds germinate very soon after sowing.
- **Care**: in arid environments, weeding of neem plantations is crucial as the trees cannot resist weed competition (especially from graminaceae) .
- **Harvest**: neem starts producing 4 to 5 years after planting, but production becomes important and stable only after 10 years. Seeds are harvested once a year. Each harvest yields between 20 to 50 kg/tree/year. One kg of seed consists of 4,000 to 5,000 seeds.

Propagation/Seed production

Mainly propagated by seed. Seed viability is very short and sowing should happen soon after harvest. No pre-treatment is necessary but removal of the pulp and cleaning of the seeds improve germination rate.

Neem can also be propagated vegetatively: cuttings, layering of roots and branches, grafting…

To learn further

Azadirachta indica, in C. Orwa *et al.*, *Agroforestry Database 4.0*, World Agroforestry Centre, 2009, 8 p. www.worldagroforestry.org.

Le neem (*Azadirachtaindica* A. Juss.), une espèce exotique adoptée par les paysans du centre-ouest du Burkina Faso, Babou André Bationo, Barthélémy Yelemou, Sibiri Jean Ouedraogo, *Bois et forêts des tropiques*, n° 282 (4), 2004, pp. 5-10. http://bft.cirad.fr.

Azadirachta indica, documents pour le développement durable de l'Afrique à l'usage des ONG, Benjamin Lisan, 2014, 17 p. www.doc-developpement-durable.org.

Azolla pinnata

Botanical information

Vernacular names: mosquito fern, water velvet, african azolla, ferny azolla.

Family: Azollaceae.

Morphological description: aquatic fern.

Root system: fine lateral rootlets (giving water a fluffy appearance).

Life cycle: reproduces very quickly either vegetatively or by spores (its biomass can double within 5 to 10 days).

Geographical distribution: native to Africa, Asia and Oceania, can also be found in the USA.

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- Fixes atmospheric nitrogen
- Multiplies extremely fast
- Controls weeds
- Can be used as fodder
- Is nematode resistant

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- Can become invasive
- Is prone to certain fungal diseases

Description

Azolla pinnata is a small aquatic fern that multiplies extremely quickly. It is usually found on the surface of stagnant water. Due to the dense vegetative cover it provides, azolla inhibits the development of deeper aquatic plants by blocking their access to sunlight. It can become problematic and pose a threat to biodiversity; therefore azolla is sometimes considered an invasive species. Nevertheless, when used in flooded rice cultivation, this plant can act as an excellent fertilizer thanks to its ability to fix atmospheric nitrogen through a symbiotic relationship with cyanobacteria (see factsheet no. 10 on green manure). In addition, azolla also helps to control weeds.

It is 1.5 to 2.5 cm tall and made of a main pinnately branching stem, more or less straight, from which lateral branches are attached, giving it a slightly triangular shape. Branches are pinnate and divide to form new plants. Stems redden or brown in full sunlight.

Uses

Function	Use	Quality	Benefit
Soil Fertilization	Flooded rice cultivation	Very good	Fixes 50 kg/ha of nitrogen in 35 days, 90 kg/ha within 2 months
Weed control	Flooded rice cultivation	Very good	
Fodder	Leaves and stem	Very good	730 t/ha or 56 t/ha dry weight

Requirements and adaptability

- **Growing environment**: doesn't grow on land but on the surface of water bodies. Abundant in stagnating water with high nutrient content, such as pound found in cattle pen where it readily covers the whole surface.
- **Temperature**: best between 15 to 30°C but can tolerate temperatures as low as 4°C and as high as 35°C.
- **Rainfall**: most suited to extremely humid climates. Nevertheless, azolla can survive on constantly humid soils, on the shore of rivers or ponds, which allows it to survive with little water and tolerate some dry spell.
- **Altitude**: from 0 to 3,000 m depending on varieties.

Cultivation

Azolla can be introduced in the flooded rice field 5 to 10 days after rice transplantation, at 7 to 8 kg/ha seed rate. It takes azolla 20 to 25 days to multiply and spread throughout the field.

It is also possible to integrate fish farming with Azolla pinnata in flooded rice fields, the plant providing food for the fish.

- Care: none.
- Harvest: 30 days after seeding of the rice field. Involves draining the rice field and requires good water control. Azolla is then left to dry on the plot – on its own or combined with weeds after hoeing – and allowed to decompose (see factsheet no. 10 on green manure).

To learn further

Azolla pinnata (mosquito fern), Invasive Species Compendium (ISC), CABI, Royaume Uni, Datasheet, 2015. www.cabi.org.

Azolla pinnata (aquatic plant), IUCN/SSC Invasive Species Specialist Group (ISSG), 2010. www.issg.org.

Azolla: a sustainable feed for livestock, S. Rajamony , S. Premalatha, P. Kamalasanan Pillai, Leisa Magazine, 2005, 2 p. www.agriculturesnetwork.org.

Azolla - Document de formation, Stéphane Fayon, Annadana Soil and Seed Savers Network, Inde, 2005.

Brachiaria brizantha

Botanical information

Vernacular names: beard grass, signal grass, brizantha.

Family: Poaceae.

Morphological description: semi-erect herbaceous species.

Root system: deep and fibrous (develops an abundance of adventitious roots).

Life cycle: perennial (lives an average of 5 years).

Geographical distribution: native to Africa, naturalized throughout the humid and sub-humid tropics.

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- Loosens the soil thanks to its powerful root system
- Produces an abundance of biomass that can be used for erosion control and soil fertilization
- Fixes carbon at depth
- Recycles leached nutrients located deep in the soil thanks to its extensive root system
- Fixes nitrogen in the soil thanks to its association with free nitrogen fixing bacteria
- Produces quality fodder
- Controls weeds
- Is fire tolerant
- Has higher disease resistance compared to other species from the *Brachiaria* genus
- Is tolerant of grazing

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- Can be invasive
- Requires regular and meticulous cutting

NB: this herbaceous plant is hard to tell apart from *Brachiaria decumbens* to which it is closely related.

Description

Brachiaria brizantha is an herbaceous plant adapted to compacted, poor and acidic soils and efficient in restoring their fertility. Moreover, *Brachiaria* produces root exudates helping to resume soil microbial activity and encourage mycorrhizal development. (see factsheet no. 13 on living mulch). It also provides an excellent source of fodder for cattle. Brachiaria can be grown on its own but is most interesting in intercropping with long duration cycle crops such as banana. It can reach up to 2 m in height and tends to form clumps if not regularly cut. Leaves are dark green and slightly hairy and can be up to 100 cm long and slightly less than 2 cm wide. *Brachiaria* roots can penetrate the soil to a depth of approximately 2 m.

Uses

Function	Use	Quality	Output
Erosion control	Cover crop/ living mulch	Very good	25 t/ha of biomass (dry weight)
Soil fertilization	Intercropping Association with free nitrogen fixing bacteria	Very good	Cassava yield can double or even triple when combined with brachiaria compared to cassava grown in monoculture 50 nitrogen unity/ha/year
Fodder		Very good	25 t/ha of biomass (dry weight). *Brachiaria* should not constitute 100% of the feed ration for young cattle, lambs and goats as it can trigger a hypersensitivity to light.
Weed control	Cover crop/ living mulch	Very good	
Soil loosening		Very good	

Requirements and adaptability

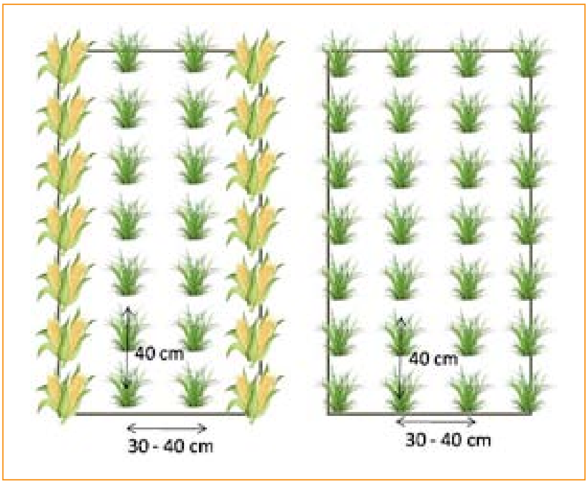
- **Soil**: adapted to a broad variety of pH, ranging from 4 to 8.Tolerates soils with high aluminum concentration. All *Brachiaria* species can grow on poor and compacted soil but they are not tolerant of flooding.
- **Temperature**: frost tolerant.
- **Light**: can tolerate slight shade.
- **Rainfall**: drought tolerant, can survive 5 to 6 months without rain. Optimum growth occurs under rainfall regimes exceeding 800 mm/year.
- **Altitude**: can be found up to 2,000 m a.s.l. in the tropics and 1,000 m a.s.l. beyond the tropics.

Cultivation

- **Breaking of dormancy**: dormancy last up to 6 or 9 months after harvest. Fresh seeds do not germinate and have to be kept for that duration or soaked in sulfuric acid.

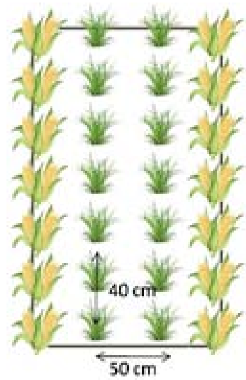
  Since the germination rate of *Brachiaria brizantha* seeds is very heterogeneous (sometimes less than 20%) propagation by root division is usually preferred to propagation by seeds.

- **Sowing**: direct seeded at the start of the rainy season, on its own for pasture establishment or intercropped with a food crop. Recommended spacing: 30 to 40 cm x 40 cm on its own, or 30 to 40 cm x 40 cm in double rows established between 2 rows of short duration crops. Seed rate: 8 to 15 seeds/hill, sown 1 to 2 cm deep. Grown in combination with short duration rice (90-100 days) *brachiaria* can either be sown simultaneously or 20 days after sowing the rice.



  Brachiaria can also be planted after cultivation of food crops for pasture establishment.

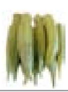
Root slips are planted 30 days after sowing corn and 60 days after okra, or when cassava is 30 to 40 cm tall, at 50 cm x 40 cm spacing using 2 root slips per hill, two thirds buried into the soil.



Spacing can be slightly wider as growth is faster than when propagated by seed. When intercropped with banana, maize or cassava, it is recommended to plant double rows of *brachiaria* between single rows of the associated crop while, when intercropped with peanuts, beans, soy beans or cow peas, single rows are used.

When intercropped with rice, single rows of *brachiaria* are established between double rows of rice.

Example of planting calendar for *brachiaria* intercropped with maize, okra or rice

Week 1	W 2	Week 3	Week 4	Week 5	Week 6	Week 7	W 8	Week 9
Sowing  		Refill 		Or root slips 		Refill 		
Sowing 								Éclat 
Sowing 			Refill or sowing 		Refill 			

- **Care**: when direct seeded, refilling of the rows is necessary 10 days after establishment. Hoeing is recommended 1 month after sowing. *Brachiaria* should be cut before it goes to seed as it can become invasive in the humid tropics. If not managed carefully it might lead to the use of herbicide thus generating a negative economical and environmental impact.

Cutting of *brachiaria* in a cassava plantation (left) and banana plantation (right), Dominique Violas, GRET, DRC, 2015.

Plants should not be cut too close to the ground or they risk being damaged and weakened.

It is recommended to leave the cut plants on the ground to protect the soil from erosion, control heliophytic weeds (that needs full sun to thrive) and fertilize the soil through their decomposition.

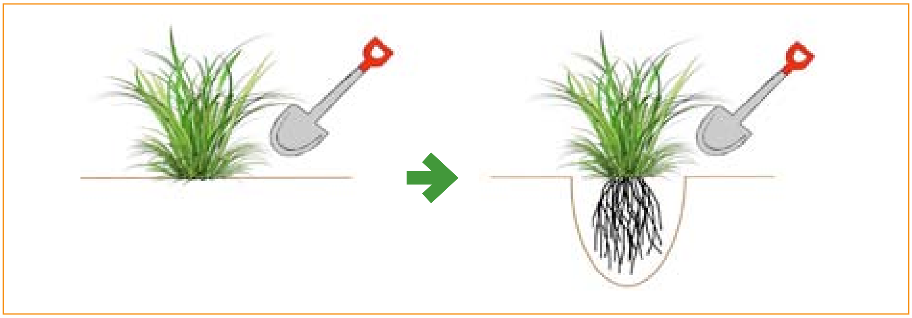
Once the main crop is harvested, the rows are switched: cassava, maize or banana rows are planted instead of brachiaria and vice versa for the following season. This allows cultivating a plot sustainably and reduces shifting cultivation.

- Intercropping: maize, banana, cassava, okra, rice, coconut, beans, cowpeas, groundnut, peanuts, etc.

Propagation/Seed production

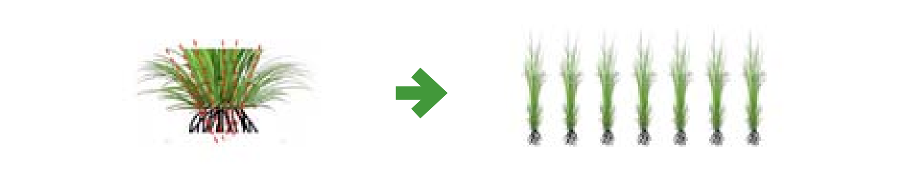
Seeds remain viable for 3 years. Harvesting by hand can yield 100 to 500 kg/ha for only 50 to 100 kg/ha of pure seeds.

Nevertheless, root division gives better results. To propagate *brachiaria* by root division, a mother clump is dug out and the tillers are divided.



Using a machete, the stems should be cut back to 20 cm length and the roots to 5 cm.

The clump is divided in bare root slips ready to be transplanted.



Before transplanting, it is recommended to soak the bare root slips in a root dip mixture containing 1/3 of cow dung, 1/3 of clay and 1/3 of water.

To learn further

Brachiaria sp. : B. ruziziensis, B. brizantha, B. decumbens, B. humidicola, in Olivier Husson *et al.*, *Manuel pratique du semis direct à Madagascar*, Cirad, GSDM, 2008, 20 p. Fiches techniques plantes de couverture : graminées pérennes. http://agroecologie.cirad.fr.

Brachiaria brizantha, Agriculture et développement en pays Antandroy : fiches techniques, Objectif Sud, Madagascar, Gret, GSDM, 2010, 3 p. http://semencesdusud.com.

Brachiaria brizantha, Tropical Forages, CSIRO Sustainable Ecosystems, CIAT, ILRI, 2005. www.tropicalforages.info.

Cajanus cajan

Botanical information

Vernacular names: pigeon pea, congo pea, ambrevade.

Family: Fabaceae.

Morphological description: shrubby plant, 3 to 5 m tall.

Root system: deep tap root developing quickly.

Life cycle: pluriannual, 1 to 5 years (but often grown as an annual). Production cycle: 8 to 9 months.

Geographical distribution: native to India, found throughout the tropics.

+

- Fixes nitrogen in the soil
- Restructures the soil
- Produces quality fodder
- Produces firewood
- Produces edible seeds for human consumption
- Is adapted to many soil types
- Does not compete with neighboring crops when intercropped as initial growth is slow
- Can grow in semi-arid climates as well as tolerate abundant rainfall

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- As initial growth is slow, requires weeding in the early stage after sowing
- Might require pesticidal and fungicidal treatments

Description

Cajanus cajan is a semi-perennial shrubby legume growing to a maximum height of 5 m. Its root system can easily penetrate the soil beyond 2 m depth. Flowers are yellow, sometimes striped with mauve or red. It produces flat pods, 5 to 9 cm long, green in color and slightly striped, each containing three to six seeds. Seeds are beige, green or brown in color, depending on varieties.

