Australian Government
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INTEGRATING HERBACEOUS LEGUMES

into crop and livestock systems in eastern Indonesia

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Editors: Jacob Nulik, Neal Dalgliesh, Kendrick Cox and Skye Gabb

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FOREWORD

The recognition that cattle production improves farmer livelihoods in eastern Indonesia forms the basis of a program of research being undertaken by the Australian Centre for International Agricultural Research (ACIAR). In traditional subsistence farming systems, cattle represent a source of wealth to the farmer and are only sold in times of family emergency or social occasion. However, with the longer term national goal of increasing Indonesian self-sufficiency in cattle production, there is potential for farmers to engage with the broader market economy and move from being animal 'keepers' to animal 'producers'. Currently, farmers rely on low-quality native forages supplemented by higher quality legume material to feed their animals. However, in this monsoonal and highly variable climatic region, it is common for feed demand to outstrip supply, resulting in erratic animal liveweight gains and slow overall production rates.

While improved animal production provides entry to the market economy, the most critical issue facing farmers is the need to ensure the food security of their families. Maize and rice form the basis of this security but yields are often low due to poor crop nutrition and management.

The challenge for researchers has been to find ways in which both animal and crop production can be improved without markedly increasing the level of risk experienced by farmers. Australian and Indonesian research supported by ACIAR has shown that one method of improving the productivity of both animals and crops is as part of an integrated farming system. It involves growing herbaceous legumes, either in annual rotation with a cereal or after wet-season cereal production has been completed, when land is traditionally left fallow and allowed to grow weeds. In essence the research has shown that it is possible to add an additional crop into the traditional farming system without detriment to existing food security; that feeding forage legumes to cattle during the late dry or early wet season results in increases to overall liveweight gains compared with feeding native forages; and that nitrogen provided by the legumes may also improve maize production in subsequent crops.

ACIAR-funded research verified the technical feasibility of integrating short-term herbaceous legumes into the farming systems of eastern Indonesia. The next challenge is to ensure that farmers are aware of these opportunities and are capable of adopting them as required. This will only occur if government and non-government research and extension agencies understand the potential for herbaceous legumes in the farming system and have the skills to facilitate implementation. This manual provides those agencies with the resources necessary to undertake this task.

Nick Austin
Chief Executive Officer
ACIAR

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The contents of this publication are based on research findings from ACIAR project LPS/2006/003 (*Integrating forage legumes into the maize cropping systems of West Timor*). A number of organisations and many individuals have been critical to the success of this project. The project team, listed on page 8, wish to acknowledge the contribution of the partner organisations, BPTP-NTT (Departemen Pertanian, Balai Pengkajian Teknologi Pertanian – Nusa Tenggara Timur), CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia) and QDAFF (Queensland Department of Agriculture, Fisheries and Forestry), for managerial support, as well as the many individuals from within these organisations who contributed to the project. The project team also wishes to acknowledge the funding support of the Australian Centre for International Agricultural Research (ACIAR), the ongoing advice and mentoring provided by program managers Drs Bill Winter and Peter Horne, and the editorial input of Georgina Hickey to the publication of this manual. Lyle Winks and Bruce Cook also contributed to the reviewing of the manual and their contributions are gratefully acknowledged.

The ultimate indicator of project success will be improved livelihoods of the farmers of East Nusa Tenggara through the adoption of herbaceous legumes. This requires continuing effort by the Indonesian research, development and extension agencies BPTP-NTT, BAPPEDA Ende (Badan Perencanaan dan Pembangunan Daerah Kabupaten Ende), Dinas Peternakan and Dinas Pertanian; and non-government organisations, including Yayasan Mitra Tani Mandiri (YMTM) and Oasis, that are already promoting legumes in local farming systems. We thank them for their involvement and wish them every success in their future endeavours. Finally, we would like to thank the farmers of West Timor and Flores for their unconditional hospitality and willingness to participate in the research process.

CONTRIBUTORS

Dionisius Bria, BPTP-NTT

Esnawan Budisantoso, Australia Indonesia Partnership for Decentralisation Program (AIPD)
E: esnawanbudi@gmail.com

Toni Basuki, BPTP-NTT

Kendrick Cox, QDAFF
E: Kendrick.Cox@daff.qld.gov.au

Neal Dalgliesh, CSIRO Ecosystem Sciences
E: neal.dalgliesh@csiro.au

Paskalis Fernandes, BPTP-NTT
E: paskalisf@yahoo.com

Skye Gabb, Australian Volunteers for International Development
E: skye_gabb@hotmail.com

Debora Kana Hau, BPTP-NTT
E: debora_nulik@yahoo.com

Marsel Meo Muku, BPTP-NTT

Yustinus Namang, BPTP-NTT

Jacob Nulik, BPTP-NTT
E: jacob_nulik@yahoo.com

Simon Quigley, University of Queensland
E: s.quigley@uq.edu.au

Johanna Suek, University of Nusa Cendana
E: johanna.suek@gmail.com

Photographs used in this publication were provided by members of the project team, unless otherwise indicated.

ABBREVIATIONS

ACIAR	Australian Centre for International Agricultural Research
ASL	above sea level
BAPPEDA	Badan Perencanaan dan Pembangunan Daerah Kabupaten
BPTP-NTT	Departemen Pertanian, Balai Pengkajian Teknologi Pertanian – Nusa Tenggara Timur
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DW	dry weight
ENT	East Nusa Tenggara (Nusa Tenggara Timur)
N	nitrogen
NGO	non-government organisation
PAWC	plant-available water capacity
QDAFF	Queensland Department of Agriculture, Fisheries and Forestry

HERBACEOUS LEGUME SPECIES DISCUSSED IN THIS MANUAL

Scientific name	Suitable cultivars	Common English names	Common Indonesian names	Name used in manual[a]
Centrosema pascuorum	Bundey	Bundey centro	sentro, bundei	*Centrosema pascuorum*
	Cavalcade	Cavalcade centro	sentro, kavalked	
Clitoria ternatea	Milgarra, Q5455	butterfly pea	kacang kupu	*Clitoria ternatea*
Lablab purpureus	Highworth, Rongai, CQ3620	Lablab bean, dolichos	kacang lablab	*Lablab purpureus*
Centrosema molle	Cardillo	Cardillo centro	molle	*Centrosema molle*
Macroptilium bracteatum	Juanita, Cardarga	burgundy bean	kacang burgundy	*Macroptilium bracteatum*
Stylosanthes guianensis	CIAT 184, Nina (ATF 3308), Temprano (ATF 3309)	common stylo	Stylo guianensis	*Stylosanthes guianensis*
Stylosanthes seabrana	Primar, Unica	Caatinga stylo	Stylo seabrana	*Stylosanthes seabrana*

[a] The cultivar will be specified where there is more than one, and emphasis on a particular cultivar is important.

KEY POINTS

Using herbaceous legumes for livestock feeding

- Cattle production in East Nusa Tenggara (ENT) is limited by an irregular supply of high-quality forage, particularly late in the dry season.
- Animals on locally available feeds often have low rates of liveweight gain, mainly because of low nitrogen (N) levels within feeds during the dry season.
- Supplementing with forage from tree legumes such as *Leucaena leucocephala* and *Sesbania grandiflora* improves animal performance but supply is not always available.
- Herbaceous legumes such as *Clitoria ternatea* and *Centrosema pascuorum* provide an alternative source of high-N forage for feeding and may complement supplies from other sources.

Using herbaceous legumes in cereal systems

- Herbaceous legumes can be grown as a relay within cereal crops or as a rotation with cereals.
- The legumes can grow into the early dry season on residual stored soil moisture after the harvest of the cereal crop (when grown in relay).
- The forage can be fed to livestock fresh, or stored for feeding later in the dry season.
- The legume forage can be conveniently stored as hay.
- Herbaceous legumes can access atmospheric N ('fixation') through bacterial activity in root nodules. The 'fixed' N becomes available to the legume and subsequent cereal crops.
- Introduced legumes appear to nodulate effectively and fix N with native soil bacteria.
- The N contributed to crop production through fixation is reduced if legume material is removed, for example through cut-and-carry.

Producing seed

- Herbaceous legumes are best planted from seed.
- Seed can be produced successfully in ENT at the smallholder and commercial scales.
- Correct timing of sowing and harvesting is critical for the success of seed crops.
- Establishment of a suitable plant population is critical to successful production. Seed should be checked for germination and dormancy before planting, and the site should be prepared to maximise plant establishment.
- Seed can be planted in shallow furrows or by dibbling, with the planting configuration and rate dependent on species and seed size.
- Weed control is important, particularly during crop establishment.
- Trellises can encourage vigorous seeding of some legumes when grown in small areas.
- The chosen method and timing of harvest greatly influences recovered seed yields.
- Seed should be dried before storage.

Encouraging adoption

- Farmers who are actively engaged in animal production and have access to limited supplies of high-quality animal feed are most likely to grow herbaceous legumes.
- Adequate supplies of seed are needed if farmers are to plant herbaceous legumes.
- Education of farmers and extension staff on the benefits of legumes and how to grow them is critical for rapid adoption.
- Continuing support of farmers during the legume production process is critical to the successful adoption of the technology.
- On-farm demonstrations of legumes and the benefits to be obtained will hasten adoption.

1. INTRODUCTION

Although the annual average rainfall for the eastern Indonesian province of East Nusa Tenggara (ENT) is over 1,000 mm, subsistence farmers often face food shortages during the late dry and early wet seasons (September to November). This is a consequence of reliance on the short and highly variable wet season for the production of maize, the main food security crop. While research indicates that maize yields of >4 tonnes per hectare (t/ha) are achievable, the provincial average during 2000–09 remained at around 2.3 t/ha (Badan Pusat Statistik Republik Indonesia 2010), a consequence of climate variability, varietal selection, poor crop nutrition and suboptimal agronomic practice.

In recent years farmers have sought to participate in the broader cash economy, thereby providing the means to educate their children, purchase consumables and provide for medical and family emergencies. The common opportunity provided to farmers, through various government and non-government organisation (NGO) support programs, is to fatten cattle and export them live to the population centres of Java, Sumatra and Sulawesi. However, here also, production is constrained by a lack of suitable and consistent animal forages, resulting in low and erratic animal production rates.

The recognition that the inclusion of an annual or semi-perennial herbaceous legume may hold the key to improvement in both the animal and crop components of the farming system resulted in the commencement, in 2006, of the ACIAR project 'Integrating forage legumes into the maize cropping systems of West Timor'. The project began as a collaborative activity between the Indonesian Government research organisation Departemen Pertanian, Balai Pengkajian Teknologi Pertanian - Nusa Tenggara Timur (BPTP-NTT); the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia; and the farmers of West Timor. It later expanded to include the Queensland Department of Agriculture, Fisheries and Forestry (QDAFF); the farmers of Flores; the Indonesian Government agencies Badan Perencanaan dan Pembangunan Daerah Kabupaten (BAPPEDA) Ende; Dinas Peternakan-Kabupaten Ende, Dinas Pertanian, Dinas Peternakan and Perkebunan-Kabupaten Nagekeo; SMKs (Agricultural High Schools), particularly at Soe; and the NGOs Yayasan Mitra Tani Mandiri (YMTM) and Oasis.

Over the 6 years of on-farm and detailed research, the project team identified a small suite of legumes that farmers consider appropriate for use within the cereal (maize and upland rice)-based systems. These have been shown to be able to produce significant quantities of biomass for animal feeding and contribute to nitrogen (N) supply without jeopardising existing production of food security crops such as maize. The key to this success has been the recognition that water remaining in the soil as the main wet-season cereal crop matures is a resource available for the subsequent dry-season production of herbaceous legumes, a season in which food crops are not traditionally grown.