Uses

Function	Use	Quality	Output
Soil fertilization	Improved fallow Green manure Intercropping	Very good	40 kg nitrogen/ha
Erosion control	Hedgerow (windbreak) Intercropping	Very good	
Firewood		Good	7 t/ha on average in monoculture
Fodder	Leaves for ruminants Seeds for poultry and ruminants	Good	3 to 8 t/ha on average but much greater yields can be achieved
Human diet	Mostly seeds, source of vitamin A Green (immature) pods	Good	0.5 t 2 tons seeds/ha
Beekeeping	Melliferous plant	Good	
Medicinal plant			

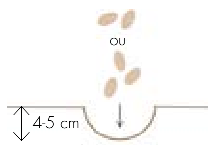
Requirements and adaptability

- **Soil**: tolerant to a broad range of soil types, it is notably well adapted to poor and degraded soils. Nevertheless, it requires good drainage. Growth is optimal at pH 5 to 7 but maximal nitrogen fixation occurs at pH 7. Responsive to organic fertilization.
- **Temperature**: even though it is not frost tolerant, it can tolerate relatively low temperatures. Optimum development occurs at 24°C.

- **Light**: performs best in full sun but can tolerate some shade during the vegetative growth phase. Nevertheless, shade can lead to the etiolation of the stems. Highly sensitive to shade during the fruiting stage, requires full sun during this phase.
- **Rainfall**: grows in areas with rainfall ranging from 300 mm/year up to 2,500 mm/year, but performs best at 1,000 mm/year.
- **Altitude**: performs best from 0 to 2,000 m a.s.l. but can grow as high as 3,000 m a.s.l.

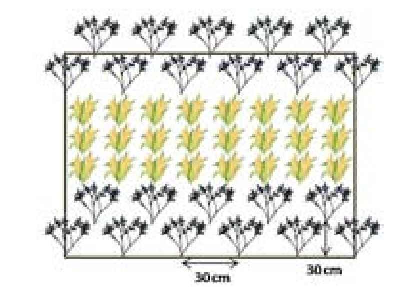
Cultivation

- **Breaking of dormancy**: none.
- **Direct seeding**: 16,000 to 18,000 seeds/kg. Does not propagate well by cuttings. Sow 2 to 3 seeds per seed hole, 4 to 5 cm deep.

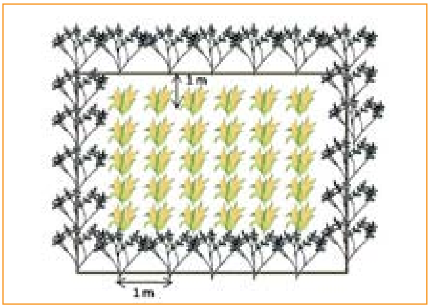


In mono-cropping: when grown on its own, pigeon pea is planted in staggered rows at 30 cm x 30 cm spacing but spacing can vary from 40 cm x 20 cm up to 200 cm x 180 cm according to numerous factors such as farmers' needs, irrigation availability, intercropping combination, average rainfall, soil fertility, etc. *Cajanus* can be grown both as single crop and intercrop, the technical itinerary changing considerably in accordance.

This technique refers to improved fallow and intercropping (see factsheet no. 1 and no. 7).



Along plot's perimeter: established as hedgerow, at 1 m in-row spacing and 1 m away from the main crop or in staggered double rows. This technique refers to hedging (see factsheet no. 19 on agroforestry).



- **Germination**: 2 to 3 days after sowing. Full emergence occurs 2 to 3 weeks after sowing.
- **Flowering**: approximately 56 to 210 days after sowing.
- **Production**: 95 to 260 days after sowing (depending on the cultivars) for seed production, 90 to 180 days when used as fodder or green manure and between 30 to 365 days for other uses.

<table>
<tr><td colspan="8">Month 1</td><td colspan="4">Month 2</td><td>M 3</td><td colspan="4">Month 4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td></tr>
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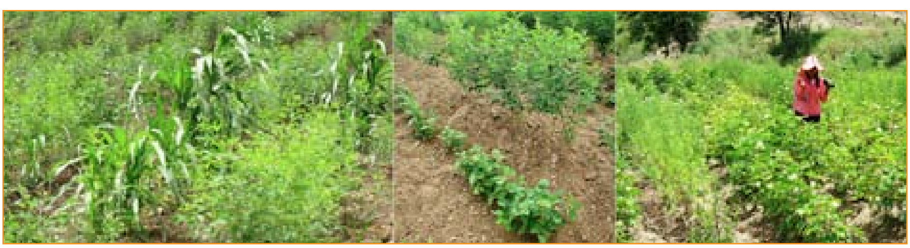
<tr><td rowspan="2"></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="9">Seed production</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="6">Green manure and fodder production</td><td></td><td></td><td></td></tr>
</table>

- **Care**: requires weeding during the first year following establishment. When used as hedgerow, coppice the plants at 40 cm height at the end of the rainy season or cut at 80 cm above ground for fodder production.

  Cajanus cajan coppices very well.

  Cajanus cajan has to be reestablished after 3 to 5 years (maximum 3 years when used to produce seeds for human consumption).
- **Intercropping**: maize, sorghum, Bambara groundnut, cassava, millet, cotton, mung bean, sesame, sunflower, peanuts.



Example of *Cajanus cajan* intercropped with (from left to right): sorghum, mung bean and cotton, Stéphane Fayon, GRET, Myanmar, 2014 et 2015.

Propagation/Seed production

Pods are harvested when fully mature and left to dry. When they crack open, seeds can be collected and stored to be used the following season.

To learn further

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Cajanus cajan, C. Orwa *et al.*, *Agroforestree Database 4.0*, World Agroforestry Centre, 2009, 5 p. www.worldagroforestry.org.

Cajanus cajan (L.) Millsp., Daniel Anand Raj, *EcoPort*, 2001. www.ecoport.org.

Cajanus cajan (L.) Millsp., L.J.G. van der Maesen, *PROTA4U*, Brink, M. & Belay, G. (Editors). PROTA (Plant Resources of Tropical Africa / Ressources végétales de l'Afrique tropicale), 2006. www.prota4u.org.

Cajanus cajan, Tropical Forages, CSIRO Sustainable Ecosystems, CIAT, ILRI, 2005. www.tropicalforages.info.

Diversité génétique des Rhizobia associés à un champ de pois d'Angole (Cajanus cajan l.) à Yamoussoukro (centre de la Côte d'Ivoire), Kouakou Romain Fossou, mémoire de diplôme d'agronomie approfondie, École supérieure d'agronomie de l'Institut national polytechnique Félix Houphouët Boigny de Yamoussoukro, Côte d'Ivoire, 2011. www.memoireonline.com.

Calliandra calothyrsus

Botanical information

© Scamperdale.

Vernacular name: calliandra.

Family: Fabaceae.

Morphological description: small tree growing to a height of 5 to 6 m with a 20 cm diameter trunk on average. In optimal conditions, it can reach a height of 12 m and the trunk can reach 30 cm in diameter.

Root system: combination of deep roots as well as extensive lateral roots.

Life cycle: fast growing perennial, the first cut is possible 8 to 12 months after sowing.

Geographical distribution: native to Central and South America, naturalized in Africa and Asia.

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- Fixes nitrogen in the soil
- Fast growing
- Produces fodder
- Produces fuel wood
- Melliferous, can be used as bee fodder in beekeeping
- Low demanding, adapted to many soil types
- Restructures the soil
- Provides erosion control

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- Weeding is compulsory during the establishment phase as it is highly sensitive to weed competition
- Aggressively colonizes perturbed environments and secondary vegetation
- Does not tolerate grazing
- Starts to become sensitive to disease in East-Africa

Description

Calliandra calothyrsus is a small tree with compound leaves made out of 19 to 60 pairs of leaflets, each measuring 5 to 8 mm long and 1 mm wide. Inflorescences are 10 to 30 cm long and red and green in color. It produces flat, brown fruits approximately 10 cm long and 1 cm wide, each containing 8 to 12 seeds. Pods spontaneously crack open when fully mature. The ellipsoidal seeds are mottled dark brown and measure 5 to 7 mm.

Uses

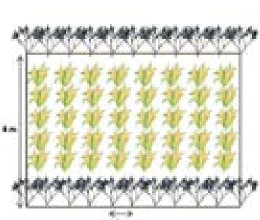
Function	Use	Quality	Output
Soil fertilization	Improved fallow Intercropping Mulch	Very good	Fixes 200 to 643 kg/ha of nitrogen
Fodder	Leaves	Good	3 to 9 t/ha/year of leaves. Due to the presence of tannins it is important to properly dose this fodder in the feed ration.
Fuel wood	Firewood Charcoal	Good	Firewood: 2 to 7 t/ha/year of small branches for firewood. 15 to 40 t/ha as soon as the first year from prunings. Charcoal: 14 t/ha/year
Erosion control	Improved fallow Intercropping	Very good	
Beekeeping		Very good	
Shade	For houses and nurseries	Very good	

Requirements and adaptability

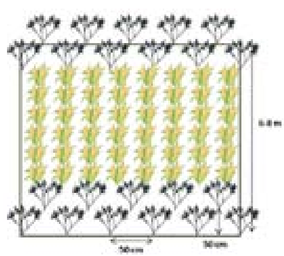
- **Soil**: intolerant of water logging and compacted soils but well adapted to poor soils and tolerant to slightly acidic soils.
- **Temperature**: from 18 to 28°C, doesn't tolerate frost.
- **Light**: full sun, doesn't tolerate shade.
- **Rainfall**: 2,000 and 4,000 mm/year with 3 to 6 months dry season.
- **Altitude**: optimum below 1,300 m a.s.l. but can grow up to 2,000 m a.s.l.

Cultivation

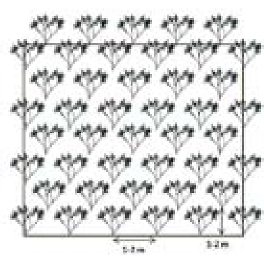
- **Breaking of dormancy**: scarification or soaking of the seeds in lukewarm water for 24 hours.
- **Propagation**: direct seeding, saplings raised in nursery or cuttings are established simultaneously to the food crop at the start of the rainy season. Recommended spacing:
  - 1 m x 2 m (minimum 1 m x 1 m) for firewood, fodder or honey production;
  - 25 cm x 4 m for single hedgerows or 50 cm x 6 to 8 m for double hedgerows when used for soil fertilization.



Single hedgerow



Double hedgerow



Fallow plot

- **Germination**: 4 to 21 days after sowing.
- **Care**: weeding is crucial the first months following establishment to prevent weed competition.
- **Harvest**: first cut is possible as early as 8 to 12 months after sowing. Can be coppiced at 50 cm from ground level every 2 to 3 months for 10 to 50 years. Can be used for improved fallow (see factsheet no. 7).
- **Intercropping**: coconut, banana etc. (see factsheet no. 19 on agroforestry).

Propagation/Seed production

Approximately 19,000 seeds/kg.

Seed viability can be preserved for several years when stored in an air tight container at 3°C.

To learn further

Guide PST pour l'établissement et l'aménagement des haies vives, Manuel pratique n° 1, Projet Sove Te, Associates in Rural Development, USAID, 1990, 37 p. http://pdf.usaid.gov.

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Gestion de la fertilité du sol à travers les techniques de jachères améliorées, T. Sado, World Agroforestry Centre publications, Icraf, 2008, 10 p. www.worldagroforestry.org.

Évaluation de l'effet fertilisant de *Mucuna utilis* L. face à deux doses de NPK (17-17-17) sur la croissance et la production de la variété samaru du maïs (Zea mays L.) dans les conditions optimales, W. Mokuba, R.V. Kizungu, K. Lumpungu, *Congo Sciences*, vol. 1, n° 1, nov. 2013, pp. 23-30. www.congosciences.cd.

Calliandra calothyrsus, Tropical Forages, CSIRO Sustainable Ecosystems, CIAT, ILRI, 2005. www.tropicalforages.info.

Canavalia ensiformis

Botanical information

Vernacular names: jack bean, pois sabre, sword bean.

Family: Fabaceae.

Morpholigical description: subligneous herbaceous plant with a climbing habit, growing to a height of 0.5 to 2 m. Can sometimes be shrubby.

Root system: deep.

Life cycle: semi-perennial.

Geographical distribution: native to Central America, naturalized throughout the world.

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- Fixes nitrogen in the soil
- Produces edible pods and fruits for human consumption
- Produces fodder
- Fast growing
- Disease and pest resistant
- Adapted to poor soils
- High biomass producer
- Secretes a nematicidal substance
- Potentially fungicidal
- Controls weeds

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- Fodder is toxic to pigs
- It should not constitute more than a little fraction of the feed ration for ruminants. Seeds must be boiled first

Description

Canavalia ensiformis is an erect herbaceous legume, less than 2 m tall but reaching up to 10 m long. It is very fast growing and can completely cover the soil in less than 2 months. Leaves are trifoliate, 8 to 20 cm long. Flowers are pink, mauve or white with a red base and approximately 2.5 cm in length. Pods are very elongated, approximately 30 cm long, with two longitudinal ribs near the upper suture. Seeds are white and smooth and measure 1 to 2 cm.

Uses

Function	Use	Quality	Output
Soil fertilization	Green manure	Very good	Produces 40 to 50 t/ha wet weight or 23 t/ha dry weight of biomass within 9 months, potentially providing 80 kg of nitrogen
Human consumption	Seeds (eaten or used as coffee substitute) Pods	Very good	5.4 t dry seeds/ha
Fodder	Leaves Seeds Stem	Medium	18 to 23 t/ha. As it is slightly toxic, so it should uniquely be used when dry and in small quantities (maximum 30% of the feed ration) for cattle or else boiled seeds can be used. Not recommended for pigs
Pest and disease control	Root exudates have nematicidal compounds	Good	

Requirements and adaptability

- **Soil**: well adapted to poor and acidic soils (pH 4.3 to 6.8), tolerates very short flooding and soil salinity.
- **Temperature**: optimum from 14 to 27°C but can tolerate slight frost as well as resist high temperatures (though excess of heat will have a defoliating effect).
- **Light**: sun loving plant, tolerates some shade.
- **Rainfall**: drought tolerant. Nevertheless, optimal development occurs under rainfall regimes of 800 to 2,000 mm/year.
- **Altitude**: best from sea level up to 1,500 m but can be found up to 1,800 m.

Cultivation

- **Breaking of dormancy**: seeds should be soaked in water overnight.
- **Sowing:** broadcasted when seeds are abundant, otherwise sown in furrows after plowing prior to rainy season. Seed rate: 95 to 125 kg/ha.
- **Germination**: starts 7 days after sowing.
- **Care**: very little to no care is required as *Canavalia* quickly covers the ground and smothers weeds. Therefore, the need for hoeing is greatly reduced.
- **Harvest**: incorporation 64 days after sowing when used as green manure (see factsheet no. 10 on green manure). Flowering occurs 45 to 50 days after sowing. For pods production, harvest starts 80 to 120 days after sowing. Seeds are harvested 180 to 300 days after sowing (when plants have not suffered flooding).
- **Intercropping**: banana, yam, in rotation with rice.

Propagation/Seed production

For seed production, sow *Canavalia ensiformis* directly after rice harvest, when the soil is still moist or sow seeds on the rice field berms, above flood level.

To learn further

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Canavalia ensiformis (L.) DC, *Grassland Species Profiles*, CIAT, FAO. www.fao.org.

Canavalia ensiformis, une plante de service fournissant de l'azote et à propriétés nématorégulatrices, Harry Ozier-Lafontaine, Régis Tournebize, Isabelle Boulogne, Mylène Ariste-Zelise, Trans-FAIRE, Inra. http://transfaire.antilles.inra.fr.

Jack bean (*Canavalia ensiformis*), Valérie Heuzé, Gilles Tran, *Feedipedia*, Inra, Cirad, AFZ, FAO, 2015. www.feedipedia.org.