While the identification of the legumes and their niche within the broader farming system forms the basis of future adoption, of equal importance is the development of expertise within existing research and extension agencies and the training of future staff at the undergraduate level. This manual is designed to provide a scientific basis for the recommendations being made, as well as practical information on legume biomass and seed production, the agronomy associated with their production, and the potential benefits emanating from their use.

The publication of this manual is an important output from 6 years of participatory research. While the work was undertaken within a particular farming system in eastern Indonesia, the information contained is also relevant to a broader international audience grappling with increasing food security in smallholder mixed farming systems where land is constrained, population is increasing and climate variability is an ever-present issue.

2. HERBACEOUS LEGUMES IN EASTERN INDONESIA

The current situation

Smallholder farmers in eastern Indonesia have traditionally relied on the production of annual cereal crops and cattle to meet family food and cash requirements. Cattle production levels are low due to the feeding of local forages, which decline in protein level and digestibility as the dry season progresses (Fig. 1). This results in animals barely maintaining weight or suffering weight loss, particularly during the September–November period. Up to 60% of the weight gained during the wet season can be lost during the late dry and early wet seasons. This has resulted in very low overall levels of production, with typical annual weight gains in cattle of less than 200 g/day. To achieve the Indonesian national goal of self-sufficiency in cattle production, both the quality (particularly the N content) and quantity of the diet on offer must be improved.

Fig. 1: *Traditional grazing systems rely on low-quality grasses with small amounts of native or introduced legumes.*

What are the possible solutions?

In some western economies the direct feeding of N plant supplements or fertiliser to cattle is an appropriate means of improving the overall quality of feed intake. However, this response is not appropriate for smallholder subsistence systems where farmers have difficulty in both sourcing and paying for external sources of N. The growing of herbaceous legumes provides a cheaper and more suitable option.

What are legumes?

Legumes are a group of broad-leaved plants from the botanical families Fabaceae, Mimosaceae and Caesalpiniaceae. They are characterised by producing seedpods that open along a seam. An important feature of legumes is their capacity to convert atmospheric N into a form useful to the legume and companion plants (see pages 18 and 19).

Legumes vary considerably in growth habit and include:

- low-growing herbaceous types, which are prostrate and produce stolons or rhizomes (underground stems)
- trailing, sprawling or twining herbaceous types
- low-growing, fine, woody plants, which produce edible stems and leaves
- taller shrubs or trees, which are quite woody but produce nutritious foliage.

Forage from shrub (or tree) legumes such as leucaena (*Leucaena leucocephala*) and sesbania (*Sesbania grandiflora*) make excellent feed for cattle (Figs 2 and 3). However, as the dry season progresses, feed demand can outstrip supply, which results in a shortage of the protein necessary to support cattle production in the driest months of the year.

Unlike shrub legumes, which are difficult to remove once established, herbaceous legumes can be directly incorporated into cropping systems based on maize and rice (Figs 4 and 5). In this way herbaceous legumes can be managed for high levels of biomass production and can contribute to the production of companion or later crops. They can also be grown close to livestock compounds, reducing the amount of labour required to source high-quality forage for animals. In this manual we explore ways to take advantage of these useful characteristics.

Fig. 2: *Leucaena forage is transported to a feedlot in Amarasi, Kupang district, West Timor.*

Fig. 3: *Sesbania is grown as cut-and-carry in Lili, Kupang district, West Timor.*

Fig. 4: *A farmer group member from Tobu, South Central Timor district, West Timor, shows the growth of* Clitoria ternatea *planted in relay with maize.*

Fig. 5: *The perennial forage legume* Clitoria ternatea *is grown under irrigation as part of a rice rotation in Mbay, Nagekeo district, Flores.*

Why are legumes useful?

All plants need N to grow and they extract it from the soil through their roots. In many soils the amount of N available for the growth of plants is low and limits plant growth. Most legumes can absorb or 'fix' N from the atmosphere with the help of specialised bacteria (rhizobia) on their roots and convert it into a form that can be used by growing plants (Fig. 6). The bacteria form nodules on the roots in which the N is fixed, and the correct strains of bacteria must be present in the soil for this to happen. While most soils contain large populations of different N-fixing strains of bacteria, some legumes need specific strains to be able to fix N.

The amounts of N fixed by legumes depend on how well the legumes grow. This is influenced by the availability of a good growing environment (e.g. a supply of water and other soil nutrients, suitably drained soils and sufficient light) and the presence of effective strains of rhizobia. The levels of fixed N can range from less than 50 kg/ha/year (equivalent to 100 kg urea/ha) to more than 200 kg/ha/year (equivalent to more than 400 kg urea/ha). The N becomes available to the plants for growth when nodules break off the legume root and decompose. Nitrogen also becomes available to nearby plants through the decomposition of parts of the legume (e.g. roots and leaves) after they detach from the legume plant. Crops grown with or following the legume have the potential to produce higher yields as a result of access to higher levels of N; however, this is highly dependent on the management of the legume and the amount of biomass removed for animal feeding.

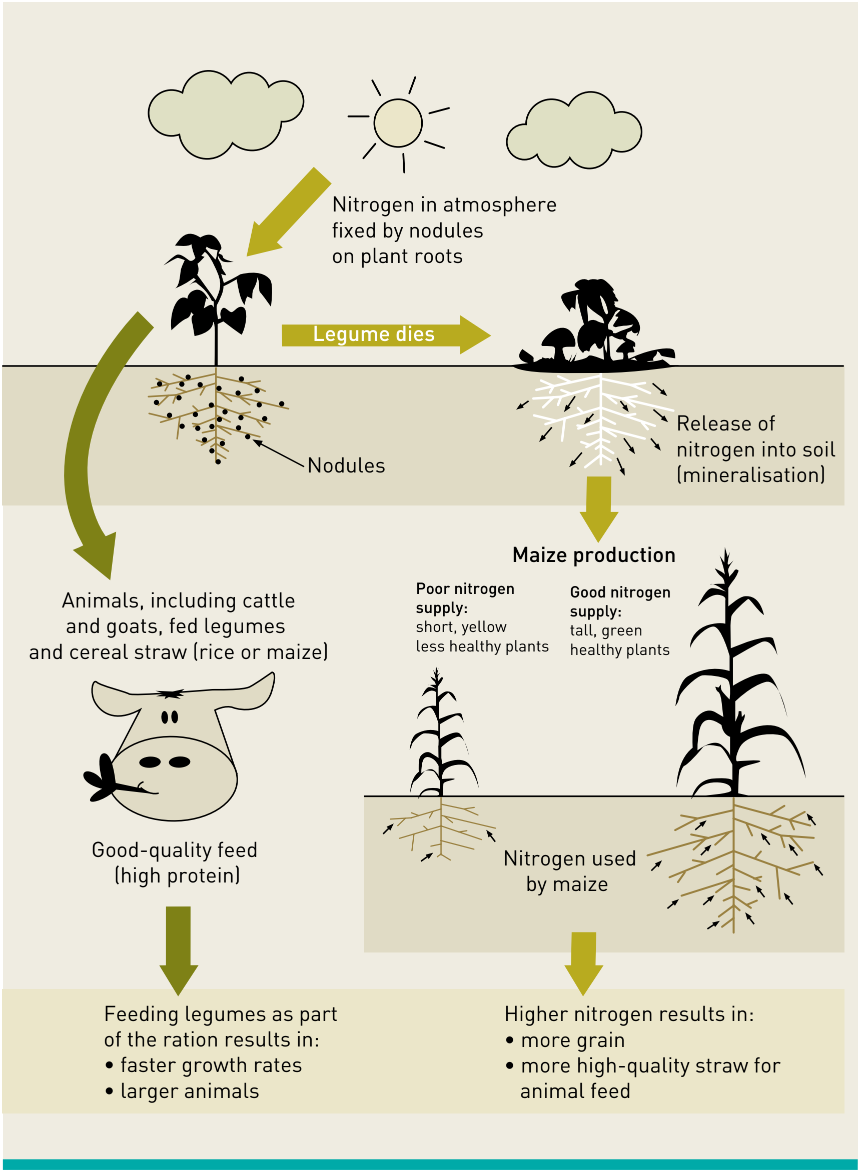


Fig. 6: *The nitrogen (N) cycle shows the fixing of atmospheric N and the contribution of forage legumes to animal production and subsequent cereal crops.*

CASE STUDY

After planting legumes, farmers found that their second crop of maize yielded just as much as the first crop

Kosmas S. Kusi and his fellow farmers live in the village of Nakuramba in the mountainous Ende district of Flores. Land is commonly used for 2 years before crop yields decrease so much that they have to clear a new area for planting. The yield of the second-year crop is normally lower than the first year's. The farmers found that second-year maize crops yielded as much as the first-year crop when legumes were planted in relay with the first maize crop. They believe that herbaceous legumes can be used to extend the cropping period by 3 or 4 years before nutrient decline forces a move to new land. This both increases overall production from the one piece of land and reduces the labour required for land clearing. Farmers found that herbaceous legumes have the additional benefit of erosion control on steep slopes.

The farmers were also impressed by the cattle growth rates they saw when visiting the village of Marapokot in the coastal district of Nagekeo, where farmers feed their cattle a mixture of herbaceous legumes and grass. As a result of this visit, seven Nakuramba farming families purchased cows and a bull (there are now over 20 cattle in the village) and commenced selling the progeny to other farming communities interested in cattle fattening.

Farmer group leader Kosmas speaks at a cross-visit to Marapokot about the benefits of forage legumes in Nakuramba.

Farmers in Nakuramba show second-year maize, which was planted following a crop of forage legumes and later yielded as much as first-year maize.

How does the animal benefit?

Cattle and goats are ruminants and need an adequate supply of plant nutrients to survive, grow and produce milk or meat. Ingested plants are broken down by microbes present in the rumen, or first stomach, and converted to forms that can be later absorbed by the animal. The numbers of these microbes and the speed with which they break down the material depend on a suitable supply of nutrients, especially protein, being available in the feed. Some carbohydrate components of plants, mostly structural parts of cells such as cell walls, are more difficult to break down than others, resulting in lower 'digestibility' (i.e. how much is reduced into smaller, usable components) of the feed (Fig. 7). Grasses supply good levels of protein (9–15%) and energy when young, but protein levels drop to 3–6% as the plant matures. Levels of poorly digested components increase in the maturing plant and digestibility tends to drop from about 70% to 40%. As a result microbes tend to break down feed rapidly when the grass is young but much more slowly as the plant matures.

The amount of useful feed an animal can eat (the 'intake') and use for growth is determined by the amount available to eat and how quickly it is broken down by the animal. Less-digestible feeds reduce intake. Therefore, animals grow well when grasses are young and growing rapidly but may lose weight when grasses are mature, because they eat less feed and less of it is digested.

Cattle eating legumes benefit from the higher protein levels compared with grasses. Legumes contain about 15–30% protein when young, dropping to 9–15% when mature. The increased supply of protein allows the bacteria to multiply and break down the feed more quickly in the rumen. It then continues through the digestive tract and allows the animal to eat more feed (increased intake). Many legumes, particularly the herbaceous types, are highly digestible. Weight gains and milk yields are therefore improved through an overall increased uptake of protein and energy.

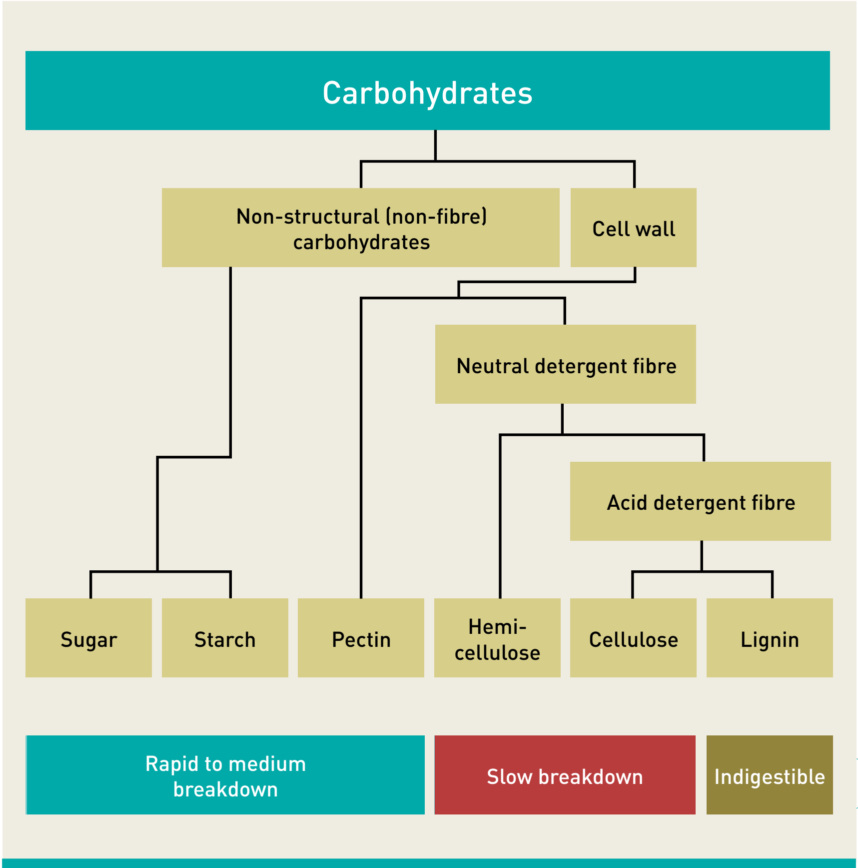


Fig. 7: *Different plant components break down at different rates in the animal's rumen.*

CASE STUDY

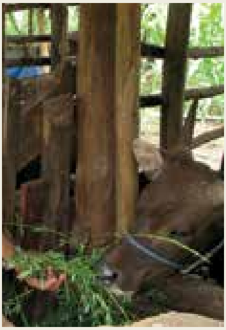
Herbaceous legumes helped farmers fatten and sell 50 head of cattle per year

Leonardus Lau and his fellow farmers grow maize and cattle in the North Central Timor district of West Timor. In the village of Usapinonot the farmers' cash income comes from fattening and selling cattle. The faster their cattle grow, the more they are able to buy and sell, which has a significant impact on their cash income.

Leonardus inspects his maize, which was planted in relay with forage legumes.

Before using herbaceous legumes grown in combination with maize, it took Leonardus 1–2 years to fatten a bull ready for sale. However, through supplementing his cattle feed with herbaceous legumes, he has been able to decrease the time required to fatten cattle to 8–9 months. Animal growth rates are 90 g/day faster than when fed grasses only.

With assistance to purchase cattle, the farmer group increased its number of animals from 20 to 50. By supplementing local feed resources with high-quality herbaceous legumes, the farmers were able to supply sufficient feed for their newly acquired cattle and met market weights in less than 1 year.



Legumes are fed to penned cattle in Usapinonot to supplement poorer quality feeds.

While cattle provide his cash income, Leonardus plants maize to meet the food requirements of his family. However, his maize crops were often unable to compete with weeds, especially striga (*Striga* spp.), resulting in reduced yields or complete crop failure. Striga favours soils with low N levels and Leonardus found that weed levels declined after integrating herbaceous legumes into his maize crops. As a result maize yields increased and his crops no longer failed due to competition for water and nutrients.

How can legumes be used in farming systems?

Herbaceous legumes grown within cropping systems can increase the amount of N available to companion or later crops while producing high-quality fodder for livestock production. If well managed, as much as 5,000 kg (dry weight)/ha/year of high-quality fodder can be produced in 1 year. Under rainfed conditions in ENT herbaceous legumes can grow well into the dry season, providing a valuable source of high-quality feed for livestock after maize production has finished (Fig. 8). There are a number of ways of using them in a cropping system. These are broadly discussed below as green manure, rotation and relay systems.

Green manure

With this method a legume crop is grown in the wet season before the planned production of a cereal crop. It is ploughed or hoed into the soil when still green and growing, and allowed to decompose during the dry season. The cereal crop is planted the following wet season and takes advantage of the N produced by the legume. Unfortunately, the area of land cannot be used for food or fodder production during the growing season of the green manure crop, and there must be sufficient labour available to plant and manage the crop as well as complete other farming activities.

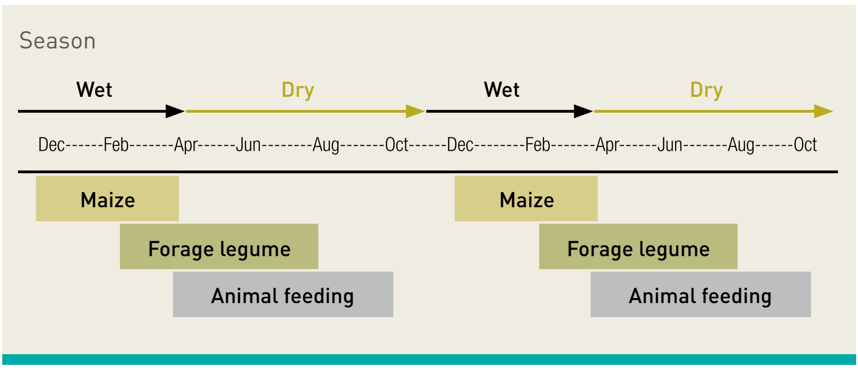


Fig. 8: *This is an example of a rainfed upland cropping system incorporating a forage legume and maize, with the legume fed to animals.*

Rotation

In this method the legume is grown in the wet season before a cereal crop in the same way as for a green manure, but the forage is harvested for feeding to animals during the dry season (Fig. 9) or grown as a seed crop. Since the residue (i.e. less what is fed to animals) is all that is turned into the soil, less N and organic matter are added to the system than with a green manure crop.

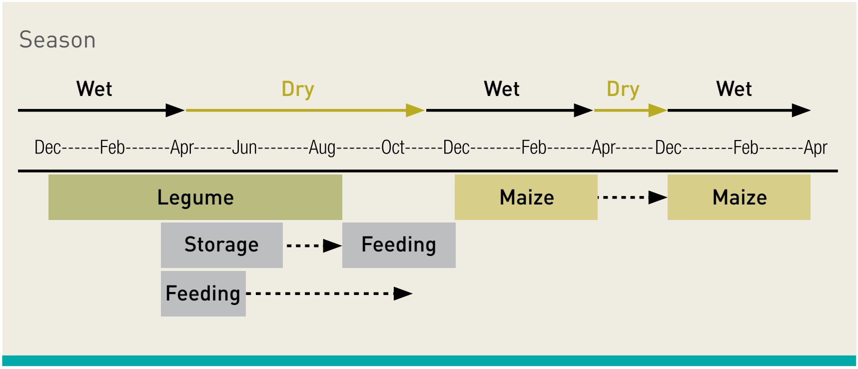


Fig. 9: *This shows a rotation system, with a legume grown in one wet and dry season before maize is planted in the following wet season or seasons.*

Relay

With this method legumes are planted into the maize or rice crop while the cereal is growing (usually around flowering time) (Fig. 10). The legume continues to grow after the cereal crop has been harvested (usually in the early dry season) and is later cut for feeding to livestock. In cases where perennial herbaceous legumes are grown, the plants can be retained for another season and cut for fodder, while maize is planted between the rows. In many areas crops such as cowpea, peanut, mungbean and pumpkin are already intercropped with maize during the wet season. As the legume and the cereal crop compete for moisture, light and nutrients, the legume will produce less forage than if sown as a green manure or a rotation.

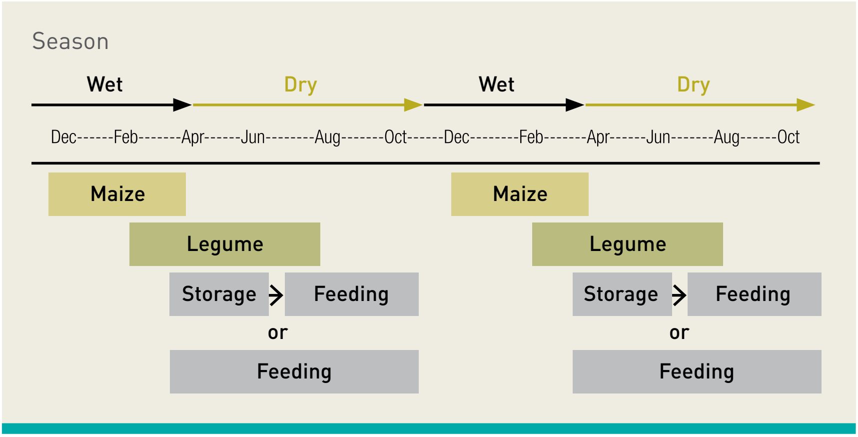


Fig. 10: *This shows a relay cropping sequence in which a legume is grown with a maize crop during each wet season and into the dry season.*

Herbaceous legumes and browse legumes

The use of herbaceous legumes is also complementary to tree or shrub (browse) legumes such as *Leucaena leucocephala*, *Sesbania grandiflora* and *Gliricidia sepium*, which are an important component of the animal feed supply. Whereas the tree legumes are best used as live fences, in alley cropping systems or as monoculture fodder banks, herbaceous legumes are best grown directly within the cereal-based system, either in relay or rotation with maize.

Note: Herbaceous legumes are also able to be grown successfully in association with other cereals including rainfed upland rice and irrigated lowland rice; however, for simplicity, maize is used as the example cereal crop in this manual, except where information relating directly to rice production is required.

3. WHAT ARE THE IMPORTANT CONSIDERATIONS WHEN SELECTING LEGUMES?

The environment

Eastern Indonesia varies greatly in its physical characteristics, from coastal lowlands to mountainous areas in excess of 1,000 m above sea level (ASL), with soil types including alkaline or near neutral Vertisols (self-mulching highly fertile cracking clays), Inceptisols (relatively fertile silty loams) and Alfisols (moderately fertile sandy clay loams). The amounts and distribution of rainfall also vary. While a range of legumes will grow across the different environments, some are better adapted to particular situations. The critical factors determining their suitability to an area are temperature, rainfall, soil type and resistance to insect and disease attack.

Effect of elevation and temperature

While the legumes described in this manual will grow from the coastal plains to elevations above 1,000 m ASL (Table 1), the time of flowering and forage yield can vary with elevation and associated changes in temperature and rainfall. In general, lower temperatures at higher elevations reduce growth rate, but the growing season may be extended through an increase in the length of the rainy season and lower evaporation rates.