Information and data on the use of Greenmanure/Covercrops (gmcc) from manual on "Natural Paddy Cultivation" by the Surin Farmers Support (SFS) project, Surin Province, NE Thailand, 9 p. http://sri.cals.cornell.edu/

Jack bean, Canavalia ensiformis, USDA, Natural Resources Conservation Service, Plant Guide, 4 p. http://plants.usda.gov.

Chromolaena odorata

Botanical information

Vernacular names: herbe du Laos, Bitter bush, Siam weed, zaïre.

Famille: Asteraceae.

Morphological description: bushy plant 1.5 to 2 m tall with a partially lignified stem. Grows in dense thickets.

Root system: deep taproot with a fibrous and shallow (20-30 cm maximum) secondary root system.

Life cycle: perennial, grows up to 5 meters per year.

Geographical distribution: native to the American continent, naturalized in Oceania, Africa and Asia.

+

- Protects forest against bushfire
- Encourages forest pioneer species establishment in savannas thanks to the shade it provides
- Used on fallow plots, it improves soil fertility and allows intensifying cultivation in the case of shifting agriculture
- Is drought resistant
- Helps to control erosion
- Helps in controlling nematodes in pepper and tomato plantations
- Helps in controlling *Imperata cylindrical* (an aggressive graminacea)
- Is used in traditional medicine

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- Is highly invasive (considered one of the 100 most invasive species)
- Constitutes a challenge for animal husbandry in savannas because of its invasiveness.
- Competes with local flora

Description

Chromolaena odorata is a 1.5 to 2 m tall herbaceous perennial forming dense thickets. It can reach 6 to 10 m when climbing on other plants. Stems are soft with a ligneous base.

The whole plant is covered in fine and short hairs (pubescent). Crushed leaves produce a strong smell. Flowers are white or bluish and cover the whole surface of the shrub.

Uses

Function	Use	Quality
Soil fertilization	Fallow	Good
Erosion control	Fallow	Very good
Weed control	Competes with *Imperata cylindrica*	Very good
Integrated pest management	Deters nematodes and certain species of insects	Good
Protection against wildfire	Forest edge	Very good
Encourage forest establishment	Thanks to the shade it produces, this shrub promotes the establishment of forest species. Nevertheless, it requires regular care to prevent smothering of the tree seedlings	Good given care is provided

Requirements and adaptability

- **Soil**: tolerates neutral and acidic soils. Can adapt to different soil textures and does not require good drainage.
- **Temperature**: can tolerate temperature as low as 0°C but grows usually in temperatures close to 20°C.
- **Light**: grows best in full sun.
- **Rainfall**: 1,000 to 3,000 mm/year.

Cultivation

This plant is not cultivated but is harvested in the wild for the confection of biopesticides (see factsheet no. 5).

Propagation/Seed production

Chromolaena odorata flowers every year during dry season and produces an abundance of seeds. On average, 50% of the seeds lose their viability after 3 months when buried in the ground and 90% when on the surface. Nevertheless, some seeds can remain viable up to 5 years, both at the surface or buried in the ground.

Sexual propagation occurs when conditions for vegetative propagation are not favorable.

To learn further

Chromolaena odorata, la plante qui protège la forêt, IRD, Fiche d'actualité scientifique n° 61, 1998, 1 p. www.ird.fr.

Chromolaena odorata (herb), Colin Wilson, *Global Invasive Species Database*, IUCN/SSC Invasive Species Specialist Group (ISSG), 2016. www.issg.org.

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Chromolaena odorata (Siam weed), Nick Pasiecznik, Invasive Species Compendium (ISC), CABI, 2007, datasheet. www.cabi.org.

Crotalaria juncea

Botanical information

Vernacular names: sunn hemp, chanvre indien, chanvre du Bengale.

Family: Fabaceae.

Morphological description: shrub growing to a height of 1 to 3 m (not exceeding 4 m).

Root system: shallow taproot with an abundance of lateral roots.

Life cycle: annual.

Geographical distribution: native to Asia, grown throughout the wet and dry tropics.

+

- Fixes nitrogen in the soil
- Is fast growing
- Produces quality fodder
- Is resistant to nematodes, can actually control nematode population in a plot thanks to biochemical interactions
- Is drought tolerant
- Is adapted to a wide range of soil types
- Restructures the soil thanks to its extensive root system
- Controls weeds

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- Sensitive to pest and disease
- Slight risk of becoming invasive in certain environments
- Intolerant of water logging

Description

Crotalaria juncea is an erect annual plant, halfway between an herbaceous and shrubby habit, which rarely exceeds 3 m in height. It has extensive lateral roots in addition to a strong tap root. Stems are 2 cm in diameter and 0.6 to 1.5 long but these measurements vary with plant density. It has simple, bright green leaves, 4 to 12 cm long and spirally arranged along the stem. Inflorescences are made out of 10 to 20 yellow flowers and measure 15 to 25 cm on average. Pods are cylindrical, plump and grooved on the upper surface. They are light brown when mature and measure 2 to 4 cm long and 1 to 2 cm wide. Each pod contains 6 to 12 seeds.

Uses

Function	Use	Quality	Output
Soil fertilization	Green manure Intercropping	Very good	Fixes 120 kg/ha of nitrogen
Fodder	Dry leaves Seeds for horses and pigs	Good	40 to 60 t/ha or 2.5 to 4.5 t/ha of dry matter. Toxic when given in big quantities, should not exceed 45% of feed ration for sheep and10% for cattle. Pigs and horses should not be fed leaves.
Weed control	Fast growing and high biomass producing cover crop	Very good	
Fiber production		Very good	
Nematode control	Biochemical interaction	Good	
Erosion control	Fast growing and high biomass producing cover crop	Very good	

Function	Use	Quality	Output
Human diet	Coffee substitute (toxic if not roasted)	Poor	
Paper, fibers	Best when low humidity	Good	

Requirements and adaptability

- **Soil**: well adapted to poor soils and responsive to fertilizer application. Performs best in well drained soils. Adapted to pH ranging from 5 to 8.4 but optimal growth at pH 6 to 7. Mostly intolerant of soil salinity.
- **Temperature**: adapted to temperatures ranging from 8°C to 30°C. Can tolerate light frost (– 2°C) for very short periods.
- **Light**: any reduction in light exposure translates into slower growth rate.
- **Rainfall**: highly drought resistant. Can survive with as little as 200 mm/year rainfall (but biomass production is low).
- **Altitude**: up to 1,500 m a.s.l.

Cultivation

- **Breaking of dormancy**: none.
- **Sowing**: surface harrowing followed by sowing at 1 or 2 cm depth, at a rate of 30 kg/seed/ha.
- **Germination**: 3 days after sowing.
- **Care**: highly competitive, does not require any care.
- **Harvest**: mechanical termination using a roller at flowering peak, 40 to 45 days after sowing or 3 to 4 weeks before main crop cultivation. For fodder production, four hoeing cycles starting 6 to 8 weeks after sowing are required. For fiber production, plants are harvested 90 to 110 days after sowing. Seeds can be harvested 120 to 160 days after sowing. When used as green manure, plant biomass can be incorporated 45 to 90 days after sowing (see factsheet no. 7 on improved fallow and factsheet no. 10 on green manure).
- **Intercropping**: can be grown in combination with maize, sorghum, tobacco, cotton, sugar cane, pineapple, coffee. Can also be grown alongside fruit trees in orchards or used as green manure in rice cultivation.

Propagation/Seed production

Cross pollination by means of insects is very high between *Crotalaria juncea* varieties. In order to preserve purity, it is crucial to grow the different varieties in plots sufficiently spaced apart. Seed yield varies greatly depending on the varieties as well as with pest and disease occurrence. Yield is usually between 0.5 to 1 t/ha but, in optimal condition, it can reach 1.8 to 2.5 t/ha. Seeds should be dried to below 10% moisture content and stored in a cold, dry place.

To learn further

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Les plantes de couverture en Côte d'Ivoire : guide pratique de reconnaissance et d'utilisation des légumineuses en Côte d'Ivoire, H. Botton, N. Hallé, Paris, Museum d'histoire naturelle, 1958, *Journal d'agriculture tropicale et de botanique appliquée*, tomes IV (1957) et V (1958), 194 p. www.documentation.ird.fr.

Gliricidia sepium

Botanical information

Vernacular names: madre de cacao, gliricidia.

Family: Fabaceae.

Morphological description: small tree 5 to 15 m in height and 50 to 70 cm in diameter at its base. Low ramification.

Root system: deep.

Life cycle: perennial.

Geographical distribution: native to South and Central-America, naturalized in Africa and Asia.

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- Fixes nitrogen in the soil
- Is fast growing
- Produces fuel wood and timber
- Produces fodder
- Is tolerant of repeated coppicing, pruning and defoliation
- Is fire resistant
- Melliferous, can be used in beekeeping
- Can be used as medicinal plant
- Can be used as rat poison
- Is resistant to *Heteropsylla cubana*
- Is mostly disease resistant
- Is adapted to many soil-climatic conditions

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- Prone to pest attack in certain areas (Indonesia, Caribbean)
- Can be invasive in its native range
- Inoculation with the appropriate rhizobium strain might be necessary outside of its native range (when not yet naturalized) to allow nitrogen fixation

Description

Gliricidia sepium is a very fast-growing (after the first year) leguminous tree growing up to 3 m/year. It can be found in humid areas throughout the world, in plains or on hills and gentle slopes. Gliricidia is evergreen under humid conditions. The bark ranges from white-grey to brown-red. The 30 cm long leaves are made of 7 to 25 leaflets, 2 to 7 cm long. Inflorescences are 5 to 15 cm long and flowers are pink with a white tinge and usually have a yellow dot at the base of the petals. It produces green pods that acquire a purple-reddish tinge when maturing. Pods are 10 to 18 cm long and 2 cm wide, containing approximately 7 seeds.

Uses

Function	Use	Quality	Benefit
Soil fertilization	Improved fallow Mulch Green manure Hedgerow	Very good	Improved fallow: up to 345% increase in maize yield. Fixes 212 kg/ha of nitrogen. Mulch: up to 140% increase in maize yield. Green manure: produces 15 t/ha/year equivalent to 40 kg ha/year of nitrogen
Fuel wood	Firewood	Very good	4,550 kcal/kg
Timber		Very good	Hard wood, termite resistant 8 to 15 m^3/ha after 3 or 4 years, 11 to 21 m^3/ha by coppicing
Erosion control	Hedgerow	Very good	
Fodder	Only suitable for ruminants, toxic to other animals	Good	2 to 20 t/ha/year of dry matter (depending on technical itinerary). Leaves are high in protein and easily digestible
Weed control	*Imperata cylindrica* control	Good	
Beekeeping		Very good	
Human diet	Flowers	Good	
Shading	For coffee, tea or cacao plantation	Very good	

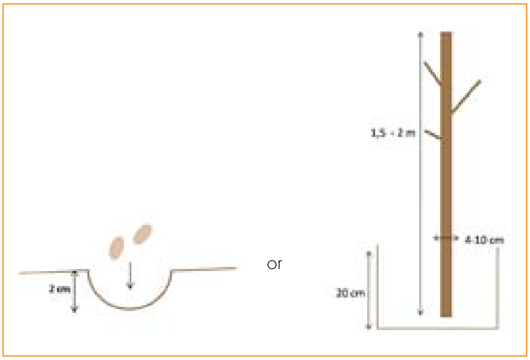
Function	Use	Quality	Benefit
Stake	For vanilla, black pepper, passion fruits	Good	
Poison	Seeds		
Medicinal	Leaves	Good	

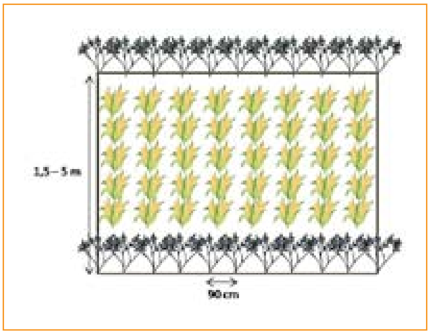
Requirements and adaptability

- **Soil**: adapted to a broad range of sandy, silty or clayey soils. Likes acidic soils (pH 4.5 to 6.2) and is tolerant of poor soils. Intolerant of water logging, requires well drained soil.
- **Temperature**: 15 to 30°C, frost intolerant.
- **Sunlight**: shade intolerant (even light shade).
- **Rainfall**: can grow in areas with rainfall ranging from 600 to 3,500 mm/year. Drought tolerant.
- **Altitude**: 0 to 1,600 m a.s.l.

Cultivation

- **Breaking of dormancy**: not required for fresh seeds. For stored seeds, soaking in hot water overnight is recommended. Seeds have to be planted immediately after soaking.
- **Planting**: gliricidia can be propagated either by cutting or by seed. Cuttings are made using branches 5 to 6 months old, 1.5 to 2 m long and 4 to 10 cm in diameter and planted at 20 cm depth. Seeds are sown directly in the field or in planting bags at 2 cm depth. When raised in nursery, seedlings can be transplanted 3 months after sowing.





To establish hedgerows in a plot, gliricidia should be sown at 90 cm (or closer, down to 50 cm) in-row and 1.5 to 5 m inter-row spacing.

In-row spacing can also be greater when using gliricidia for perimeter hedgerows. In this case, cuttings are often used.

There are many possible intercropping layouts, depending on the producers' needs, ranging from 4,000 to 10,000 tree/ha, planted in double or single rows, at different inter-row spacing but always staggered (see factsheet no. 19 on agroforestry for further details on possible layouts).

- Germination: 90 to 100% germination 7 days after sowing. When using cuttings, leaves start appearing approximately 4 weeks after planting under humid condition.
- Care: weeding is crucial the first few months to prevent weed competition as gliricidia grows slowly the first year following establishment. Gliricidia can be pruned 2 to 3 times/year, 0.3 to 1.5 m above ground level to stimulate leaf production. Coppicing is practiced in the case of firewood production.
- Harvest: gliricidia starts producing seeds 6 to 8 months after sowing. For timber, harvest starts 3 to 4 years after planting (8 to 15 m^3/ha), then every 2 to 3 years by coppicing (11 to 21 m^3/ha). Pruning residues can be used for fodder.

Propagation/Seed production

Orthodox seeds, can be dehydrated without damage and stored for 12 months in open storage. 8,500 seeds/kg.

Gliricidia is most often propagated by cuttings as it responds very well to this technique. Nevertheless, cuttings are not adapted to poor soils.

To learn further

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Indigofera hirsuta

Botanical information

Vernacular names: indigo poilu, hairy indigo.

Family: Fabaceae.

Morphological type: herbaceous subligneous species, 50 to 1.50 m in height (80 cm on average).

Root system: taproot.

Life cycle: annual or biannual.

Geographical distribution: native to Africa, Asia and Oceania, can be found throughout the tropics and in the USA.

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- Fixes nitrogen in the soil
- Produces a lot of biomass
- Is resistant to nematodes and to most diseases and insects
- Is adapted to poor and acidic soils

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- May become invasive

Description

Indigofera hirsuta occurs naturally in many environments, such as emerged parts of rice fields, fallow lands, savannas, forest edges and river banks. It has been grown for green manure since the beginning of the 19th century.

Branches are covered in brown hairs. Leaves are alternate, with 5 to 7 (sometimes 11) leaflets, each 4 cm long and 2.5 cm wide. Flowers are bright pink and grouped in 25 to 30 cm long compact clusters.

Stems become hard when the plant reach maturity. Pods are 12 to 20 mm long and 2 mm wide, covered in brown hairs, and contain 6 to 9 seeds each.