Table 1: *Physical and climatic information on sites in East Nusa Tenggara (ENT), Indonesia, where evaluation of forage legumes was undertaken between 2005 and 2011*

Region (district)	Village	Latitude, Longitude	Elevation (m ASL)[a]	Annual rainfall (mm); pattern	Soil order (USDA[b] soil classification)
West Timor (Kupang)	Sillu	10.053°S, 123.960°E	440	800–1,200; unimodal	Alfisols, Entisols and Inceptisols
	Oebola	10.069°S, 124.006°E	557	800–1,200; unimodal	Alfisols, Entisols and Inceptisols
	Naibonat	10.077°S, 123.863°E	28	1,000–1,800; unimodal	Inceptisols (Vertic Ustropepts) and Vertisols
	Fatukanutu	10.156°S, 123.911°E	191	unimodal	Inceptisols and Vertisols
West Timor (South Central Timor)	Biloto	9.873°S, 124.222°E	560	1,500–2,000; unimodal	Inceptisols, Entisols and Vertisols
	Soe (SMK)	9.855°S, 124.264°E	900	700–2,300; unimodal	Entisols, Inceptisols and Alfisols
	Tobu	9.567°S, 124.325°E	1074	1,000–2,000; unimodal	Entisols and Inceptisols
	Soe (Dinas)	9.812°S, 124.303°E	713	unimodal	Alfisols and Vertisols
West Timor (North Central Timor)	Usapinonot	9.452°S, 124.544°E	360	400–1,000; unimodal	Inceptisols (Vertic Ustropepts) and Entisols
	Lapeom	9.497°S, 124.576°E	360	400–1,000; unimodal	Inceptisols (Vertic Ustropepts) and Entisols
West Timor (Belu)	Kakaniuk	9.578°S, 124.845°E	48	1,500–2,000; bimodal	Inceptisol (Typic Ustropepts)
	Kletek	9.588°S, 124.933°E	70	1,500–2,000; bimodal	Inceptisols (Typic Ustropepts)
	Betun	9.602°S, 124.929°E	10	1,500–2,000; bimodal	Inceptisols (Typic Ustropepts)
	Nurobo (Dinas)	9.394°S, 124.828°E	460	1,500–2,000; unimodal	Inceptisols and Entisols

continued over

Table 1: *continued*

Region (district)	Village	Latitude, Longitude	Elevation (m ASL)[a]	Annual rainfall (mm); pattern	Soil order (USDA[b] soil classification)
Flores (Ende)	Nakuramba	8.754°S, 121.578°E	382	1,500–2,300	Inceptisols
	Reworangga	8.821°S, 121.672°E	152	1,000–1,600	Inceptisols
	Wolomasi	8.771°S, 121.729°E	715	1,500–2,000; unimodal	Inceptisols and Vertisols
Flores (Nagekeo)	Mbay	8.547°S, 121.296°E	20	1,000–1,500; unimodal	Inceptisols
	Ulupulu	8.732°S, 121.303°E	529	1,500–2,000; unimodal	Inceptisols

[a] metres above sea level
[b] United States Department of Agriculture

Effect of rainfall

Annual rainfall in eastern Indonesia can vary widely in amount (from 400 to >2,300 mm) and seasonal distribution. While some areas have distinct wet and dry seasons (unimodal pattern) (Fig. 11), others have two annual wet seasons (bimodal pattern), which results in a shorter annual dry season (Fig. 12). Wet-season length, in combination with the quantity of soil water remaining at the end of the wet season, determine the potential legume biomass production during the dry season. While prolonged rainfall experienced in bimodal regions during April–October can give more prolonged growth and higher forage yields, it also increases the potential for insect pest attack. The longer wet period can also make it difficult to harvest seed crops, especially if seed is recovered from the ground.

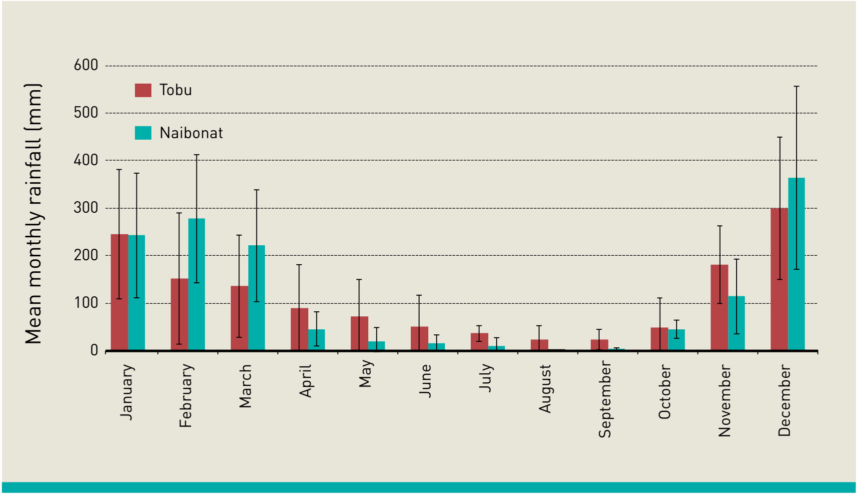


Fig. 11: *The mean monthly rainfall amounts, variability and distribution are shown for Naibonat, Kupang district (28 m ASL), and Tobu, South Central Timor district (1,074 m ASL), for 2001–09 (BPTP-NTT data). The average annual rainfall for both sites was approximately 1,360 mm.*

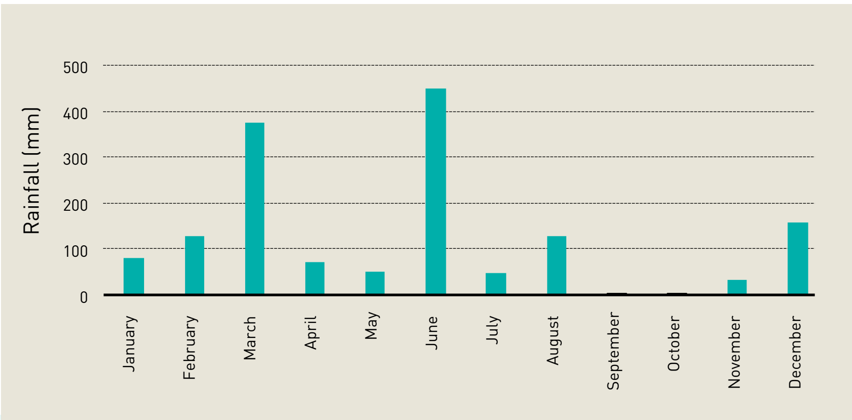


Fig. 12: *This is an example of bimodal rainfall distribution from Belu district, West Timor, in 2007, in which 848 mm fell during the first wet season (November–April) and 681 mm during the second wet season (May–October).*

Effect of soil type on soil moisture availability

The capacity of the soil to store moisture for use by plants (called the plant-available water capacity—PAWC) during the early to mid dry-season period is a strong determinant of plant survival and forage yield. The amount of water available to plants is affected by the texture and depth of the soil and the ability of the particular species to extract water from the soil. In general, clay soils hold more water than sandy soils and deeper soils store more water than shallow ones (Dalgliesh and Foale 1998). The rooting depth of the plant affects the amount of moisture available to it (Fig. 13; Table 2). Many herbaceous legumes can develop roots more than 2 m deep, while crops such as maize reach a depth of 1.5–1.8 m and quick-maturing crops such as mungbean reach only 0.9–1.2 m. Rooting depth and water extraction are also affected by the level of soil fertility as this influences the growth of the plant.

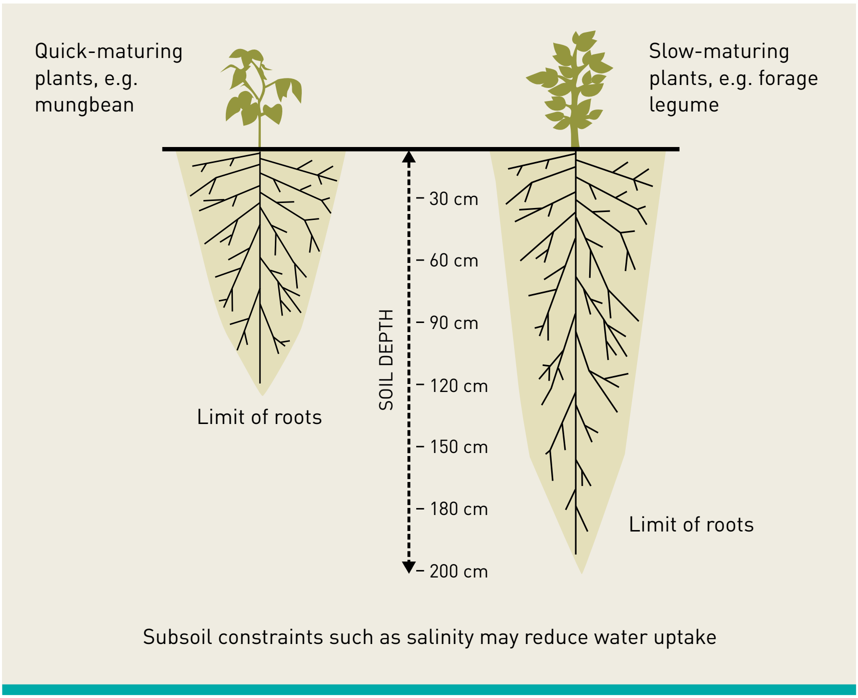


Fig. 13: *Differences in rooting depth between short- and long-lived plants have an impact on the amount of water available for biomass production.*

INFORMATION

How can a herbaceous legume grow successfully during the dry season when there is little rainfall?

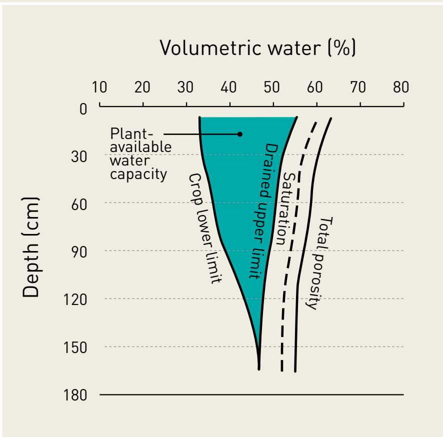
Stored soil water unused by the maturing maize crop, as well as water from late wet-season rainfall, is available for use by a herbaceous legume that grows into the dry season. Normally this water grows only weeds, which provide a low-quality source of forage for the 'tether' grazing or 'cut-and-carry' feeding of animals. However, this water can be used much more effectively for the production of legumes.

Understanding 'stored' soil water

To understand the contribution that soil water makes to dry-season crop production, it is necessary to understand the cropping soils of ENT, their potential to store water (the 'plant-available water capacity' (PAWC)) and the potential impact of this water on crop production.

What is PAWC?

PAWC is the measure of a soil's ability to hold water available for use by a particular type of plant. It is measured in millimetres (the same units as rainfall) and is described as 'millimetres of available water' (Table 2).



An example of a soil water profile shows the volumetric water percentage at drained upper limit (DUL), crop lower limit (CLL), saturation and total porosity for a soil of 180 cm depth. The plant-available water capacity (PAWC) of the soil is the difference between DUL and CLL and is highlighted in blue.

INFORMATION

Why does the PAWC vary between soils and crops?

One of the main determinants of a soil's PAWC is the texture—the higher the clay percentage, the higher the PAWC; and the sandier the texture, the lower the PAWC. The presence and level of subsoil constraints (including chloride, sodium and boron) also impact on the PAWC, as does the physical depth of the soil.

The grey-coloured cropping soils encountered in West Timor and Flores are likely to be Inceptisols or Vertisols. These silty loam and clay-textured soils have a higher PAWC than the Alfisols, which are the other common cropping soil in the province. Alfisols are red or brown in colour and sandy clay loam in texture.

This is an Inceptisol in Nakuramba, Ende district, Flores.

A Vertisol in Naibonat, Kupang district, West Timor, cracks when dry.

This is an Alfisol in Sillu, West Timor.