Uses

Function	Use	Quality	Benefit
Soil fertilization	Green manure Living mulch/ cover crop	Very good	80 to 90 kg/ha/year of nitrogen on average but can fix up to 126 kg/ha/year
Fodder	Leaves	Very good	9.7 t/ha of dry matter (40 t/ha of fresh matter)
Erosion control	Living mulch/ cover crop	Good	40 t/ha of fresh matter
Weed control	Living mulch/ cover crop	Good	40 t/ha of fresh matter
Dye	Leaves	Good	
Medicinal	Leaves	Good	

Requirements and adaptability

- **Soil**: ruderal species, adapted to poor and sandy soils, slightly acidic (pH from 5 to 8). Intolerant of waterlogging.
- **Temperature**: 15 to 28°C.
- **Light**: long-day photoperiodic species. Shade intolerant.
- **Rainfall**: optimum from 900 to 1,700 mm/year but can tolerate up to 2,500 mm/year.
- **Altitude**: from sea level up to 1,350 m or even as high as 1,500 m a.s.l.

Cultivation

- **Breaking of dormancy**: soaking seeds for 5 min in 80°C water accelerates germination and significantly increases germination rate.
- **Direct seeding**: 3 to 5 kg seed /ha if sown in furrows or 6 to 10 kg seed/ha if broadcasted.
- **Germination**: 7 days after sowing.
- **Care**: weeding is required 4 to 6 weeks after sowing, once the plant can be told apart from the weeds. *Indigofera hirsuta* grows relatively slowly in its early stage.
- **Harvest**: 100 to 120 days after sowing for green manure incorporation (see factsheet no. 10 on green manure). 2 years after sowing for dye.
- **Intercropping**: other pasture plants, coconut.

Propagation/Seed production

Usually propagated by seed. 440,000 seed/kg.

Plants can only regrow if harvested young. Indeed, once already tall, axillary buds are cut during harvest, hindering regrowth.

To learn further

Indigofera hirsuta L., *Plantes des rizières de Guyane*, Cirad. http://plantes-rizieres-guyane.cirad.fr.

Indigofera hirsuta L., Globinmed. www.globinmed.com.

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Indigofera hirsuta (indigo velu), *Invasive Species Compendium* (ISC), CABI, 2014, datasheet. www.cabi.org.

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Leucaena leucocephala

Botanical information

Vernacular names: white popinac, faux mimosa, jumbay, cassis, leucéna à tête blanche.

Family: Fabaceae.

Morphological description: small tree 3 to 10 m tall (can reach up to 20 m in certain conditions).

Root system: tap root and extensive secondary root system.

Life cycle: perennial.

Geographical distribution: native to Central America, common throughout the lowland tropics.

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- Is drought tolerant
- Fixes nitrogen in the soil
- Produces fodder
- Is very good for erosion control as it grows well on steep slopes and degraded lands (good candidate for reforestation and watershed protection)
- Loosens the soil thanks to its strong root system
- Is very fast growing
- Is relatively fire tolerant
- Is a good shade tree thanks to its growth habit
- Nearly continuous flowering, making it suitable for beekeeping

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- Sensitive to pests
- Invasive in certain environments (perturbed environments, secondary vegetation)
- Contains toxic compounds
- Low tolerance to low temperatures and acidic soils

Description

Leucaena leucocephala is a very fast growing shrub or small tree (growing up to 3-4 m/year) with abundant foliage and a highly ramified growth habit. Flowers are white. Fruits are brown flat pods, 8 to 20 cm long and 2 cm wide. Pods are arranged in clusters of 5 to 20. Each pod contains 8 to 18 seeds, brown-orange in color when fully mature.

Uses

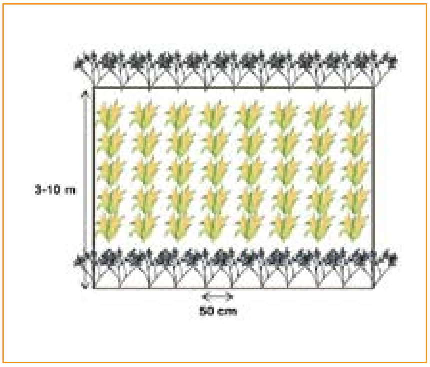
Function	Use	Quality	Benefit
Fodder	Leaves are high in protein but should not make up too much of the feed ration as they contain mimosine and tannins (toxic in high doses to non-ruminants)	Medium	3 to 9 t/ha/year of leaves Should not exceed 30% of feed ration
Soil fertilization	Green manure Intercropping Improved fallow Mulch	Good	Approximately 500 kg/ha/year of nitrogen. Up to 86% increase in maize yield
Human diet	Young pods, flowers, leaves, seeds (as coffee substitute). Gum can also be used	Good	
Fuel wood	Firewood	Good	2 to 7 t/ha/year of small branches, 4,600 kcal/kg
Timber		Good	800 kg/m^3 but seldom exceeds 30 cm in diameter
Shading	For coffee, cacao or tea	Good	
Stake	Black pepper vines etc.	Good	

Requirements and adaptability

- **Soil**: adapted to most soil types but grows best in well drained, neutral to calcaerous soils. Grows poorly on acidic soils.
- **Temperature**: intolerant of temperatures below 15°C. Performs best at 25 to 30°C.
- **Light**: sun loving.
- **Rainfall**: 650 to 3,000 mm. Can tolerate long dry seasons (6 months or more) but productivity is severely impacted.
- **Altitude**: 0 to 1,500 m a.s.l.

Cultivation

- **Breaking of dormancy**: seeds can be soaked in hot water for 2 minutes or scarified at their extremities.
- **Direct seeding**: high density is recommended for fodder production, producing up to 40-80 t/ha a year if moisture is not a limiting factor. For alley cropping, rows are spaced 3 to 10 m apart with 0.5 m in-row spacing (see factsheet no. 14 on mulch and factsheet no. 19 on agroforestry).



- **Germination**: 50 to 80% germination rate after treatment.
- **Care**: weeding is crucial to prevent competition. Coppices well. Cut 2 m above ground level for coffee substitute production. Annual pruning for timber production.
- **Harvest**: for green manure and firewood production, trees can be regularly coppiced, starting 3 years after establishment. For timber production, coppicing starts 8 years after establishment (which correspond to *Leucaena leucocephala* biological cycle). Trees can be pruned on a regular basis for fodder and liquid manure production (sheet no. 9).

Propagation/Seed production

Seed yield can range from 250 kg/ha to 2 t/ha according to cultivation conditions.

Orthodox seeds with high storing capacity (viability can last up to 20 years in open storage at room temperature). 15,000 to 20,000 seeds/kg.

Vegetative reproduction is rarely used.

To learn further

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Moringa oleifera

Botanical information

Vernacular name: moringa.

Family: Moringaceae.

Morphological description: small tree growing to a maximum height of 8 to 12 meters, for a diameter not exceeding 60 cm.

Root system: deep tap root.

Life cycle: moringa is perennial but is often cultivated as an annual crop due to its rapid growth (up to 2.5 m in 1 to 3 months).

Geographical distribution: native to India but present throughout the humid tropics.

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- Has excellent nutritional value (used as a remedy for malnutrition)
- Produces fodder
- Seeds can be used to purify water
- Is fast growing
- Is fire and wind resistant
- Has medicinal proprieties
- Can be used as firewood
- Can be used as biopesticide against fungal diseases.

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- Young plants are sensitive to termites and nematodes

Description

Moringa oleifera is a small and extremely fast growing tree found throughout the humid tropics. The 20 to 70 centimeters long leaves are made up of small rounded leaflets. Flowers are white with yellow stamens. Fruits form 20 to 60 cm long pods, brown when fully mature, each containing 12 to 35 seeds.

Moringa has excellent nutritional properties and most of its parts are edible: the leaves, dried and made into a powder added to dishes as a dietary supplement, the pods (when still tender) and the seeds.

Leaves are an excellent source of fodder for cattle.

Various plant parts are used to make medicines.

Seeds are used as a flocculant agent to clarify water.

Uses

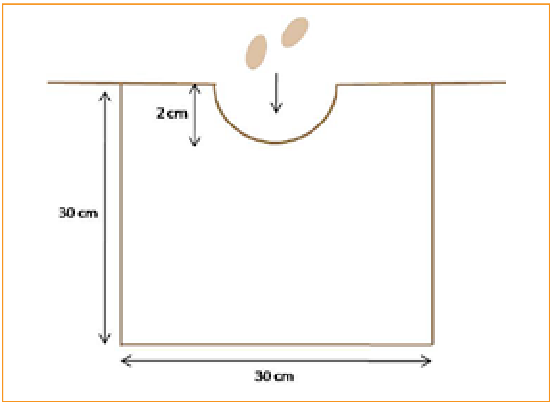
Function	Use	Quality	Output
Human diet	Leaves Pods Seeds Roots (horseradish substitute)	Very good	High in vitamins A, B and C, in proteins and in minerals. Very high biomass producer generating up to 650 t/ha in intensive cultivation (at high density with very low spacing)
Erosion control	Windbreak Used in intercropping	Good	
Fodder	Leaves and branches	Very good	High biomass producer, depending on the planting density
Fuel wood	Firewood	Good	
Water purification	Flocculant	Very good	
Medicinal		Very good	

Requirements and adaptability

- **Soil**: tolerant of poor soils provided they are well drained; adapted to silty, sandy or sandy-silt soils (with pH ranging from 5 to 9) but not resistant to very clayey soils.
- **Temperature**: optimal growth at 25 to 35°C but can tolerate temperatures as high as 40°C.
- **Light**: sun loving tree, saplings can benefit of some shade in the nursery depending on climate.
- **Rainfall**: 800 to 2,000 mm/year.
- **Altitude**: generally found from sea level up to 1,000 m, but can be seen as high as 1,300 m a.s.l.

Cultivation

- **Germination**: 85% germination rate, 5 to 12 days after sowing (14 days maximum).
- **Breaking of dormancy**: unnecessary, but seeds can be soaked overnight in cold water to increase germination rate.



- **Sowing**: direct seeding in the field is preferred over nursery raising. Dig (or loosen) 30 cm x 30 cm x 30 cm holes and back fill without compacting the soil, so it remains loose, in order to facilitate tap root development. Sow two seeds per seed hole at 2 cm depth. In the case of saplings raised in nursery, when direct seeding is not possible, sow two seeds per planting bag at 2 cm depth. Saplings should be transplanted after 4 to 6 weeks, when 30 cm tall, in 30 cm x 30 cm x 30 planting holes (see factsheet no. 17 on tree nursery).

› **Propagation by cuttings**: plant cuttings 4 to 5 cm in diameter and 1 to 1.5 m long in 50 cm x 50 cm x 50 cm planting holes, burying a third of their length.

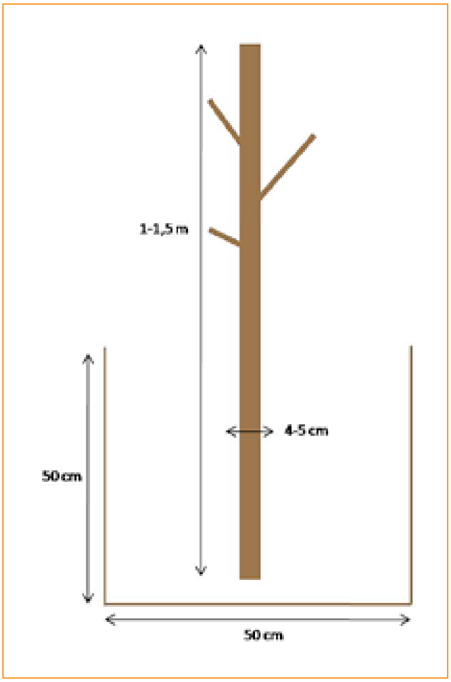
Plant spacing depends on the objective:

– for leaf production in monocropping, a 50 cm x 1 m planting pattern is used. It is possible to use closer in-row and inter-row spacing, but soil amendments are then required and the risk of disease increases, necessitating specific preventive techniques, making management difficult for small producers;

– used in alley cropping, moringa rows are inserted every 2 to 4 m between subsistence crops;

– to form a windbreak, moringa is planted along the perimeter of the plot (see factsheet no. 19 on agroforestry);

– for seed production, trees are planted in staggered rows at 3 m x 3 m spacing.



› **Care**: if both seeds germinated, select the most vigorous sapling when reaching 15 cm in height, carefully uprooting the other one without damaging neighboring roots.

Trees are pollarded at 0.5-1 m from ground level to give a bushy shape at man's height and favor lateral branching. Cut terminal bud of lead branch as well as the ones from the lateral branches appearing then. Some further pruning might be necessary to maintain the shape.

› **Harvest**: leaves are harvested several times a year, according to seasons. During rainy season (or when irrigated), they can be harvested every 30 to 40 days. Leaves are harvested by cutting branches at desired height – between 30 to 100 cm above ground level – or by plucking.

Seeds are harvested when fruits are fully mature: pods turn brown, dry up and split open.

- Intercropping: moringa can be grown alone or in association with other crops such as black eyed peas, soy beans or peanuts. It is not recommended to intercrop moringa with crops requiring high level of nitrogen, such as maize or cassava, or growing tall like millet and sorghum (competition for light).

Propagation/Seed production

Propagation can be done by cuttings or by seed. A single tree can produce 15,000 -25,000 seeds/year. There are approximately 4,000 seeds (with their envelope) per kg of seed.

When left in the open air, seeds lose their germination capacity after 1 year; therefore they should not be stored for extended period of time. On the other hand, when stored at low temperature (approximately 3°C) in an airtight container, the germination capacity can be preserved for a few years.

To learn further

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Mucuna pruriens

Botanical information

Vernacular names: mucuna, pois mascate, velvet bean.

Family: Fabaceae.

Morphological description: climbing vine.

Root system: shallow.

Life cycle: annual, 3 to 12 months duration crop.

Geographical distribution: native to South China and East India, naturalized throughout the world.

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- Fixes large amounts of nitrogen in the soil
- Produces high biomass quantity
- Large seeds, making seedlings resistant in their early stage
- Is easy to establish
- Produces good quality fodder
- Has a medium duration cycle. Allows not occupying the soil too long for farmer producing on small plots
- Is resistant to pests and diseases

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- Must be controlled in order not to smother other species intercropped or diffuse out of the field
- Requires protection during dry season
- Sensitive to weed competition in its early stage
- Fast mineralization of the residues making it of low interest for mulching
- Low level of leaf palatability for cattle

Description

Mucuna pruriens is an annual leguminous vine with stems reaching up to 18 m in length. The white or mauve flowers grow in clusters and inflorescences measure up to 32 cm in length. Pods are oblong, S shaped, and 3 to 14 cm long.

Uses

Mucuna pruriens is efficient in maintaining and restoring soil fertility, making it easier to resume cultivation after a fallow period. Indeed, by producing an abundance of biomass and providing a thick ground cover, *Mucuna pruriens* limits erosion and smothers weeds thus diminishing the arduousness of soil preparation. This species is notably recommended for soil rehabilitation, in combination with a restructuring plant. Also provides fodder.

Seeds are toxic if not treated but become edible to humans after roasting like coffee. In some countries, mucuna seed flour is used in gravies (Ghana). Contrary to *Mucana pruriens utilis*, *Mucuna pruriens* has skin-irritating hair on mature pods, making it difficult to harvest seeds.

Function	Use	Quality	Benefit
Erosion control	Living mulch/Cover crop	Very good	5 to 12 t/ha of dry matter depending on rainfall
Weed control	Living mulch/Cover crop	Very good	5 to 12 t/ha of dry matter depending on rainfall
Soil fertilization	Relay cropping Improved fallow Green manure	Very good	Provides up to 200 kg/ha of nitrogen for the following crop. Biomass production: 8.2 to16.4 t of leaf/ha
Fodder	Seeds can contain up to 20% protein (requires treatments, as for non-ruminants) Leaves (for ruminants)	Good*	Seeds: 0.2 to 2.0 t/ha Leaves: 8.2 to 16.4 t/ha
Human diet	Coffee substitute (must be roasted to suppress toxicity)	Low	
Medicinal		Good	

* In the case of sheep, weight increase of 60 g/day/animal has been recorded compared to 44 g with commercial feed.