Table 2: *The plant-available water capacity (PAWC) for a range of forage and cereal crops grown at sites in West Timor, showing the differences in PAWC between soils and locations, and between individual crops grown on a particular soil at a location*

District (village)	Latitude, Longitude; elevation (m ASL)	Soil type (order)	PAWC to 180 cm depth (in mm of available water)
Kupang (Sillu)	10.032°S, 123.962°E; 440 m	Alfisol	Maize *(Zea mays)*: 105 Butterfly pea *(Clitoria ternatea)*: 194 Cavalcade *(Centrosema pascuorum)*: 170 Dolichos lablab *(Lablab purpureus)*: 172 Burgundy bean *(Macroptilium bracteatum)*: 172
Kupang (Oebola)	10.067°S, 124.006°E; 557 m	Alfisol	Maize *(Zea mays)*: 151 Dolichos lablab *(Lablab purpureus)*: 209 Burgundy bean *(Macroptilium bracteatum)*: 217
Kupang (Naibonat)	10.077°S, 123.863°E; 28 m	Inceptisol	Maize *(Zea mays)*: 155 Butterfly pea *(Clitoria ternatea):* 308 Cavalcade *(Centrosema pascuorum)*: 319 Peanut *(Arachis hypogaea)*: 196 Mungbean *(Vigna radiata)*: 170
South Central Timor (Biloto)	9.878°S, 124.226°E; 560 m	Vertisol	Maize *(Zea mays)*: 154 Butterfly pea *(Clitoria ternatea):* 161 Cavalcade *(Centrosema pascuorum)*: 161 Burgundy bean *(Macroptilium bracteatum)*: 161

continued over

Table 2: *continued*

District (village)	Latitude, Longitude; elevation (m ASL)	Soil type (order)	PAWC to 180 cm depth (in mm of available water)
North Central Timor (Usapinonot)	9.487°S, 124.558°E; 360 m	Inceptisol	Maize *(Zea mays)*: 245 Butterfly pea *(Clitoria ternatea):* 191 Cavalcade *(Centrosema pascuorum)*: 219 Burgundy bean *(Macroptilium bracteatum)*: 206
Belu (Kakaniuk)	9.574°S, 124.845°E; 48 m	Inceptisol	Maize *(Zea mays)*: 155 Butterfly pea *(Clitoria ternatea):* 200 Cavalcade *(Centrosema pascuorum)*: 183 Burgundy bean *(Macroptilium bracteatum)*: 190
Belu (Kletek)	9.573°S, 124.936°E; 70 m	Inceptisol	Maize *(Zea mays)*: 129 Butterfly pea *(Clitoria ternatea)*: 146 Cavalcade *(Centrosema pascuorum)*: 149 Dolichos lablab *(Lablab purpureus)*: 144 Burgundy bean *(Macroptilium bracteatum)*: 149

Will there be sufficient rainfall in the late wet season to produce legume biomass?

The amount of rainfall and its distribution varies considerably between locations and seasons across ENT. As a result farmers rely on their experience to make judgments on the likely length of a particular season. Fig. 14 provides examples of the variability in wet-season rainfall distribution between locations (Biloto, South Central Timor district (560 m ASL)—1,042 mm; Usapinonot, North Central Timor district (360 m ASL)—486 mm; and Kakaniuk, Belu district (48 m ASL)—1,484 mm). Kakaniuk, which is located on the southern coast of West Timor, has a bimodal rainfall pattern, which contributes to its higher annual rainfall compared with the unimodal sites of Biloto and Usapinonot.

In terms of rainfall contribution to dry-season legume production, the rain that falls after the assumed flowering date for maize (1 March) is the most important. In the year described in Fig. 14 Biloto received 204 mm, Usapinonot 178 mm and Kakaniuk 1,154 mm (shown in red). While as much as 70% of this water could be lost to evaporation, run-off and drainage, it is still a potentially significant source of water for dry-season legume production.

What properties should a legume have?

Suitable herbaceous legumes should be of high feed quality for livestock (ideally protein concentration above 18% and digestibility above 60%) and well adapted to growing within cereal cropping systems in ENT. Legumes should be selected that fix higher levels of N, produce higher levels of biomass under cutting, require lower levels of management and are not prone to becoming weeds within the farming system. Considerations for selecting suitable herbaceous legumes for use in relay and rotation systems are presented in Table 3. Descriptions of performance of useful legumes are described on pages 41–47 and in Table 4.

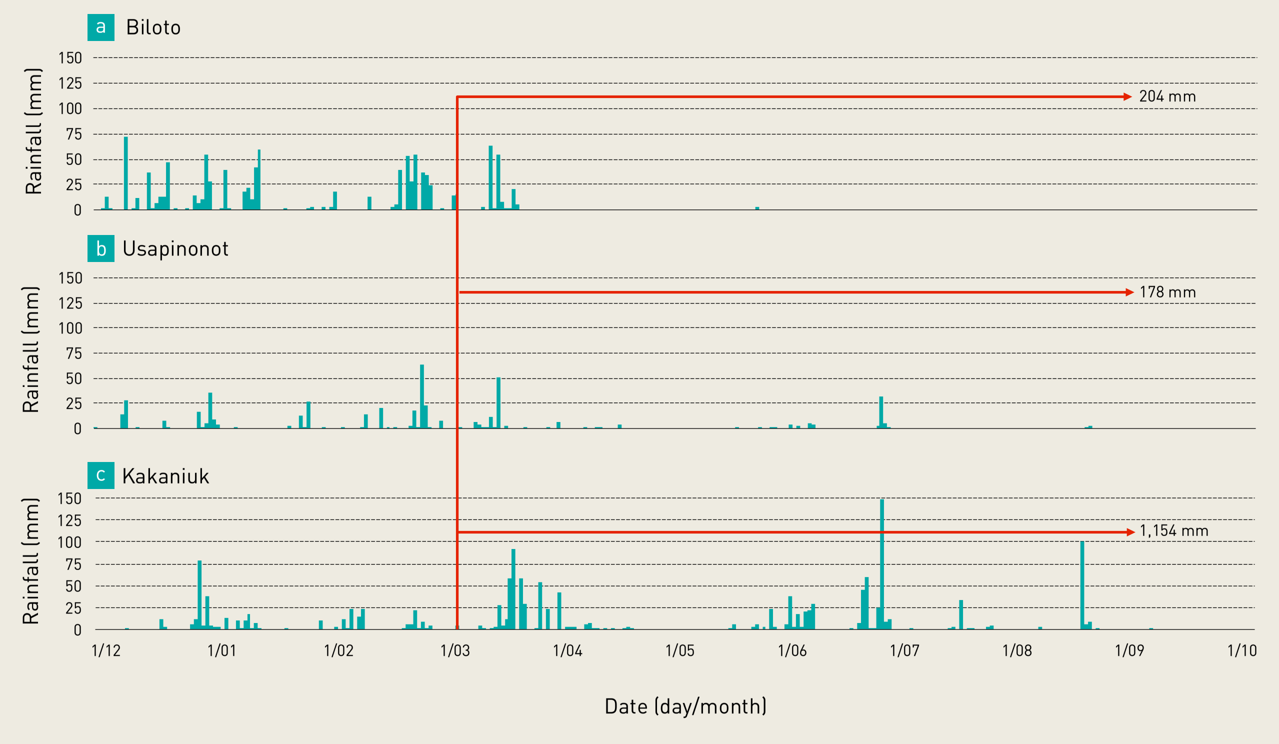


Fig. 14: *2006–07 rainfall quantity and distribution for the villages of (a) Biloto, (b) Usapinonot and (c) Kakaniuk in West Timor show the variability in annual rainfall and rainfall after the end of February. Stored water from late rainfall (after 1 March) is available to contribute to forage legume production during the dry season.*

Table 3: *Desirable characteristics of a good legume for maize–legume and rice–legume relays in East Nusa Tenggara (ENT)*

Desirable characteristic(s)	Reason(s)
Good growth in the humid but seasonally dry tropics	ENT is a tropical environment with a strong (and sometimes unreliable) dry season. The legumes will usually be sown during the wet season but are expected to grow into the dry season.
Adapted to a range of soil types, but particularly alkaline and slightly acid clay and loam soils	There is a range of soil types in ENT, including well- and poorly developed soils. Alkaline clay soils (Vertisols, Inceptisols and Alfisols) are commonly used for maize and upland-rice production.
Tolerant of short-term waterlogging	High wet-season rainfall can result in temporary waterlogging of clay soils, which can increase disease development in some legumes.
Easy to establish from seed: > larger seeds (5+ mm long) > low proportion of hard seeds (dormancy) > seed easy to produce and harvest	Seed needs to be available and establish rapidly with a minimum of care following scattering, 'dibbling' (planting into holes made with a handtool with a pointed end) or row planting. Larger seeds tend to establish most rapidly and from a wider range of depths. High levels of hardseededness lead to slow and uneven establishment. Hard seed needs to be treated (scarified) before planting.
Resilient to pests and diseases: > insects feeding on leaves, stems and roots > soil-borne diseases > leaf diseases	There is little scope to treat legumes against insects or diseases. The plants must have an inherent tolerance to diseases (or to stresses that predispose disease) and be unattractive to insects that feed on other legumes in ENT.

continued over

Table 3: *continued*

Desirable characteristic(s)	Reason(s)
Tolerant of at least moderate shade	The companion crop, particularly maize, will partially shade the legume until it is harvested. Some legumes tolerate low light conditions better than others.
Able to efficiently access available soil moisture to depth to ensure extended dry-season forage production and plant survival	Legumes that can continue to grow under lower soil moisture conditions will continue to produce fodder into the dry season. Perennial legumes that can extract moisture to depth will survive the dry season and contribute to forage production in the following wet and dry seasons.
Moderate persistence: > low levels of hard seeds >	Some legumes can be difficult to remove from a site once planted, e.g. those that produce many dormant (hard) seeds or woody types.
For fodder	
Suitable for livestock production: > acceptable to livestock (taste, smell) > no anti-nutritional factors/toxins > high digestibility, energy and protein levels	The legume must contribute to livestock growth and reproduction in fresh, wilted and dried (hay) forms. Some legumes contain chemicals that interfere with livestock metabolism or require alteration of rumen microflora before they can be used safely. Legumes vary widely in feed quality.
Rapid growth: > high forage production	The opportunity for growth is usually between 3 (short wet season) and 6 months (longer wet season or bimodal rainfall). Legumes vary widely in their capacity to establish and produce fodder.

continued over

Table 3: *continued*

Desirable characteristic(s)	Reason(s)
Suited to cut-and-carry (by hand): > easy to cut > non-irritating to skin	The fodder must be cut and moved by hand. Any features of the legume that interfere with this (e.g. woody stems or low-growing and sticky leaves) may reduce its use. Plants with a more erect growth habit can be easier to cut than twining legumes.
Easy to dry and bale: > thin stems > retains leaves when dry	Legumes need to be dried evenly and quickly to produce high-quality hay that stores well. Leaves are usually the most nutritious part of the plants and pods are good too—these should all be retained if possible.
Good regrowth after cutting	Vigorous regrowth after low cutting (usually 10–15 cm) is needed if more than one cut is planned. Legumes vary widely in their ability to regrow after cutting.
For nitrogen (N) fixation	
Rapid growth and high levels of forage production	The amount of N made available for later crops depends in part on how much high-quality plant material is produced and the amount that remains in the field (i.e. not removed for animal feeding).
Compatibility with native N-fixing bacteria	Legumes that are able to fix N using native bacteria (as do the recommended legumes) do not require inoculation with specially introduced bacterial strains.
High N-fixation potential	Legumes vary in their ability to fix N, independent of dry matter production.

Which legumes for different situations?

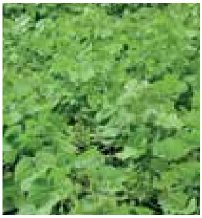
The following recommendations are based on studies on research stations and farms covering a wide range of environments in ENT.




Centrosema pascuorum (kavalked)	
Cultivars:	Cavalcade, Bundey
Best use(s):	> Short-term relay with maize or rice > Rotation with maize or rice
Best soils:	Has been grown successfully on sandy clays and medium to heavy clays with pH 6–8
Best rainfall:	Short (ends April) or long (ends June) wet season or bimodal
Growth habit:	Sprawling with some twining
Life span:	Usually less than 1 year unless soil moisture levels remain high
Flowering time:	Early, 3–4 months after establishment and whenever good growing conditions occur; Cavalcade flowers earlier than Bundey
Strengths:	> Ease of establishment > Excellent wet-season growth > High-quality fodder for cattle and goats > Suitability for hay production > Improvement of soil nitrogen levels
Limitations:	> Less capacity to regrow after cutting in the dry season than other legumes (e.g. *Clitoria ternatea*) > Temporary damage by a leaf mining insect, mostly at higher elevations in wet conditions > Seed production requires special management

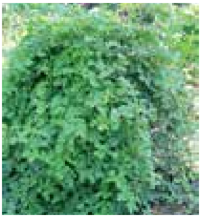
Clitoria ternatea (kacang kupu)	
Cultivars:	Milgarra, Q5455
Best use(s):	> Long- or short-term relay with maize or rice > Rotation with maize or rice
Best soils:	Has been grown successfully on sandy clays and medium to heavy clays with pH 6–8
Best rainfall:	Short (ends April) or long (ends June) wet season or bimodal
Growth habit:	Initial growth erect, twining thereafter
Life span:	Perennial
Flowering time:	Very early, 1–3 months after establishment and whenever good growing conditions occur
Strengths:	> Ease of establishment > Excellent regrowth after cutting > Excellent wet- and dry-season growth > High-quality fodder for cattle and goats > Suitability for hay production > Ease of village seed production > Improvement of soil nitrogen levels
Limitations:	> Seasonal defoliation by *Catopsilia* sp. butterfly larvae

***Lablab purpureus* (kacang lablab)**	
Cultivars:	Highworth, Rongai, CQ3620
Best use(s):	> Rotation with maize or rice
Best soils:	Moderately to well-drained, slightly acid to slightly alkaline clay soils; avoid poorly drained areas
Best rainfall:	Short (ends April) or long (ends June) wet season
Growth habit:	Twining
Life span:	Mostly annual; some plants may regrow if sufficient soil moisture
Flowering time:	Late, usually strongest in May–August
Strengths:	> Ease of establishment > Excellent wet-season growth > Large biomass and good nitrogen fixer > Pods provide a source of human food > Relative ease of village seed production
Limitations:	> Poor regrowth after cutting, especially if cut below 10 cm > Susceptibility to disease in wet, poorly drained soils

Centrosema molle	
Cultivars:	Cardillo
Best use(s):	> Short-term relay with maize or rice > Rotation with maize or rice
Best soils:	Slightly alkaline to slightly acid clay soils
Best rainfall:	Short (ends April) or long (ends June) wet season or bimodal
Growth habit:	Twining, forms a dense leafy canopy and roots form on the stems in wet conditions
Life span:	Perennial
Flowering time:	Late, usually in June–August; may not flower in the first season
Strengths:	> Ease of establishment (once hard seed is treated) > Excellent wet- and dry-season growth > High disease and insect tolerance > High-quality fodder and hay
Limitations:	> Rooting from stems may interfere with cutting > Seed production can be poor in the first season

Macroptilium bracteatum (kacang burgundy)	
Cultivars:	Cardarga, Juanita
Best use(s):	> Short-term relay with maize or rice > Rotation with maize or rice
Best soils:	Alkaline to slightly acid clay soils
Best rainfall:	Short (ends April) or long (ends June) wet season or bimodal
Growth habit:	Initial growth erect, twining thereafter; Cardarga is more erect than Juanita
Life span:	Usually 1–2 years
Flowering time:	Early, 2–3 months after establishment and whenever good growing conditions occur
Strengths:	> Ease of establishment (once hard seed is treated) > Moderate regrowth after cutting > Excellent wet- and dry-season growth > High-quality fodder > Ease of haymaking
Limitations:	> Can get leaf diseases in cool, wet weather > Seed pods readily shatter once mature, requiring careful management during seed harvest

Stylosanthes guianensis (Stylo guianensis)	
Cultivars:	Anthracnose-resistant types, e.g. CIAT 184, Nina (ATF 3308) and Temprano (ATF 3309)
Best use(s):	> Fodder banks in non-crop areas
Best soils:	Sandy or light clay soils, acid to slightly alkaline
Best rainfall:	Short (ends April) or long (ends June) wet season or bimodal
Growth habit:	Erect and branching
Life span:	2–4 years if not cut short (<20 cm) when seeding
Flowering time:	Late, usually beginning in May–June
Strengths:	> Excellent wet- and dry-season growth > Few pests and diseases > High-quality fodder although cattle may take time to adapt > Ease of haymaking if plants cut when not woody
Limitations:	> Slow establishment > Poor growth in wet, poorly drained soils > Seeds are shed from seedheads when mature, requiring careful management during seed harvest



Stylosanthes seabrana (Stylo seabrana)	
Cultivars:	Primar, Unica
Best use(s):	> Fodder banks in non-crop areas
Best soils:	Alkaline to slightly acidic clay soils and loams
Best rainfall:	Short (ends April) or long (ends June) wet season or bimodal
Growth habit:	Erect and branching
Life span:	2–4 years if not cut short (<20 cm) when seeding
Flowering time:	Mid-season, usually beginning in April–May
Strengths:	> Excellent wet- and dry-season growth > Few pests and diseases > Moderate- to high-quality fodder > Ease of haymaking if plants cut when not woody
Limitations:	> Slow establishment > Poor growth in wet, poorly drained soils > Small seeds held in heads may be difficult to harvest

Table 4: *Performance of selected legumes in relays and rotations in East Nusa Tenggara*

Feature	*Centrosema pascuorum*	*Clitoria ternatea*	*Lablab purpureus*	*Centrosema molle*	*Macroptilium bracteatum*	*Stylosanthes guianensis*	*Stylosanthes seabrana*
Good growth in the humid but seasonally dry tropics	•••	•••	•••	•••	•••	•••	•••
Adaptation to a range of soil types:							
> alkaline clay soils	•••	•••	••	••	•••	••	•••
> slightly acid clay soils	•••	•••	•••	•••	•••	•••	••
Tolerance to short-term waterlogging	•••	•••	•	•••	••	••	••
Ease of establishment from seed:							
> larger seeds (5+ mm length)	••	•••	•••	••	••	•	•
> low proportion of hard seeds (dormancy)	••	••	•••	••	••	•	•
> seed easy to produce and harvest	••	•••	•••	?	••	•	•
Resilience to pests and diseases:							
> insects on leaves, stems and roots	••	•	••	•••	••	•••	•••
> soil-borne diseases	••	•••	•	•••	••	••	••
> leaf diseases	•••	•••	••	•••	••	•••	•••
Growth under moderate shade	•••	•••	••	•••	••	•	•
Efficient use of available soil moisture:							
> continued growth in drier conditions	•••	•••	••	•••	•••	•••	•••
Moderate persistence:							
> low levels of hard seeds	••	••	•••	••	••	•	•

continued over

Table 4: *continued*

Feature	*Centrosema pascuorum*	*Clitoria ternatea*	*Lablab purpureus*	*Centrosema molle*	*Macroptilium bracteatum*	*Stylosanthes guianensis*	*Stylosanthes seabrana*
For fodder							
Suitability for livestock production:							
> acceptable to livestock (taste, smell)	•••	•••	••	••	•••	••	••
> no anti-nutritional factors/toxins	•••	•••	•••	•••	•••	•••	•••
> high digestibility, energy and protein	•••	•••	•••	•••	•••	••	••
Rapid growth:							
> high forage production	•••	•••	•••	•••	•••	•••	•••
Suited to cut-and-carry (by hand):							
> easy to cut	••	•••	••	••	•••	•••	•••
> non-irritating to skin	•••	•••	•••	•••	•••	•••	•••
Easy to dry and bale:							
> thin stems	•••	•••	••	•••	•••	•••	•••
> retains leaves when dry	•••	•••	••	•••	••	•••	•••
Regrowth after cutting	••	•••	•	•••	••	••	••
For nitrogen fixation							
Grows without inoculation of seeds	•••	•••	•••	•••	•••	?	?
Suited to legume–cereal relays	•••	•••	••	?	?	•	•
Suited to legume–cereal rotations	•••	•••	•••	?	••	•	•
Suited to green manures	•••	••	•••	?	••	•	•
Suited to fodder banks in non-crop areas	•	•	•	•	•	•••	•••

••• = rates highly for this characteristic; •• = rates moderately; • = rates poorly;
? = potential—more experience required

4. HOW TO GROW LEGUMES

As with the production of all cultivated plants, the performance of herbaceous legumes is strongly influenced by management. While herbaceous legumes are generally highly robust plants, failure to establish and successfully grow useful populations of plants will result in lower levels of biomass production and nitrogen (N) fixation.

Preparing the land

The appropriate method for preparing the land depends on whether the legume will be grown in relay with a cereal crop or as a rotation (or green manure).

In relay with a cereal

Tillage of the land is not possible when the legume is grown in relay with a cereal crop, so seed must be sown in dibble holes (see Fig. 15a, b) or directly onto the soil surface between the rows of the already established cereal.

In rotation

There are two main methods of preparing the land when rotations are used.

Full tillage: ploughing twice to 5 cm depth, several weeks apart, will control most weeds, but 20 cm depth is needed for weeds such as blady grass *(Imperata cylindrica)*. Ensure a fine and level seedbed for best establishment. Spraying with glyphosate herbicide between cultivations will ensure better control of emerging weeds such as *I. cylindrica* and nut grass *(Cyperus rotundus)*.

Zero tillage: this method uses herbicides to control weeds rather than ploughing. Weeds are sprayed with glyphosate at the recommended rate for the type of weed(s) 4–6 weeks before the planned planting date. To get best results, weeds should be growing vigorously and 10–20 cm tall when sprayed. A second spraying should be carried out a few days before planting to control any emerging weeds.

Sowing time

Legumes should be sown only if soil moisture is adequate and the wet season is well established. The best time to sow is different for a relay crop than for a rotational crop. When planted in relay with a cereal crop, the legume should be sown at flowering of the maize or rice (usually February to early March depending on the cultivar and time of planting), whereas rotational crops are planted from January onwards to maximise use of rainfall and soil moisture.

Sowing method

Planting by hand

When planting by hand in relay, legume seed is 'dibbled' (planted into holes made with a handtool with a pointed end) at set spacings between the crop rows (Fig. 15) or sown into furrows made with a sharp stick or hoe (Fig. 16). After sowing, the seed is covered with soil and pressed to improve seed–soil contact. Alternatively, species with small seeds can be broadcast onto the soil surface within the crop. In this situation the sowing rate should be increased by at least 20% to allow for poorer plant establishment, and there must be ample organic matter on the surface to trap seed during heavy rainfall.

For hand-sowing of rotational crops, seed is either dibbled into holes in the soil or sown in shallow furrows, with the best depth, spacing and configuration depending on seed size and the appropriate plant spacing for the particular species.

Fig. 15a, b: *Seed of* Lablab purpureus *is dibbled into zero-tilled soil.*

Fig. 16: *Seed is planted into a furrow formed using a hoe. The seed will be covered after planting has been completed.*

Mechanised planting

Mechanisation of legume sowing is expensive and useful only for larger commercial areas (rotation) or where labour for hand-sowing is unavailable. For machine planting, two- or three-row planters can be attached to a two-wheeled tractor (Fig. 17), with seed sown in furrows at a constant spacing, depth and sowing rate. The seed is covered with soil to improve germination and emergence.

Fig. 17: *An Australian-manufactured seed planter is attached to a two-wheeled tractor.*

Planting configuration

Relay systems

The planting configuration for legumes depends on the row spacing of the cereal crop (Fig. 18). If maize rows are 80 cm apart, three lines of legume may be planted between the maize rows—one in the centre of the inter-row space and the others at 15 cm spacing from each of the maize rows. Dibble holes are 20 cm apart for small or medium seed and 25 cm for large seed (e.g. *Lablab purpureus*).