Requirements and adaptability

- **Soil**: adapted to many soil types but prefers loose and well drained soils. Not adapted to poor and gravel soils. Tolerates pH ranging from 5 to 8.
- **Temperature**: optimum temperature range is 19 to 27°C.
- **Light**: requires high light intensity.
- **Rainfall**: performs best under rainfall ranging from 1,000 to 2,000 mm/year but tolerates drought (as low as 400 mm/year). On the other hand, it is intolerant of water logging. Mucuna is mostly found in humid environments but adaptation to more arid conditions have been observed.

Cultivation

Used in **improved fallows** to increase soil fertility, control weeds and ease field preparation (see factsheet no. 7).

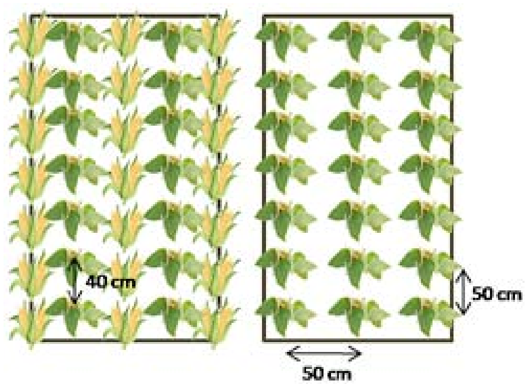
Intercropped with grains such as maize, sorghum or millet to increase soil fertility and control weeds (see factsheet no. 1).

Used for **green manure** (see factsheet no. 10).

- **Breaking of dormancy**: not required for fresh seeds. Stored seeds should be soaked in water for 24 h.
- **Direct seeding**: seeds are sown at 2 cm depth directly in the field.

- Monocropping: sown in rows at 50 cm x 50 cm spacing, 1 seed per pocket, or 50 cm x 100 cm with 2 seeds per pocket. Mucuna is sown at the start of the rainy season.
- Relay cropping: sown between the main crop rows (every 80 to 100 cm) at 40 to 50 cm in-row spacing.

  Seeds are sown at 4 cm depth at 20 to 50 kg/ha seed rate.



Intercropped with maize   Pure cropping

To prevent competition, it is recommended to sow mucuna approximately one month after sowing the grain crop. Such systems are referred as relay cropping rather than intercropping. Example: mucuna is sown between the maize rows 30 to 45 days after sowing the maize.

- **Germination**: 4 to 7 days after sowing. Empty pockets should be resown 10 days after initial sowing. It is necessary to weed around the plants 15 days after germination to prevent competition.

Example of cultivation calendar in relay cropping with maize

D1	…	D31	…	D35	…	D38	…	D41	…	D56	…	D120	…	D150	…	D175
Sow-ing 		Mucuna sowing 		Germination 				Re-sowing 		Weeding 		Flowering 				
												Harvest for fodder				

Mucuna is responsive to phosphorous fertilization.

- **Production**: approximately 90 to 120 days after sowing for fodder, 2 to 3 months after flowering for seeds.

Post-harvest

If used to feed non-ruminant livestock, seeds have to be treated first by boiling for 1 hour, or pressure cooking for 20 min or soaking for 48 hours in water before boiling for 30 min.

Propagation/Seed production

If mucuna is grown for seed production, the plants need a support to climb on to prevent pods from touching the ground and rot. Seeds reach maturity 100 to 280 days after flowering according to varieties (non uniform).

Seeds are harvested fully mature, when the pods turn from green to brown. Plants usually die 45 to 60 days after the completion of seeds' maturation process.

Pods should be left to dry until they crack open.

Seeds should be stored dry and clean in a bag and kept in a dry and venti-lated place. Seeds remain viable for 2 years when stored in a cool, dry place or 3 months otherwise.

To learn further

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Mucuna pruriens, Ecocrop, FAO, 2001. http://ecocrop.fao.org.

Pueraria phaseoloides

Botanical information

Vernacular names: faux-haricot, tropical kudzu, pueraria javanica.

Family: Fabaceae.

Morphological description: climbing and creeping vine.

Root system: deep rooted.

Life cycle: perennial.

Geographical distribution: native to South-East Asia, Malaysia and Indonesia, it is found widely throughout the humid tropics.

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- Fixes high quantity of nitrogen
- Provides weed control thanks to its dense ground cover
- Produces good quality fodder
- Provides erosion control
- Tolerates water logging and highly acidic soils
- Is shade tolerant

–

- Slow growth during the first 4 months following establishment
- Sensitive to overgrazing
- Intolerant of fire and drought
- Seed production can sometimes be challenging
- Can become invasive if not carefully controlled

Description

Pueraria phaseoloides is dense-growing legume fodder crop widely found in low-lands and flood zones but also in mountainous areas.

Main stems are slender (6 mm thick on average), covered in short hair and can reach 10 m in length. Secondary branches grow densely and create a dense mass of vegetation, 60 to 75 cm high, 8 to 9 months after sowing. The small purple flowers are arranged in 10 to 15 cm long clusters and produce 4 to 11 cm long pods thinly covered with hair, turning black as they reach maturity. Each pod contains 10 to 20 seeds.

Uses

Function	Use	Quality	Benefit
Soil fertilization	Improved fallow Green manure	Good (but not best legumes for nitrogen fixation)	50 to 100 kg/year/ha of nitrogen
Fodder	Pasture Leaves, mainly for rabbit feed	Good	18 to 21% protein and 34 to 43% fibers for dry matter 2 to 12 t/ha/year of dry matter
Weed control	Improved fallow Intercropped with trees	Very good	
Soil loosening	Deep root system	Good	
Erosion control	Improved fallow	Good	

Requirements and adaptability

- **Soil**: adapted to a great range of soils, from sandy to clayey, including acidic as well as calcium or phosphorous deficient soils. Performs poorly on heavy clay soils and saline soils. Tolerant of temporary waterlogging.
- **Temperature**: optimum temperature 15°C. Minimum temperature 12.5°C.
- **Light**: moderately shade tolerant.
- **Rainfall**: 900 to 2,000 mm/year. Performs best under rainfall regimes exceeding 1,500 mm/year.
- **Altitude**: more common below 600 m a.s.l. but can be found up to 2,000 m a.s.l. in certain countries.

Cultivation

- **Breaking of dormancy**: requiert if seeds are stored, the dormancy has to be broken by soaking for 20 min in a solution containing sulfuric acid or by mechanical scarification or by soaking then overnight in hot water.
- **Sowing**: for green manure, seeds are sown at 2.5 cm depth and 50 x 80 cm spacing or sown in hills spaced 3 m apart in all directions using 15 to 20 seeds/hill; 500 g to 1 kg/ha seed rate is sufficient for mixed pasture.
- **Care**: weeds must be controlled in the early stage of development as *Pueraria phaseoloides* is not very competitive during the first few months.
- **Harvest**: according to needs.

In the case of pasture, it is important to prevent overgrazing to allow the reconstitution of the vegetative cover.

Can be used as a long duration green manure (see factsheet no. 10). Can also be used for liquid manure production (see factsheet no. 9).

Propagation/Seed production

Seed production is challenging in certain climatic zones. Yield is hence highly variable: 38 to 500 kg/ha. 80,000 to 88,000 seeds/kg.

Pueraria can also be propagated using 0.7 to 1 m long cuttings. Plant 2 cuttings per planting hole.

To learn further

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Effet de légumineuses herbacées ou subligneuses sur la productivité du maïs, Tetchi Nicaise Akédrin, Koffi N'Guessan, Emma Aké-Assi, Sévérin Ake, *Journal of Animal & Plant Sciences*, 2010, vol. 8, n° 2, pp. 953-963. www.m.elewa.org.

Pueraria phaseoloides, Tropical Forages, CSIRO Sustainable Ecosystems, CIAT, ILRI, 2005. www.tropicalforages.info.

Senna spectabilis

Botanical information

Vernacular name: cassia.

Family: Fabaceae.

Morphological description: small tree 7 to 10 m tall on average (maximum 15 m).

Root system: shallow.

Life cycle: perennial.

Geographical distribution: native to South America and the Caribbean, naturalized in Eastern Africa, South Asia and the USA.

+

- Fixes nitrogen in the soil
- Is resistant to pests and diseases
- Coppices very well
- Is fire resistant
- Produces good fuel wood
- Produces fodder
- Is fast growing
- Good shade tree thanks to its growing habit
- Melliferous, suitable for beekeeping

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- Can be invasive in certain environments

Description

Senna spectabilis is a small tree with a spreading crown and a trunk rarely exceeding 30 cm in diameter. It occurs naturally in environments such as forest edges, savannas, river banks, road sides and wasteland. Leaves are alternate, once-compound, up to 40 cm long with 4 to 15 pairs of leaflets (maximum 19), each up to 7.5 cm long. The 15 to 30 cm yellow inflorescences make it a highly appreciated ornamental plant. Pods are more or less cylindrical and slightly flattened.

Uses

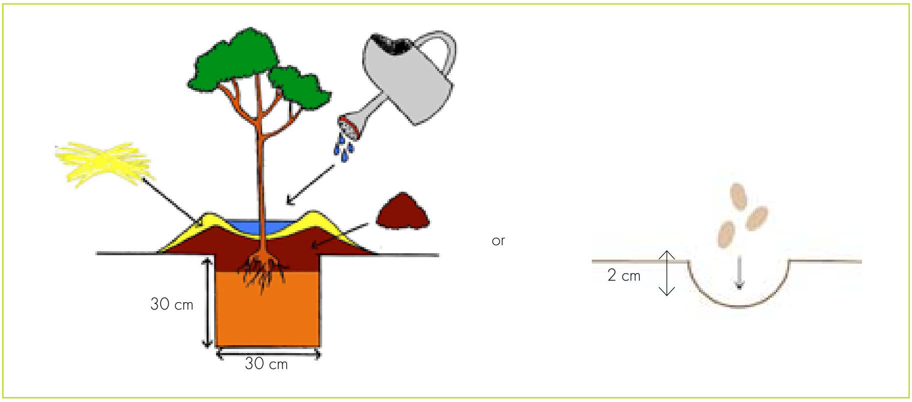
Function	Use	Quality	Benefit
Soil fertilization	Hedgerow Intercropping	Good	95 kg nitrogen/ha/year
Fuel wood	Firewood Charcoal	Good	2 à 7 t/ha/year of small branches for firewood
Timber	Formwork Termite resistant	Good	
Fodder	Leaves	Good	3 to 9 t/ha/year of leaves
Shading, ornamental	In private gardens, on road sides	Good	

Requirements and adaptability

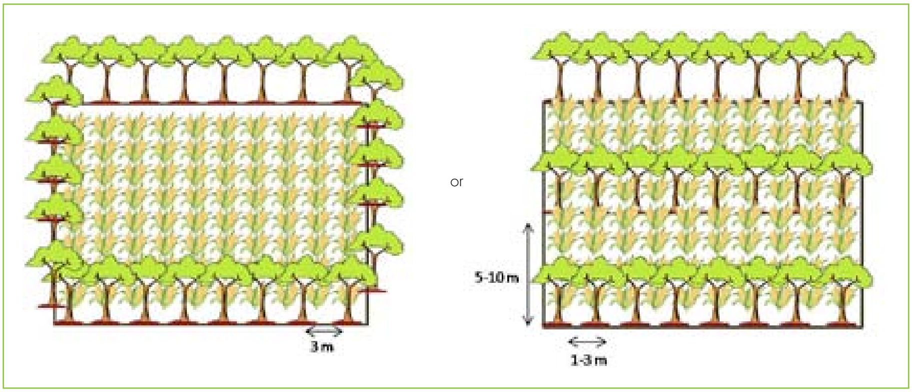
- **Soil**: adapted to a many types of soil, including poor and alkaline soils, provided they are well drained. Intolerant of saline soils.
- **Temperature**: tolerant to low temperatures but optimal temperature range is 15 to 25°C.
- **Light**: sun loving.
- **Rainfall**: performs best from 800 to 1,000 mm/year. Little tolerance to drought.
- **Altitude**: up to 2,000 m a.s.l.

Cultivation

- **Breaking of dormancy**: seeds can either be scarified mechanically or using sulfuric acid. They can also be soaked shortly in boiling water, cooled down and soaked in cold water for 24 hours.
- **Planting**: it is recommended to establish *Senna spectabilis* by transplanting seedlings in 30 cm x 30 cm planting holes but it can also be direct seeded, sowing three seeds per hill at 2 cm depth. In both case, the trees should be established at the beginning of the rainy season unless irrigation is available. Mulching the base of the trees also allows keeping soil moisture. The addition of manure is beneficial but not primordial.



When used as perimeter hedgerow, plants are established at 3 m in-row spacing and, in the case of double rows, 3 m inter-row spacing (when using double rows, the rows should be staggered). When used in alley cropping, rows are spaced 5 to 10 m apart and plants are established 1 to 3 m apart within a row (see factsheet no. 19 on agroforestry).



- **Germination**: eeds germinate very fast, 3 to 8 days after sowing. Germination rate can reach up to 100% when using scarification.
- **Care**: requires one to four weeding cycles annually for the first two years following establishment, depending on weed pressure. Lower lateral branches should be regularly pruned to provide firewood and produce a straight trunk that can be used for timber at a later stage.
- **Harvest**: starts 5 years after establishment for fuel wood. The tree can be used as bee fodder 2 years after establishment.

Propagation/Seed production

It is recommended to raise seedlings in nursery, sowing 3 seeds per planting bag, but direct seeding in the field is also possible. Seeds can be stored for 2 years in a cool, dry place. Approximately 39,000 seeds/kg.

To learn further

Senna spectabilis, H.S. Irwin et R.C. Barneby, *Agroforestry Database 4.0*, World Agroforestry Centre, 2009, 5 p. www.worldagroforestry.org.

Effets de la culture en couloirs sur les propriétés du sol et les performances des arbustes et des cultures vivrières dans un environnement semi-aride au Rwanda, V. Balasubramanian, L. Sekayange, IRD, *Bulletin - Réseau Érosion*, (12), 1992, p. 180-190. www.documentation.ird.fr.

Sesbania bispinosa

Botanical information

Synonym: *Sesbania aculeata*.

Vernacular names: prickly sesban, dhaincha.

Family: Fabaceae.

Morphological description: shrub growing to a height of 2 to 3 m (can reach 6 to 7 m under certain conditions).

Root system: can produce floating adventitious roots.

Life cycle: perennial.

Geographical distribution: native to Asia, naturalized in Africa and Central America.

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- Fixes nitrogen in the soil
- Is fast growing
- Provides weed control
- Produces firewood
- Produces fodder
- Can be used for human consumption
- Provides erosion control
- Loosens the soil thanks to its powerful root system
- Is adapted to many soil types, including degraded soils

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- Can become invasive in maize or rice fields

Description

Sesbania bispinosa is a small shrub naturally found in flood plains and humid, sub-humid or dry forest areas. The 10 to 30 cm long leaves are compound with 20 to 100 leaflets. Inflorescences are made out of 2 to 12 yellow flowers measuring 10 to 12 mm. Pods are slightly curved, 12 to 25 cm long and 2 to 3 cm wide and contain 28 to 45 seeds that are light brown, olive green or blackish in color.