For rice planted at 20 cm row spacing, a single row of legume is planted in the inter-row space (Fig. 19). Small and medium seed is spaced at 25 cm within the row and large seed at 33 cm.

Where cereal crops are grown using other row spacings, the legume planting configuration will need to be modified to obtain the appropriate plant population.

Rotational systems

Rows are established 40 cm apart with dibble points 20 cm apart within the row for medium and small seeds and 25 cm for large-seeded species (Fig. 20). The number of seeds in each hole depends on seed size and the species being sown. If sowing in furrows, they are 40 cm apart and the seed is sprinkled along the base and covered with soil.

Depth of sowing

The best depth to sow depends on seed size. Sowing at a depth of three to four times the length of the seed provides a useful estimate of sowing depth (Fig. 21). Large seeds (e.g. *Lablab purpureus*) can be planted at 25–30 mm and medium seeds (e.g. *Clitoria ternatea, Centrosema molle and C. pascuorum*) at 15–20 mm, with small ones (e.g. *Macroptilium bracteatum* and *Stylosanthes* spp.) at 10–15 mm.

When dibble planting with holes 20–30 mm deep, it is important to ensure that the appropriate amount of soil for the particular species is pressed over the seed to obtain good establishment. Small seeds can be dibble planted successfully but sowing in furrows is recommended.

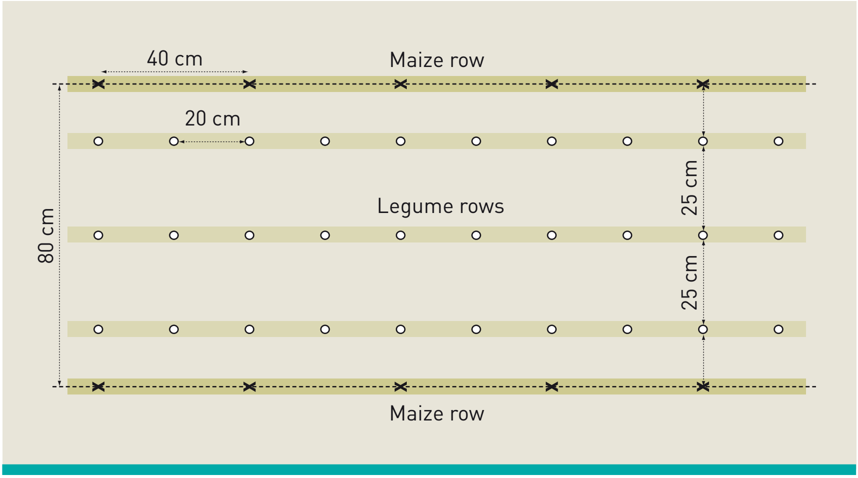


Fig. 18: *This diagram shows the dibble configuration for small- and medium-seeded legume species planted into a maize crop as part of a relay cropping system.*

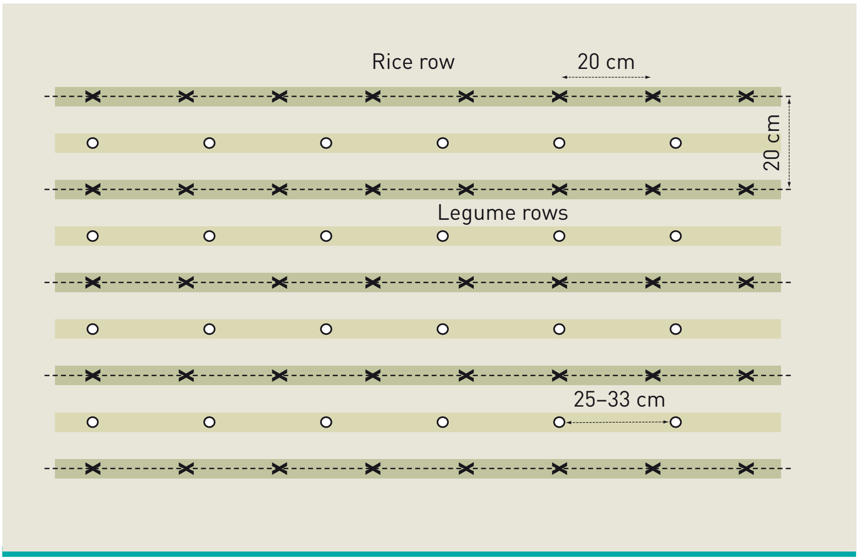


Fig. 19: *This diagram shows the dibble configuration for small-, medium- and large-seeded legume species planted into an upland rice crop as part of a relay cropping system.*

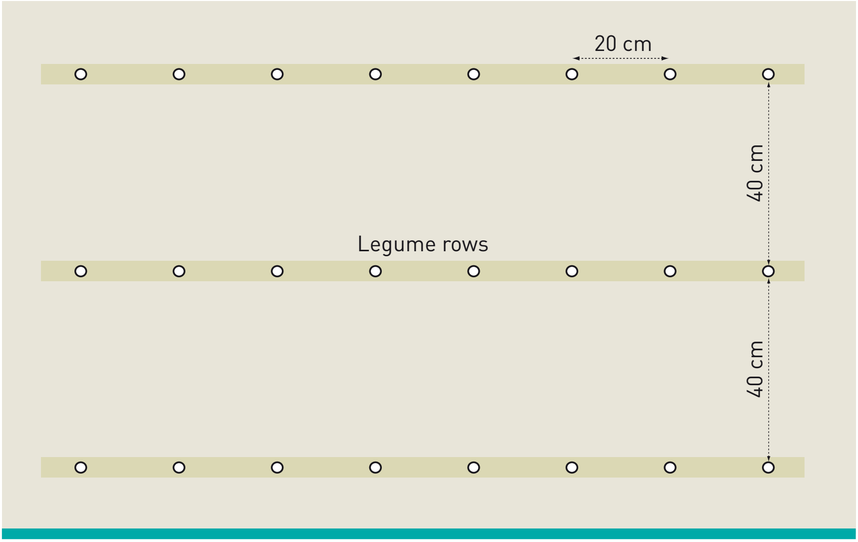


Fig. 20: *This diagram shows the dibble configuration for legumes planted as a sole crop as part of a rotation with maize (or rice).*

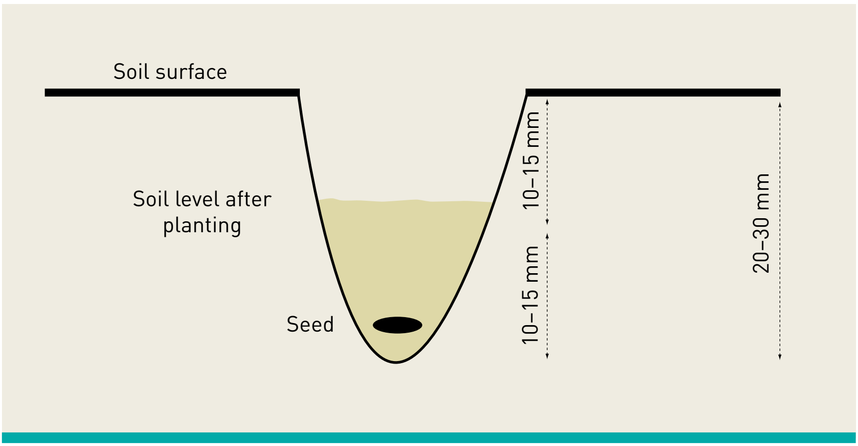


Fig. 21: *Small- and medium-seeded species should be covered by 10–15 mm of soil for successful establishment. Large-seeded species should be covered by at least 25 mm of soil.*

Sowing rate

The sowing rate depends on seed size and how the legume is being used in the farming system. Planting rates are higher for large seeds than for small seeds, and rates should be increased when planting into an established crop. The rates shown in Table 5 are appropriate for seed of high quality that has been treated for hardseed dormancy. If seed viability is lower, rates should be increased.

Seed treatment

It is important to check the quality of seed before planting as poor-quality or dead seeds often look the same as viable ones. This is particularly important if seed has been stored for some time under ambient conditions.

It is relatively simple to test whether you have good-quality seed. Seeds that are not plump will probably have poor germination. These can be removed by hand. Insect frass (droppings) and small holes in seeds indicate insect damage and probably poor germination. The remaining seeds are likely to be viable but should still be checked. Some may be dormant due to the presence of a water-impermeable or 'hard' seedcoat, which could delay or prevent germination. This is important for *Macroptilium bracteatum*, *Centrosema molle* and *Stylosanthes guianensis*, and to a lesser extent for *Clitoria ternatea* and *Centrosema pascuorum*. *Lablab purpureus* tends to have low levels of hard seed.

A simple soil test is recommended to estimate field emergence (see page 59).

Table 5: *Sowing rates for legumes dibbled into relay and rotational sequences with maize and rice. Rates should be increased by 20% when small- and medium-seeded species are broadcast onto the soil surface.*

				Rotational systems: maize and rice (assuming a legume row spacing of 40 cm)		Relay systems: maize (assuming 3 rows of dibbled legume between each 2 maize rows spaced at 80 cm)		Relay systems: upland rice (assuming 1 row of dibbled legume between each 2 rice rows spaced at 20 cm)	
Species (seed size)	Expected germination	Survival factor	Average seed weight	Target plant number	Sowing rate	Target plant number	Sowing rate	Target plant number	Sowing rate
	(%)[a]	(%)[b]	(seeds/g)	(plants/m^2)	(g/m^2)	(plants/m^2)	(g/m^2)	(plants/m^2)	(g/m^2)
Clitoria ternatea (medium)	70	70	25	20[c]	1.6	37[c]	3.0	37[e]	3.0
Centrosema pascuorum (medium)	70	60	55	20[c]	0.9	37[c]	1.6	37[e]	1.6
Lablab purpureus (large)	90	90	4	10[d]	3.1	15[d]	4.6	15[f]	4.6
Macroptilium bracteatum (small)	60	40	170	20[c]	0.5	37[c]	0.9	37[e]	0.9

a For a good-quality seed batch after treatment for hardseededness (if necessary)
b Estimates based on seed size and experience
c Assuming approximately 2 seeds/dibble at 20 cm spacing within rows
d Assuming approximately 1 seed/dibble at 25 cm spacing within rows
e Assuming approximately 2 seeds/dibble at 25 cm spacing within rows
f Assuming approximately 1 seed/dibble at 33 cm spacing within rows

RAPID TEST

Rapid test for seed emergence

Randomly select 50 seeds of large-seeded species (e.g. *Lablab purpureus*) and 100 of medium- (e.g. *Clitoria ternatea*) and small-seeded species (e.g. *Macroptilium bracteatum*) after mixing in a container.

1. Place local soil in shallow (3–5 cm depth) trays (about 20 x 30 cm) with holes in the bottom. Gently compact and water.
2. Sow seeds in rows 1 cm deep, cover and gently press with fingers. Place in a well-lit spot out of direct sunlight.
3. Add water as the soil surface dries.
4. Count plants as they emerge, record the number and remove from the tray. Repeat every 2–3 days until 14 days have elapsed.
5. Count the total number of seedlings and express as a percentage of the number sown.

If less than 40% of the seeds germinate, the percentage of hard seed should be checked using the procedures shown on page 60. As a general guide the total of germinated seeds plus hard seeds will be above 70% in a good seed lot. The total tends to be higher for larger seeds.

A shallow tray with drainage holes in the bottom is used for emergence testing.

Sow seeds in rows 1 cm deep.

Count the plants as they emerge and then remove them.