Uses

Function	Use	Quality	Benefit
Soil fertilization	Green manure Intercropping Hedgerow	Very good	80 kg/ha of nitrogen after 50 days and 133 kg/ha of nitrogen after 60 days
Fodder	Leaves Seeds	Very good	25 t/ha Good for livestock, including poultry
Fuel wood	Branches and stem	Good	15 t/ha 4,281 kcal/kg
Erosion control	Hedgerow	Good	
Human diet	Pods Flowers Seeds	Good	
Weed control	Can notably over-compete *Imperata cylindrica*	Very good	
Fibers	For fishing nets and ropes	Good	

Requirements and adaptability

- **Soil**: adapted to heavy, unfertile and poorly drained soils. It is tolerant of waterlogging but also performs well under dry conditions. It is tolerant of salinity and alkaline soils and can adapt to a wide range of soil pH, generally ranging from 5.8 to 7.5 but sometimes reaching up to 10.
- **Temperature**: optimum temperature range is 15 to 28°C but can grow under temperatures as high as 44°C.
- **Rainfall**: optimum between 550 and 2,100 mm/year.
- **Altitude**: 0 to 1,200 m a.s.l.

Cultivation

- **Breaking of dormancy**: none.
- **Direct seeding**: 90 to 100 kg of seed when broadcasted, 20 to 60 kg when sown in furrows.
- **Germination**: 7 days after sowing.
- **Care**: none required as *Sesbania bispinosa*'s very fast growth allows it to overcompete weeds.
- **Harvest**: 2 to 3 months for fodder and green manure, 5 to 6 months for mature seeds and firewood (see factsheet no. 10 on green manure).

Propagation/Seed production

Sesbania bispinosa can yield 600 to 1,000 kg/ha of seed.

When used as green manure, plants do not produce seeds as they are cut at flowering stage. Hence, it is necessary to dedicate a plot for seed production. Once sun dried, *Sesbania bispinosa* seeds can remain viable for a very long time and can germinate after several years of room-temperature storage.

To learn further

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Green Manure Crops, TNAU Agritech Portal. http://agritech.tnau.ac.in.

Sesbania bispinosa, *Agroforestry Database 4.0*, World Agroforestry Centre, 2009, 5 p. www.worldagroforestry.org.

Sesbania bispinosa, Forestry Nepal. www.forestrynepal.org.

Sesbania in Agriculture, Dale O.Evans, Peter P. Rotar, *Westview Press*, 1987, Westview Tropical Agriculture Series, 196 p. http://pdf.usaid.gov.

Sesbania rostrata

Botanical information

Vernacular names: rostrate sesbania, new dhaincha.

Family: Fabaceae.

Morphological description: shrub growing to a height of 1 to 3 m.

Root system: tap root.

Life cycle: annual. Perennial under favorable conditions.

Geographical distribution: native to West Africa, naturalized in Asia.

Sesbania rostrata flowers (Philippines). Hervé Saint Macary, © CIRAD.

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- Fixes nitrogen in the soil
- Is fast growing
- Is tolerant of flooding
- Produces fodder
- Produces edible leaves for human consumption
- Can be used as a trap crop (notably in soy cultivation)
- Produces fuel wood
- Loosens the soil thanks to its root system
- Comports aerial stem nodules in addition to root nodules

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- Sensitive to nematodes and certain insects

Description

Sesbania rostrata s a small leguminous shrub with aerial stem nodules in addition to root nodules. It occurs naturally in marshes, flood plains or on river banks as well as in savannas. The slightly hairy leaves are pinnate with 12 to 22 pairs of leaflets 3 cm long and 6 mm wide. Inflorescences are made up of 3 to 12 yellow flowers on average. Pods are 15 to 22 cm long and contains up to 50 seeds each.

Uses

Function	Use	Quality	Benefit
Soil fertilization	Green manure Intercropping	Very good	Fixes 140 kg/ha of nitrogen in 50 days
Erosion control	Intercropping	Good	
Fuel wood	Branches	Good	8 to 11 t/ha within 2 months (2 m in height)
Fodder	Leaves. Only for small ruminants	Good	5 t/ha of dry matter
Human diet	Leaves	Good	
Pest control	Controls soy pests	Good	

Requirements and adaptability

- **Soil**: tolerant of low to moderate salinity. Adapted to acidic soils (pH 5.5 without adverse effect and down to pH 4.3 with reduced nitrogen fixation). Performs moderately well on alkaline soils. Not tolerant of heavy clay soils. Performs very well on watelerlogged and flooded soils and mature plants can grow in water as deep as 1m.
- **Temperature**: grows best at temperatures above 25°C.
- **Light**: short-day photoperiodic species.
- **Rainfall**: occurs naturally in areas of 600 to 1,000 mm rainfall but only on periodically flooded or waterlogged soils.
- **Altitude**: up to 1,600 m a.s.l.

Cultivation

- Breaking of dormancy: none.
- Seeding rate: 30 to 32 kg/ha. Can be intercropped with rice (*Sesbania rostrata* is sown 30 to 60 days after the rice).
- Germination: 7 days after sowing.
- Care: once the plants have reached 20 cm in height the field should be flooded to a depth of 5 to 10 cm once every 1 to 2 weeks (according to season). Soil moisture should be monitored and the field irrigated accordingly.
- Harvest: when used as green manure, *Sesbania rostrata* is turned into the soil 45 to 55 days after sowing (when flowering). Plants are incorporated into the soil when 1 to 1.5 m tall (stems should be cut in three before incorporation).
- Intercropping: flooded rice, soy, etc.

Propagation/Seed production

Can be propagated vegetatively or by seed. When used as green manure, plants do not produce seeds as they are cut at flowering stage. Hence, it is necessary to dedicate a small plot apart from the main field for seed production. 50,000 to 70,000 seeds/kg.

To learn further

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Sesbania rostrata Brem., Henri Le Houérou. *Grassland Species Profiles*, CIAT, FAO. www.fao.org.

Effets des engrais verts et des rotations de cultures sur la productivité des sols au Mali, Z. Kouyaté, A.S.R. Juo, in D. Buckles (éd.) *et al.*, *Plantes de couverture en Afrique de l'Ouest : une contribution à l'agriculture durable*, IDRC/IITA/SG2000, 1998 pp. 171-178. http://web.idrc.ca.

Sesbania rostrata, *Tropical Forages*, CSIRO Sustainable Ecosystems, CIAT, ILRI, 2005. www.tropicalforages.info.

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Sesbania rostrata, *Agroforestry Database 4.0*, World Agroforestry Centre, 2009, 5 p. www.worldagroforestry.org.

Sesbania sesban

Botanical information

Vernacular names: common sesban, egyptian rattle pod.

Family: Fabaceae.

Morphological description: shrub or small tree 1 to 8 m tall.

Root system: deep.

Life cycle: fast growing perennial reaching 4 to 5 m in 6 months. Usually harvested within 5 years.

© Bùi Thuy Đào Nguyên.

Geographical distribution: native to Africa, naturalized in Asia and Australia.

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- Fixes nitrogen in the soil
- Provides erosion control
- Provides weed control, notably against striga
- Produces quality fodder
- Produces fuel wood
- Is very fast growing
- Produces fibers and gum
- Medicinal
- Propagates easily thanks to the production of many suckers

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- Does not tolerate repeated pruning
- Requires two to three years to produce noticeable results
- Sensitive to beetles, nematodes and diseases
- Does not tolerate pruning at early stage of development and not at all if conditions are too dry.
- Does not tolerate browsing by goats as they tend to the lower branches

Description

Sesbania sesban is a short lived, highly ramified shrub or small tree. Leaves are 2 to 18 cm, compound with 6 to 17 pairs of leaflets 25 mm long and 5 mm wide. Flowers grow in 20 cm clusters of 2 to 20 and are most commonly yellow but also sometimes red, purplish or more rarely white. Pods are 20 to 30 cm long and 2 to 5 mm in diameter and contain around 40 seeds, green or brown mottled with black.

Sesbania sesban occurs naturally in flood plains. It is not adapted to slopping land.

Uses

Function	Use	Quality	Benefit
Soil fertilization	Improved fallow Green manure	Very good	Fixes 80 to 120 kg/ha/year of nitrogen Increases maize yield by up to 161%
Erosion control	Intercropping Perimeter hedgerow Improved fallow	Very good	4 to 12 t of dry matter/ha depending on conditions
Fuel wood	Firewood Charcoal	Very good	10 t after a 2 years fallow period 4,350 kcal/kg for a 3 years old tree
Fodder	Leaves	Good	4 to 12 t of dry matter/ha depending on conditions Has to be used with caution for poultry (toxic)
Fibers	For fishing net and rope confection	Good	
Gum production	Seeds	Good	
Shading	In coffee, tea or cacao plantations	Good	
Windbreak	In banana, citrus or coffee plantations	Good	

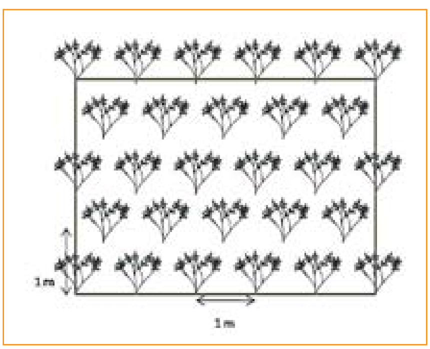
Function	Use	Quality	Benefit
Poison	Seeds	Dangerous	Can cause problems when constituting as little as 10% of poultry feed ration
Medicinal	Leaves	Good	

Requirements and adaptability

- **Soil**: adapted to all soil types, from sandy to clayey. Tolerant of salinized, alkaline and slightly acidic soils. Can grow in phosphorus deficient soils but the supply of phosphorous fertilizer allows for better growth and nodulation.
- **Temperature**: performs best at 17 to 20°C mean annual temperature, tolerant of light frost (– 1°C).
- **Light**: sun loving, does not tolerate shade.
- **Rainfall**: grows in semi-arid, sub-humid and humid areas with rainfall ranging from 500 to 2,000 mm/year.
- **Altitude**: 100 to 2,300 m a.s.l.

Cultivation

- **Breaking of dormancy**: none.
- **Propagation**: nursery raised seedlings. 30 to 150 g/ha seed rate for the establishment of an improved fallow of 1 ha with trees planted at 1 m x 1 m spacing. For intercropping, recommended spacing is 0.50 cm x 5 m. When intercropped with maize, maize yield is greater when *sesbania* is sown a month later.



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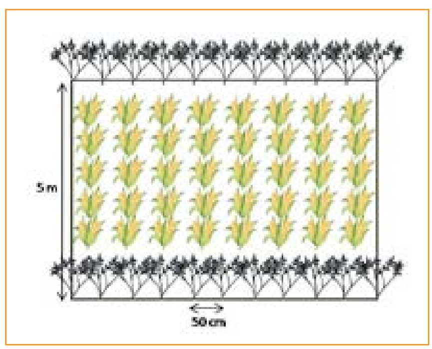

- **Germination**: less than two weeks after sowing. Nursery raised seedlings can be transplanted 6 to 10 weeks after sowing, when they have reached 20 cm in height.
- **Care**: 5 coppicing cycle/year for fodder for over five years. Cut 50 to 76 cm above ground level when plants reach 1 to 2 m in height. Growth resumes best when trees are 75 to 100 cm in height and part of the foliage is preserved.

Coppicing trees when above 4 m or below 50 cm in height can lead to their death.

- **Harvest**: when used for improved fallow, *Sebania sesban* can be harvested after 2 years, before rainy season, by cutting the trees at ground level. Trees are left to dry in the field for 1 to 2 weeks, until their leaves drop, then wood is harvested by cuttings the branches and trunks (see factsheet no. 10 on green manure).

Propagation/Seed production

Orthodox seeds, can be kept for 2 years in open storage at room-temperature. Approximately 85,000 to 100,000 seeds/kg. It is recommended to use bare root seedlings produced in nursery to ensure homogenous germination but direct seeding is also possible.

To learn further

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Évaluation de l'effet fertilisant de *Mucuna utilis* L. face à deux doses de NPK (17-17-17) sur la croissance et la production de la variété samaru du maïs (Zeamays L.) dans les conditions opti-males, W. Mokuba, R.V. Kizungu, K. Lumpungu, Congo Sciences, vol. 1, n° 1, nov. 2013, pp. 23-30. www.congosciences.cd.

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Tephrosia vogelii

Botanical information

Vernacular names: fish bean, fish-poison bean.

Family: Fabaceae.

Morphological description: small tree growing to a maximum height of 4 m.

Root system: deep.

Life cycle: perennial but often grown as an annual.

Geographical distribution: native to tropical Africa, naturalized in Asia and Latin America.

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- Fixes nitrogen in the soil
- Can be used in the confection of biopesticide
- Is resistant to wind
- Tolerates repeated pruning
- Is fire resistant; regrows readily after fire thanks to its deep root system
- Is fast growing
- Is adapted to many growing conditions
- Produces firewood

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- Used as poison for fishing, causing important damage on river ecosystems
- Can be sensitive to disease on poor and acidic soils

Description

Small deciduous tree with dense foliage growing to a height of 0.5 to 4 m. *Tephrosia vogelii* can be found in diverse environments such as prairies, savannas, forest edges, fallow lands and shrublands. Branches have a furry aspect due to the presence of short white or brown hair. Flowers are mostly white, sometimes purple or purple-blue, and form pseudo-raceme not exceeding 3 cm in length. The 6 to 14 cm pods are beige or brown in color and contain 6 to 18 black seeds, approximately 5 mm in diameter.

Tephrosia vogelii pods.

As a leguminous species, it is widely used in agroforestry (see factsheet no. 19) and its pesticidal properties make it a very good ingredient in the confection of biopesticides (see factsheet no. 5).

Uses

Function	Use	Quality	Benefit
Soil fertilization	Improved fallow Living mulch/ cover crop Intercropping Green manure	Very good	Improved fallow: fixes 147 kg/ha of nitrogen 3.7 g of nitrogen/100 g of dry matter when the plant is 2 to 3 months old, decreases afterward Significantly enhances soil fertility after 2 years of cultivation
Integrated pest management	Biopesticide	Very good	
Firewood	Improved fallow Living mulch/ cover crop Intercropping	Good	

Function	Use	Quality	Benefit
Poison	Fishing	Dangerous	Kills all fish indistinctly. Highly toxic in large quantity, can destroy entire ecosystems leading to the ban of its use for fishing by several countries
Temporary shading	For crops such as coffee, cacao, tea, cinchona or rubber	Very good	
Medicinal			

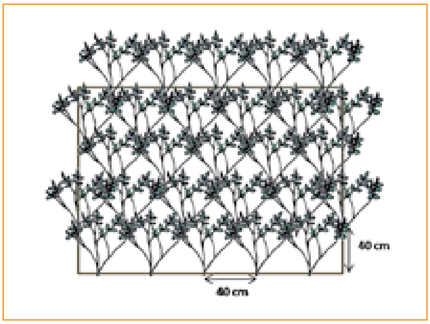
Requirements and adaptability

- **Soil**: tolerant of poor and acidic soils but growth is slow and the plant more sensitive to disease. The addition of organic or inorganic fertilizer can facilitate establishment.
- **Temperature**: optimal growth occurs in temperatures ranging from 12 to 27°C. Intolerant of temperatures below 12°C.
- **Rainfall**: drought resistant but optimum growth occurs under rainfall regimes of 850 to 2,650 mm/year.
- **Altitude**: 0 to 2,100 a.s.l.

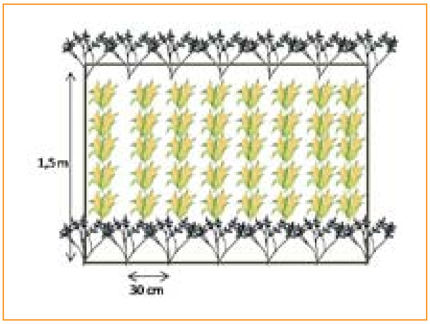
Cultivation

- **Breaking of dormancy**: not required but soaking in 45°C water or in cold water for 24 hours can improve germination rate. 65% germination rate without treatment.
- **Propagation**: most often established by direct seeding.

For green manure: 40 cm x 40 cm, 2 to 3 seeds/pocket.



In intercropping: 1.5 m inter-row and 30 cm in-row spacing.



In intercropping with maize, better yields are obtained when *tephrosia* is sown one month after the maize (however, *tephrosia* biomass production is lower).

Seeding rate: 8 to 13 kg seeds/ha if broadcasted and 5 kg/ha if sown in furrows. Approximate survival rate is 60%.

Propagation/Seed production

Seeds can be kept for 2 to 3 years in open storage at room temperature and longer if stored in a sealed container at 10°C. It is recommended to store fresh seeds for 2 months before sowing.

To learn further

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Tithonia diversifolia

Botanical information

Vernacular name: tournesol du Mexique, tree marigold.

Family: Asteraceae.

Morphological description: *Tithonia diversifolia* is a woody herb or succulent shrub growing to a height of 3 m.

Root system: taproot with extensive secondary lateral root system.

Life cycle: annual or perennial according to growing conditions.

Geographical distribution: native to Central America, naturalized throughout the tropics.

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- Provides nitrogen and phosphorous to the soil
- Has pesticidal properties
- Melliferous species
- High biomass producer
- Is adapted to poor soils

−

- Can become invasive

Description

Woody herb or succulent shrub, long considered as a weed as it quickly colonizes perturbed environments. Leaves are alternate, 13 to 15 cm in length. Flowers are yellow, similar to daisy but bigger, measuring around 10 cm in diameter. Seeds readily disperse with wind, rain or animals and can remain viable for 4 months once fallen on the ground.

Uses

Function	Use	Quality	Benefit
Soil fertilization	Mulch Hedgerow	Very good	Increases maize yield by up to 216% Leaf nitrogen concentration (3.53%) is higher than many nitrogen fixing species*
Pest control	Biopesticide	Very good	
Ornamental	Flowers	Good	

* Notably *Pueraria phaseoloides* (2.17), *Calliandra calothyrsus* (3.4) and *Tephrosia vogelii* (3.0). *Sesbania sesban* (3.7) and *Leucaena leucocephala* (3.8) have a slightly higher leaf nitrogen concentration. When it comes to phosphorous concentration, *Tithonia* is higher (0.42) than all the above mentioned species.

Requirements and adaptability

- **Soil**: adapted to poor soils.
- **Temperature**: 15 to 31°C.
- **Rainfall**: grows under rainfall regimes of 100 to 2,000 mm/year. Drought tolerant.
- **Altitude**: 100 to 2,000 m a.s.l.

Cultivation

Tithonia diversifolia can be propagated by cuttings to use as cover crop but it is most often harvested in nature to be used as mulch or for the confection of compost (see factsheet no.14 on mulching and factsheet no. 8 on compost).

Tithonia also has interesting pesticidal properties and can be used in the confection of biopesticides (see factsheet no. 5).

Propagation/Seed production

Seed heads are harvested when fully mature, directly on the flower, throughout the year. Mature plants produce 80,000 to 160,000 seeds per square meter. It can also be multiplied by cuttings.

To learn further

Climate Smart Agriculture, A review of current practice of agroforestry and conservation agriculture in Malawi and Zambia, Arslan A., Kaczan D., Lipper L., Esa Working Paper, FAO, 2013, 62 p. www.fao.org.

Le Tithonia : *providence pour les terrains pauvres*, Jardins essentiels, Willem Van Cotthem, 2007. https://desertification.wordpress.com.

Tithonia diversifolia (Tithonia), Aool Winnifred, Opio Samuel Morris, Invasive Species Compendium (ISC), CABI, 2014, datasheet. www.cabi.org.

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Vetiveria zizanoides (Chrysopogon zizanoides)

Botanical information

Vernacular names: vetiver.

Family: Poaceae.

Morphological description: herbaceous species growing to a height of 2 m.

Root system: very deep, 3 to 6 m.

Life cycle: perennial.

Geographical distribution: native to South Asia (India, Pakistan, Sri Lanka, Thailand, Myanmar), naturalized throughout the world, from the USA to Madagascar.

+

- Excellent for soil stabilization and erosion control
- High profitability thanks to the production of vetiver root essential oil
- Can act as a settling filter for wastewater treatment
- Provides thatch
- Edible to animals

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- The exploitation of vetiver roots for oil extraction destroys vegetative contour strips
- Labor intensive during establishment phase

Description

Vetiveria zizanoides is a perennial grass. It is widely used in agriculture as well as in construction and landscaping to stabilize soil on slopes, river banks and terraces as its powerful root system can extend to a depth of 6 m.

Vetiver forms dense tufts reaching up to 2 m in height. It is highly resistant and adapts to many types of climatic conditions and, once established, can tolerate shortage of water thanks to its very deep root system (it is actually one of the required condition for the production of quality vetiver oil).

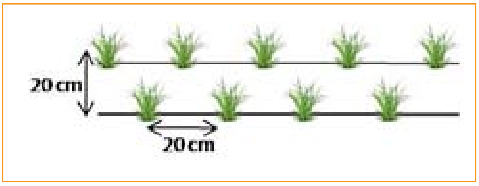
Uses

Function	Use	Quality	Benefit
Erosion control	Vegetative strips	Very good	Passive terracing: formation of a 20 cm mound over two growing seasons on a 20% slope.
Essential oil production	Roots	Very good	1.5 to 2 t/ha of dry roots (about 20 liter of oil)
Thatch production	Stems	Good	
Fodder	Stems	Good	

Requirements and adaptability

- **Soil**: adapted to many types of soils but performs poorly on clayey soils.
- **Temperature**: performs best at 21 to 43°C.
- **Rainfall**: 300 to 3,000 mm/year.
- **Altitude**: from sea level up to 1,400 m a.s.l.

Cultivation



Vetiver should be established at the start of the rainy season, simultaneously with the food crops. For the establishment of vegetative strips, to control erosion, root slips should be planted on contour lines, in staggered double rows, at 20 cm x 20 cm spacing.

The distance between the strips depends on the gradient of the slope. Vegetative strips can be planted on berms to increase their efficiency on steeper slopes.

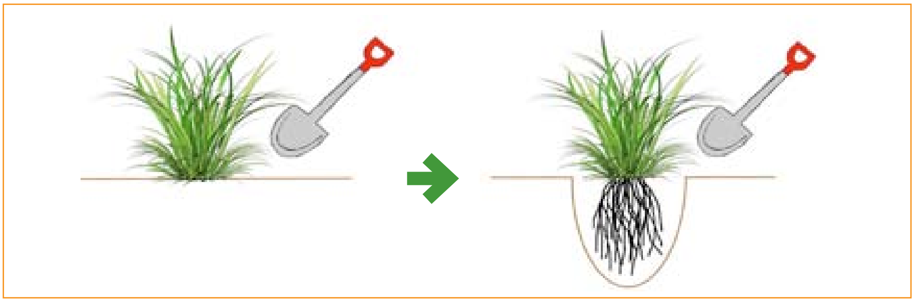
- For gentle and medium slopes (less than 20%) double rows of vetiver spaced 15 m apart are usually considered sufficient to limit erosion.
- For steeper slopes (ranging from 20 to 25%), double rows of vetiver established on berms spaced 9 m apart are necessary.

This technique is not adapted to very steep slopes where more significant arrangements have to be implemented (see factsheet no. 15 on vegetative contour strips).

- Care: once established, vetiver doesn't require any specific care. Nevertheless, it is necessary to refill the slips that have not survived transplantation in order not to leave any gap in the row as it would create a path for water and generate the formation of erosion gullies.
- Intercropping: vetiver can be combined with any crop.

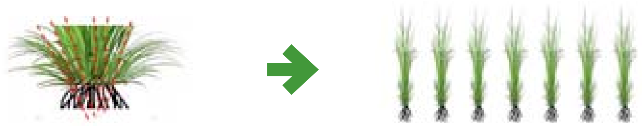
Propagation/Seed production

It is highly recommended to use vegetative propagation. In order to do so, a mother clump is dug out and the tillers are divided into root slips without harming the plant buds.



Using a machete, the stems should be cut back to 20 cm length and the roots to 5 cm.

Manually divide the clump into single root slips ready to be transplanted.



The survival rate of root slips exceeds 95%, given it is transplanted at the beginning of the rainy season.

When used for erosion control, vetiver is left permanently in place. On the other hand, for oil production, the roots are harvested.

The use of vetiver for essential oil production requires specific conditions. Indeed, as the oil is extracted from the roots, the plant is dug out to a depth of 50 cm, which weakens the soil and can lead to erosion. Hence, to limit hazards, vetiver should not be cultivated on steep slopes (for oil production) and not be harvested during rainy season. It can also be beneficial to plant vetiver on contour lines, use the trimmings to mulch the plot and harvest every alternate row in a sequence in order not to leave the whole plot barren.

To learn further

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Végétalisation de cordons pierreux au moyen du vétiver ou de l'andropogon : fiche technique n° 2, Robert Zougmoré, Lamourdia Thiombiano, Frédéric Kambou, Zacharie Zida, Koudougou, Burkina Faso, INERA SARIA, 2000, 2 p. www.fidafrique.net.

Vigna radiata

Botanical information

Vernacular names: mung bean, green gram, ambérique verte.

Family: Fabaceae.

Morphological description: erect herbaceous species ranging from 15 cm to 1 m in height.

Root system: taproot with deep lateral roots.

Flowering mung bean (*Vigna radiata*) in a rice field, Sathing Phra area (Thailand). Guy Trébuil, © CIRAD.

Life cycle: annual.

Geographical distribution: native to India, naturalized throughout the tropics.

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- Fixes nitrogen in the soil
- Produces nutritious pods and seeds for human consumption
- Produces fodder
- Is fast growing

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- Intolerant of water logging
- Sensitive to fungal diseases and certain type of insects

Description

Vigna radiata is an herbaceous legume growing to a maximum height of 1.3 m. It is particularly liked in Asia and Kenya where it is grown as a main crop. Elsewhere, it is most often intercropped with other Vigna or Phaseolus species. Stems are many-branched with a tendency to twin at the tips. Leaves are alternate, usually made up of three leaflets (but also sometimes 5). Inflorescences are approximately 20 cm long and made up of 4 to 15 yellow flowers (maximum 30). Pods are variably shaped (either linear or cylindrical), black or light brown in color and covered with short hairs. Each pod contains 10 to 15 seeds. Seeds are ellipsoidal, approximately 3 cm in diameter and are typically green but sometimes also yellow, brown, black or marbled.

Uses

Function	Use	Quality	Benefit
Soil fertilization	Green manure Cover crop Intercropping/ monocropping	Very good	Fixes 55 kg/ha of nitrogen in 45 days
Human diet	Seeds Pods Young leaves	Very good	100 to 700 kg/ha (up to 1.25 t/ha if irrigated)
Fodder	Leaves Seeds	Very good	

Requirements and adaptability

- **Soil**: adapted to many soil types but performs best on well drained loams or sandy loams with a pH ranging from 5 to 8. Does not tolerate more than 3 days of waterlogging.
- **Temperature**: performs best at 28 to 30°C but can grow from 20 to 40°C. Frost intolerant.
- **Rainfall**: 600 to 1,000 mm/year but can tolerate slightly lower rainfall regimes. Drought tolerant.
- **Light**: sun loving plant. Short-day species, flowers below 12 hours of sunlight.
- **Altitude**: 0 to 1,850 m a.s.l.

Cultivation

- Breaking of dormancy: none.
- Direct seeding: plowing, followed by broadcasting at 25 to 45 kg/ha seed rate in pure cropping (3 to 4 kg only in intercropping). Seed depth should be 4 to 5 cm. Recommended spacing is highly variable ranging from 25 to 100 cm inter-row spacing and 15 to 30 cm in-row spacing.
- Germination: 2 to 7 days after sowing.
- Care: 2 weeding cycles during the early stage of growth in monocropping.
- Harvest: can be incorporated 40 days after sowing (when flowering). Used as green manure, *Vigna radiata* often follows rice to benefit from the residual moisture of the rice field. Decomposition takes 10 to 15 days (see factsheet no. 10 on green manure). Mature seeds are ready to be harvested 50 to 120 days after sowing depending on varieties.
- Intercropping: sugar cane, maize, sorghum, agroforestry.

Propagation/Seed production

Propagated by seed. A thousand seeds of *Vignata radiata* weigh 15 to 40 g.

To learn further

Information and data on the use of Greenmanure/Covercrops (gmcc) from manual on "Natural Paddy Cultivation" by the Surin Farmers Support (SFS) project, Surin Province, NE Thailand, 9 p. http://sri.cals.cornell.edu/

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Vigna radiata (L.) R. Wilczek, K.K. Mogotsi, *PROTA4U*, Brink, M. & Belay, G. (Editors). PROTA (Plant Resources of Tropical Africa / Ressources végétales de l'Afrique tropicale), 2006. www.prota4u.org.

Vigna unguiculata

Botanical information

Vernacular names: niébé, cowpea.

Family: Fabaceae.

Morphological description: voluble herbaceous.

Root system: taproot.

Life cycle: annual.

Geographical distribution: native to West Africa, found throughout the tropics.

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- Fixes nitrogen in the soil
- Produces nutritious pods and seeds for human consumption
- Produces fodder
- Is fast growing
- Is adapted to a broad range of soil types and rainfall regimes
- Is easy to establish and propagate

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- Sensitive to disease

Description

Cowpea is one of the most widespread crops in the tropics. There are many cultivars of cow peas and morphology varies according to the different types. It is an erect or climbing herbaceous plant, growing to a height of 15 to 80 cm. Some cultivars are grown as fodder, others for seed production and some can be used for both. Leaves are trifoliate, made up of 5 to 25 cm long leaflets. Flowers can be white, yellow, mauve or violet. Pods are10 to 23 cm long and contain 10 to 15 seeds of varied color (white, brown, green), size and shape.

Uses

Function	Use	Quality	Benefit
Soil fertilization	Green manure Cover crop Intercropping/ mono-cropping	Very good	Fixes 50 to 100 kg/ha of nitrogen
Human diet	Seeds Pods Flowers Leaves	Very good	Up to 2 t/ha of seeds depending on varieties. Rich in protein
Fodder	Leaves Seeds	Very good	6 t/ha

Requirements and adaptability

- **Soil**: adapted to a broad range of soil types, including very acidic (pH 4), alkaline and poor soils but intolerant of flooding and salinized soils.
- **Temperature**: optimum temperature range is 25 to 35°C; sensitive to cold.
- **Rainfall**: relatively drought tolerant but sensitive to excessive moisture. Adapted to a variety of rainfall regimes ranging from 650 to 2,000 mm/year.
- **Light**: relatively shade tolerant.

Cultivation

- **Breaking of dormancy**: none.
- **Direct seeding**: seeding rate depends on the objective; if only to produce fodder and green manure, 20 kg/ha is sufficient (sown in furrows at 30 to 60 cm inter row spacing and 10 to 15 cm in-row spacing) while, if grown for human consumption, 50 kg/ha (if sown in furrows) up to 90 kg/ha (if broadcasted) is recommended. Seeds should be sown at 3 to 5 cm depth.
- **Germination**: 4 to 8 days after sowing.
- **Care**: one weeding cycle is required following establishment to avoid competition.
- **Harvest**: plants can be incorporated 30 to 60 days after sowing when used as green manure (see factsheet no. 10 on green manure). Seeds can be harvested 55 to 240 days after sowing depending on cultivars.

Propagation/Seed production

Propagated by seeds. 5,000 to 12,000 seeds/kg. Part of the harvest can be saved to be used the following growing season.

To learn further

Information and data on the use of Greenmanure/Covercrops (gmcc) from manual on "Natural Paddy Cultivation" by the Surin Farmers Support (SFS) project, Surin Province, NE Thailand, 9 p. http://sri.cals.cornell.edu/

Vigna unguiculata, *Tropical Forages*, CSIRO Sustainable Ecosystems, CIAT, ILRI, 2005. www.tropicalforages.info.

Further reading

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Glossary

Agro-ecosystem	An ecosystem which undergoes human intervention via the implementation of plant and animal production techniques.
Amendment	Something added to soil to improve its physical, chemical and biological properties by providing it elements that it lacks (e.g., lime, organic matter, etc.).
Apical bud	Bud located at the top of a stem.
Axillary bud	Bud located at the upper point of an axil (where a leaf stalk or branch and the stem or trunk meet).
Biodiversity	Biodiversity, or biological diversity, refers to the natural diversity of the living animal and plant organisms contained in an ecosystem.
Biomass	All organic material of plant origin (tree leaves, grass, leftover crops, etc.) that can be recycled to produce natural fertilizers (compost) or soil cover.
Blast	The main disease affecting rice. It is caused by a fungus and attacks the plant organs above the surface of the soil.
Bokashi	Burnt and washed rice bran (carbonized rice husk) used for making substratum for market gardening nurseries in Asia.
Canopy	The uppermost level of vegetation in a forest.
Coppicing	The act of cutting a tree or shrub very short, close to the ground, in order to rejuvenate it or to obtain branching.
Cotton bollworm	Type of moth.
Cultivar	A plant variety resulting from selective breeding, a mutation, or natural or induced hybridization. It is grown for its agricultural qualities.

Cyanobacteria	Photosynthetic bacteria, formerly called "blue-green algae". Like plants, they use solar energy to synthesize their molecules.
Diptera	Type of insect with only one pair of wings, such as flies, gnats and mosquitoes.
Dormancy	Biological mechanism of plants whose purpose, in nature, is to prevent seeds from germinating if climatic conditions are not favourable. "Breaking of dormancy" refers to the blocking of this mechanism so that the seeds germinate when the conditions for their development have been met.
Drainage	Action that contributes to the evacuation of excess water in soils.
Ecosystem	All the elements (fauna, flora, soil, water, climate, etc.) that make up a natural environment and that interact with one another.
Erect	Describes a plant that grows upward.
Exudate	A liquid that seeps naturally or accidentally from a plant.
Firewood / fuel wood	Wood used for heating or cooking, in the form of branches, logs or charcoal.
Food crop	Crops intended essentially for local human consumption.
Fungal diseases	Diseases caused by fungi.
Fungicidal	Describes an active substance or a preparation used to protect plants from diseases caused by fungi.
Green Revolution	A technological initiative that included several aspects: improved high-yield varieties of two basic cereals (rice and wheat); irrigation or control of water supply; a better use of humidity, fertilizers and pesticides; and associated agronomic techniques. The purpose of the Green Revolution was to increase yields and agricultural incomes in developing countries. However, the need for extensive use of agrochemical products to fight pests and weeds in some crops stirred up concern in terms of ecology, as well as fears for human health. Furthermore, input supply was not always easy and was sometimes very expensive.
Greenhouse gases	Gases present in the earth's atmosphere that capture the infrared rays emitted by the earth's surface and that lead to warming of the atmosphere.
Harrowing	The act of breaking down the surface of a ploughed field using a harrow (a frame set with teeth or tines).

Hemiptera	An order of insects.
Hoeing	An act consisting of removing weeds where crops are growing.
Hoverfly	A fly whose larva eats aphids.
Humus	A component of soil, resulting from the decomposition of organic matter (plant and animal debris). It plays a decisive role in soil fertility.
Input	In agriculture, is used to describe any product that is not naturally present in the soil and that is applied to crops. Inputs include fertilizers, pesticides and growth hormones, etc. Seeds are also sometimes considered as inputs.
Insecticide	An active substance or a preparation used to protect plants by killing insects that may attack them.
Integrated pest management	Type of crop protection whose application involves a set of methods that must meet ecological, economic and toxicological requirements, but which puts priority on the deliberate use of natural practices that respect tolerance limits.
Intercropping	The act of growing crops between rows of other crops or trees.
Invasive	Describes a plant variety or animal species that tends to colonize the environment rapidly and that enters into competition with local or cultivated species.
Leaching	Loss of mineral or organic elements of soil or manure when drained away by infiltrated water.
Leaflet	Each of the divisions of a compound leaf.
Lodging	The bending over of plant stems onto the ground, due to rain, wind or a parasite attack.
Lowlands	Low-lying and often wet or hydromorphic land, below the slopes that surround it and from which it receives water and colluvial deposit.
Melliferous	Used to describe a plant whose nectar is harvested by bees to make honey.
Metabolic	Used to describe the complex and constant processes of transformation of matter and energy by cells or the organism during phenomena of organic constitution and deterioration.
Microclimate	Climate unique to a limited portion of the environment, different from the overall climate of the latter.

Mineralization	Process during which humus in the soil is broken down and when it releases its constituent minerals.
Mite	A microscopic insect of the arachnid (spider) family.
Mulch	Layer of straw or other organic material placed on the ground to protect plants and soil.
Mycorrhizal	Symbiotic association of the vegetative part of a fungus and the roots of a tree or a flowering plant.
Nematicide	An active substance or a preparation used to protect a plant by killing nematodes that may attack it.
Nematode	Small worm that lives in the ground and may be a parasite for plants.
Nodule	Small swelling that forms on the roots of many plant varieties, especially in the Fabaceae family, due to action from bacteria in the Rhizobia family living in symbiosis with the plant.
Nutrient	An organic substance or mineral that is directly assimilable without having to undergo the breakdown processes of digestion.
Orthodox seeds	Used to describe seeds that can be dried or frozen without being damaged and that can thus be preserved for long periods
Palatability	Used to describe the state of a food that is acceptable or pleasant to consume.
Pathogen	Used to describe an organism capable of causing illnesses and infections.
Pesticide	Any substance or preparation used to protect crops from diseases and parasites. They may be natural (biopesticides) or chemical.
Photoperiodic	Used to describe a plant that is sensitive to the length of the day for its development and growth.
Photosynthesis	A biochemical reaction that takes place in plants and certain bacteria, which allows them to produce energy from sunlight and hence to produce organic matter.
Phytosanitary	Used to describe any substance or preparation used to protect crops from diseases and parasites. They may be natural (biopesticides) or chemical.

Pinnate	Used to describe leaves made up of leaflets arranged on both sides of an axis.
Pollination	The transfer of pollen seeds (male element) to the flower pistil (female element), which ensures fertilization. This mechanism is inherently natural (and often carried out by insects) but can be carried out artificially.
Pubescent	Covered by a surface of fine short hair.
Refill planting	The act of replacing dead or stunted plants in a cultivated plot.
Restructuring	Used to describe a plant whose roots are able to aerate soil and make it less compact, thereby re-establishing good soil structure.
Rhizobium	A bacterium that fixes atmospheric nitrogen and that lives in symbiosis on leguminous plant roots, where it forms nodules. Introduction of such leguminous plants in crop rotation helps enrich cultivated soil with nitrogen.
Ruderal	Used to describe a plant variety (e.g., nettle) that develops on rubble, near houses.
Shading structure	A structure providing shade to crops and young plants needing shade.
Slash-and-burn	Used to describe an agricultural practice by which fields are first cleared of trees before being burned to remove branches, stumps and residue, etc. The fields are then cultivated intermittently, using fallow periods longer than cultivation periods.
Soil structure	The more or less stable assembling of elements that make up soil (clay, sand, silt, humus, calcium, iron, etc.) in aggregates of variable size, with the free spaces providing porosity that enables water, the nutrients dissolved in the water, and gases (oxygen and nitrogen) to pass through.
Stone barrier	Construction made up of blocks of stone laid out along a contour line. It is used to fight water erosion by favouring the dispersion and infiltration of water as well as the deposit of solid elements carried to places uphill from the barrier.
Subligneous	A plant that is in the process of becoming lignified (woody).
Substrate	That which acts as a base for the development of a plant.
Tannin	A widespread natural substance in wood, bark, leaves, fruits and many plant roots. They act as defensive chemical weapons against certain parasites.

Texture	Refers to the relative proportions of the different elements of soil (sand, silt, clay, lime, organic matter) and determines the type of soil. For example, clay soil, silty-clay soil, etc.
Tiller / tillering	A tiller is a shoot. Tillering refers to shoots located at the same level as the stem, at the base of the plant. The shoots that are formed are characteristic of grassy plants.
Vegetated	Describes a site where grass, shrubbery or trees are sown or planted.
Voluble	Used to describe a plant whose spindly stem, sometimes very long, wraps itself around neighbouring bodies.
Water logging / flooding	Describes agricultural land saturated with water due to a rise in the level of groundwater, to significant water run-off or to excessive irrigation. Water logging makes soil more compact and deprives plant roots of oxygen, thereby causing plant asphyxiation.
Weed	A plant that sprouts spontaneously in a field where a crop is grown. Weeds are more or less harmful to crops because of the effects of competition with them, in terms of water, light and mineral elements contained in the soil.
Weeding	An act consisting of removing weeds where crops are growing.

Hemiptera	An order of insects.
Hoeing	An act consisting of removing weeds where crops are growing.
Hoverfly	A fly whose larva eats aphids.
Humus	A component of soil, resulting from the decomposition of organic matter (plant and animal debris). It plays a decisive role in soil fertility.
Input	In agriculture, is used to describe any product that is not naturally present in the soil and that is applied to crops. Inputs include fertilizers, pesticides and growth hormones, etc. Seeds are also sometimes considered as inputs.
Insecticide	An active substance or a preparation used to protect plants by killing insects that may attack them.
Integrated pest management	Type of crop protection whose application involves a set of methods that must meet ecological, economic and toxicological requirements, but which puts priority on the deliberate use of natural practices that respect tolerance limits.
Intercropping	The act of growing crops between rows of other crops or trees.
Invasive	Describes a plant variety or animal species that tends to colonize the environment rapidly and that enters into competition with local or cultivated species.
Leaching	Loss of mineral or organic elements of soil or manure when drained away by infiltrated water.
Leaflet	Each of the divisions of a compound leaf.
Lodging	The bending over of plant stems onto the ground, due to rain, wind or a parasite attack.
Lowlands	Low-lying and often wet or hydromorphic land, below the slopes that surround it and from which it receives water and colluvial deposit.
Melliferous	Used to describe a plant whose nectar is harvested by bees to make honey.
Metabolic	Used to describe the complex and constant processes of transformation of matter and energy by cells or the organism during phenomena of organic constitution and deterioration.
Microclimate	Climate unique to a limited portion of the environment, different from the overall climate of the latter.

Mineralization	Process during which humus in the soil is broken down and when it releases its constituent minerals.
Mite	A microscopic insect of the arachnid (spider) family.
Mulch	Layer of straw or other organic material placed on the ground to protect plants and soil.
Mycorrhizal	Symbiotic association of the vegetative part of a fungus and the roots of a tree or a flowering plant.
Nematicide	An active substance or a preparation used to protect a plant by killing nematodes that may attack it.
Nematode	Small worm that lives in the ground and may be a parasite for plants.
Nodule	Small swelling that forms on the roots of many plant varieties, especially in the Fabaceae family, due to action from bacteria in the Rhizobia family living in symbiosis with the plant.
Nutrient	An organic substance or mineral that is directly assimilable without having to undergo the breakdown processes of digestion.
Orthodox seeds	Used to describe seeds that can be dried or frozen without being damaged and that can thus be preserved for long periods
Palatability	Used to describe the state of a food that is acceptable or pleasant to consume.
Pathogen	Used to describe an organism capable of causing illnesses and infections.
Pesticide	Any substance or preparation used to protect crops from diseases and parasites. They may be natural (biopesticides) or chemical.
Photoperiodic	Used to describe a plant that is sensitive to the length of the day for its development and growth.
Photosynthesis	A biochemical reaction that takes place in plants and certain bacteria, which allows them to produce energy from sunlight and hence to produce organic matter.
Phytosanitary	Used to describe any substance or preparation used to protect crops from diseases and parasites. They may be natural (biopesticides) or chemical.

Pinnate	Used to describe leaves made up of leaflets arranged on both sides of an axis.
Pollination	The transfer of pollen seeds (male element) to the flower pistil (female element), which ensures fertilization. This mechanism is inherently natural (and often carried out by insects) but can be carried out artificially.
Pubescent	Covered by a surface of fine short hair.
Refill planting	The act of replacing dead or stunted plants in a cultivated plot.
Restructuring	Used to describe a plant whose roots are able to aerate soil and make it less compact, thereby re-establishing good soil structure.
Rhizobium	A bacterium that fixes atmospheric nitrogen and that lives in symbiosis on leguminous plant roots, where it forms nodules. Introduction of such leguminous plants in crop rotation helps enrich cultivated soil with nitrogen.
Ruderal	Used to describe a plant variety (e.g., nettle) that develops on rubble, near houses.
Shading structure	A structure providing shade to crops and young plants needing shade.
Slash-and-burn	Used to describe an agricultural practice by which fields are first cleared of trees before being burned to remove branches, stumps and residue, etc. The fields are then cultivated intermittently, using fallow periods longer than cultivation periods.
Soil structure	The more or less stable assembling of elements that make up soil (clay, sand, silt, humus, calcium, iron, etc.) in aggregates of variable size, with the free spaces providing porosity that enables water, the nutrients dissolved in the water, and gases (oxygen and nitrogen) to pass through.
Stone barrier	Construction made up of blocks of stone laid out along a contour line. It is used to fight water erosion by favouring the dispersion and infiltration of water as well as the deposit of solid elements carried to places uphill from the barrier.
Subligneous	A plant that is in the process of becoming lignified (woody).
Substrate	That which acts as a base for the development of a plant.
Tannin	A widespread natural substance in wood, bark, leaves, fruits and many plant roots. They act as defensive chemical weapons against certain parasites.

Texture	Refers to the relative proportions of the different elements of soil (sand, silt, clay, lime, organic matter) and determines the type of soil. For example, clay soil, silty-clay soil, etc.
Tiller / tillering	A tiller is a shoot. Tillering refers to shoots located at the same level as the stem, at the base of the plant. The shoots that are formed are characteristic of grassy plants.
Vegetated	Describes a site where grass, shrubbery or trees are sown or planted.
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The DEFIV project

From 2010 to 2015, the DEFIV project (Development of agricultural commodity chains in Mayanda, in the Democratic Republic of Congo), funded by the European Union and Agence française de Development and managed by GRET, aimed to improve food security in Bas-Congo province and combat the economic vulnerability of populations. Its objective was to improve supply of food crops, fruit, fish and meat for the population in the town of Boma through agricultural enhancement and opening up the Mayanda area. This led to the construction of paths and platforms for trading agricultural products to facilitate marketing via the promotion of improved plant varieties and innovative crop practices respecting the environment, and to the promotion of family farming and farmers' organisations. Agroecology played a significant role.

The APICI project

Since 2010, GRET and its Cambodian partner CIRD have been implementing the APICI project, which aims to increase income and improve the living conditions of small farmers in the region of Siem Reap in Cambodia. GRET provides support for the intensification and diversification of agriculture, and for the strengthening of farmers' groups. The project aims to improve rice growing (SRI technique), to diversify vegetable crops, improve the production of chicken, and promote the participation of farmers in savings groups.

Agroecological and agroforestry practices in tropical wet zones

This guide was created following a request by African farmers who wanted to engage in agricultural practices that are more respectful of their environment and more sustainable. It was designed as a support tool for all farmers and technicians wanting to develop agroecology and agroforestry in tropical wet zones.

After a brief reminder of the current context and issues of agroecology, it provides technical information generated by experience in four "fields" (the Democratic Republic of Congo, Myanmar, Cambodia and India). The first part presents the various agroecological techniques that can be easily and quickly put in place. The second describes the plants used to implement these techniques.

Abundantly illustrated and very operational, this guide should make it possible to test these agroecological practices and adapt them to suit various contexts (social, agronomic, climatic, etc.).

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