Rapid test for hardseededness

1. Randomly select 50 seeds of large-seeded species (e.g. *Lablab purpureus*) and 100 for medium- (e.g. *Clitoria ternatea*) and small-seeded species (e.g. *Macroptilium bracteatum*) after mixing in a container.
2. Place on a small cloth and wet with water. Roll up and allow to soak for 24–48 hours.
3. Remove seeds and count the number of seeds that have *not* become swollen and soft. These are hard seeds. Express as a percentage of the total number.

Use a small wet cloth for hardseed testing.

Roll and allow to soak.

Count the swollen and hard (small) seeds.

Treating hard (dormant) seeds

Generally, a seed lot should be treated only if more than 40% of the seeds are dormant (hard). For the legumes described in this manual the simplest method is to gently scuff the seed with an abrasive material. Placing seed on a flat surface and rubbing with sandpaper is suitable for small seed lots (Fig. 22). Be careful not to rub too vigorously and damage the seed. For larger samples pouring seed continuously onto a motor-driven circular sanding disc gives good results (Fig. 23a, b). After the seed has been treated, a sample should be retested to determine whether hardseededness has been overcome to a satisfactory level.

Fig. 22: *A scarifier box is used for treating seed, with corrugated rubber in the base and a block of wood covered in sandpaper for scuffing the seed.*

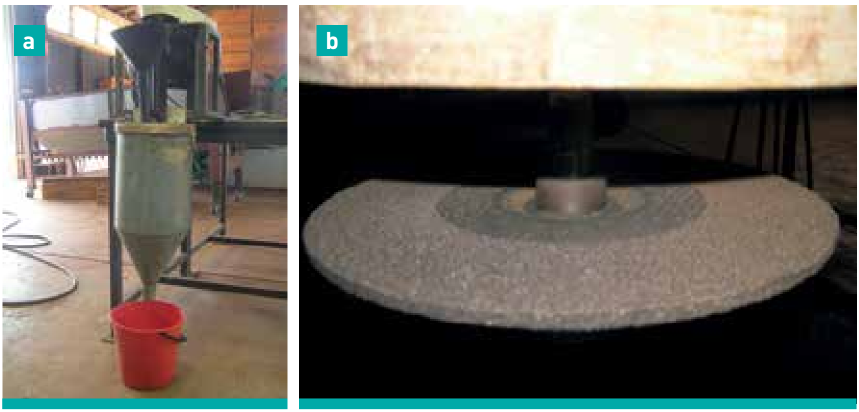


Fig. 23a, b: *A mechanised rotary sander houses a spinning sandpaper disc (b) to scarify seed.*

Using seed inoculant

Experiments conducted in eastern Indonesia have shown that legumes mentioned in this manual all grew well without nitrogen (N) fertiliser. This suggests that native soil bacteria were fixing N effectively with these legumes. If legumes have grown poorly in an area previously, applying inoculants is recommended. Refer to section 6, 'The benefits of legumes in cereal systems', for more detail.

Controlling weeds

Controlling weeds, especially annual grasses, during establishment is important. This is most critical for small-seeded legumes such as *Stylosanthes guianensis*, as the legume seedlings grow slowly and compete poorly with other plants. If the legume is sown in rows, weeds can be controlled through hand-weeding (Fig. 24) or spraying those between the rows with herbicides (e.g. glyphosate or paraquat). To avoid spray-drift damage to seedlings, use a protective shield over the spray nozzle (Fig. 25).

Selective herbicides for control of grass and broadleaf weeds in legume crops are not recommended for smallholders because of their high cost and limited availability. On larger areas the cost of selective herbicides could be justified to reduce labour costs. Always consult local agricultural herbicide companies for suitable chemicals to use.

Fig. 24: *Hand-weeding is undertaken in a crop of* Clitoria ternatea *in Tobu, South Central Timor district, West Timor.*

Fig. 25: *A shielded knapsack sprayer is used to control weeds between rows with herbicides such as glyphosate and paraquat.*

WARNING

Using pesticides

Before using agricultural pesticides it is important that the label on the product packaging be read, and application and safety recommendations complied with. Agricultural chemicals are dangerous and require that operators protect themselves against inhalation and direct contact with the chemical during mixing and application. Safety equipment, as recommended on the label, should be used. Equipment is likely to include the use of an appropriate respirator, gloves, covered boots and full-length clothing. Care should also be taken that chemicals are mixed and applied at recommended rates and that any residual chemical is disposed of as recommended.

Controlling insects

Larvae of a yellow butterfly (*Catopsilia* sp.) may attack *Clitoria ternatea* during the late wet and early dry seasons, especially in lowland areas (Figs 26 and 27). Harvesting the crop at about 10 cm above the ground as soon as low numbers of the yellow butterflies are seen near the crop is the best way to deal with the problem. The crop will regrow and produce worthwhile yields as long as the reserves of soil water are sufficient.

Fig. 26: *Larvae of the yellow butterfly (*Catopsilia *sp.) eat the leaf of* Clitoria ternatea.

Fig. 27: *This shows the underside of the yellow* Catopsilia *sp. butterfly, the larvae of which cause damage to* Clitoria ternatea.

In more elevated and wetter areas, particularly under shade, leaf-mining insects can attack *Centrosema pascuorum,* resulting in complete leaf loss (Fig. 28). The best method to avoid the problem is to not plant this species in these environments.

Fig. 28: *The results of leaf miner attack on* Centrosema pascuorum *are evident.*

Fertiliser application

To grow successfully, all plants require a balance of 12 nutrients (see pages 65–66), 6 in relatively large amounts (macronutrients—N, P, K, Ca, Mg, S) and the remaining 6 in small amounts (micronutrients/trace elements—Fe, B, Mn, Zn, Cu, Mo). Plants cannot grow to their potential if nutrients are in limited supply (i.e. deficient). Typical symptoms of nutrient deficiency in legumes are described pages 65–66. No major nutritional deficiencies have been observed in herbaceous legumes on the heavier clay soils (Vertisols and Inceptisols) or red sandy loam soils (Alfisols) in ENT. However, if legume production and biomass removal becomes more intensive, P, K and trace elements may need to be applied at similar rates to other legume crops grown locally. Fertiliser should also be considered where the area has grown cereals for many years and no inorganic fertiliser or manure has been applied. Fertiliser can be incorporated during tillage, broadcast onto the soil surface before planting when zero tillage is being used, or applied to individual seedlings after emergence.

SYMPTOMS

What are the symptoms of plant nutrient deficiency?

Nutrient deficiencies are currently not a major issue for herbaceous legumes grown in eastern Indonesia. However, crops should be monitored for signs of deficiency. If nutrients are deficient, plants will show the following typical symptoms for each individual nutrient.

Nitrogen (N)

Nitrogen deficiency is shown initially as a yellowing of older leaves, and petioles of older leaves may become pink in the early stages. As the condition worsens, older leaves die and younger ones turn yellow. Nitrogen deficiency in a N-fixing legume can be attributed to poor nodulation or Mo deficiency, resulting in reduced growth and branching.

Phosphorus (P)

Growth of plants can be severely restricted by P deficiency before leaf symptoms appear. P-deficient plants are stunted and leaves are abnormally dark green. Leaflets tend to fold together, giving a pointed appearance, with purplish colour underneath. Some plants get red stems when deficiency is severe (although some *Stylosanthes* species have naturally red stems).

Potassium (K)

With K deficiency the lower leaves are affected first, with small brown dead spots appearing between the veins near the edge of the leaf. These spots grow until the whole edge of the leaf is brown and dead. The lower leaves then die and fall off. Symptoms may affect progressively younger leaves up the stem.

Magnesium (Mg)

With Mg deficiency the lower leaves are affected first and develop yellowing between the veins, especially on the upper surface. There may be some puckering of the leaf surface.

Sulfur (S)

When S-deficient, younger leaves of legumes are uniformly pale green to yellow. Plants are small and slender. In the early stages of deficiency older leaves remain dark green but will eventually turn yellow. Note: S and N deficiencies produce similar symptoms but N deficiency appears first in older leaves and S deficiency in younger leaves.

continued over

Copper (Cu)

The first sign of Cu deficiency in legumes is wilting of younger leaves. They soon turn a faded greenish-yellow colour. As the deficiency worsens, older leaves down the stem are affected. Growth is reduced and internodes shortened, so the plants appear bushy. Copper deficiency can be induced when Mo fertiliser is applied.

Molybdenum (Mo)

Symptoms of Mo deficiency are similar to those of N deficiency. Legumes turn pale green, show reduced growth and eventually lose lower leaves. Neutral and alkaline soils can be deficient through having low Mo levels, while acid soils can have adequate Mo levels but the Mo is not available to plants. The addition of lime can make the Mo available to plants. As the level of Mo applied to the soil increases, the colour of the legume leaves progressively changes to green.

Iron (Fe)

Iron deficiency is common in leached tropical soils, especially in calcareous soils derived from limestone and poorly drained soils. Legumes are particularly sensitive. The main symptom of Fe deficiency is yellowing between the veins of new leaves. This effect is more pronounced than with Mg deficiency.

Zinc (Zn)

Both solubility of Zn in soils and its uptake by plants fall rapidly as soil pH increases. High levels of P in soils can make Zn deficiency worse in some crops. Deficient plants are stunted with upright growth habit, while young leaves are smaller than normal and may be thick and brittle. White stripes on maize leaves are the best indication of Zn deficiency.

Manganese (Mn)

As with Fe, Mn deficiency is common in leached tropical soils, especially in calcareous soils derived from limestone. Legumes are particularly sensitive. The main symptom of Mn deficiency is yellowing between the veins of new leaves.

Note: To the authors' best knowledge, the specific symptoms of deficiency for the individual legumes in this manual have not been described. The above descriptions have been collated from a number of sources (McMurtry 1948; Nelson and Barber 1964; Woodhouse 1964; Andrew and Pieters 1970, 1972; Woodhouse and Griffith 1973; Salisbury and Ross 1978; Smith and Van den Berg 1992a, b) and should be considered as generic.

Timing of forage harvest

Legume forage is first harvested in the late wet-season to early dry-season period. Rotational crops can generally be harvested earlier than relay crops as they are planted earlier in the season and do not have competition from the cereal crop. If soil moisture levels are high some legumes will regrow and provide a second harvest during the mid dry season. This is more likely to occur on heavier clay soils in bimodal rainfall regions, such as the Belu district of West Timor or the Ende district of Flores, while the use of irrigation in unimodal areas can allow a second harvest. The harvested material can be fed to livestock fresh, or dried for storage and fed later to stock. Strongly perennial legumes such as *Stylosanthes guianensis* and *S. seabrana* can grow and produce substantial forage throughout the dry season.

Cutting method and height

The legume crop should be cut when plants are growing vigorously and when dry conditions are anticipated over the subsequent few days, to allow rapid drying. The harvested material will have a higher feed value when harvested with a high proportion of leaves compared with stem. Perennial legumes with an erect growing habit, such as *Clitoria ternatea* and *Stylosanthes guianensis,* should be cut at 10–15 cm height above the ground as this produces a high-quality ration and allows vigorous regrowth. Prostrate, leafy legumes such as *Centrosema pascuorum* are best cut lower (5–10 cm) to maximise harvested biomass. Strongly annual legumes such as *Lablab purpureus*, which are unlikely to regrow after harvest, should also be cut low.

Storing forage

Legume forage must be dry before being placed in storage. The legume should be cut and spread evenly (less than 30 cm deep) on a compacted surface in an open sunny area or on plastic sheeting, and allowed to dry (Fig. 29). The hay needs to be turned each day to speed up drying and prevent spoiling of the material. The hay is safe for storage when the moisture concentration is at 18–20% (see page 68). Storage at higher levels of moisture may result in the development of moulds or, in extreme cases, the destruction of the hay through fire (internal combustion). If hay becomes too dry, leaves may fall off, resulting in a reduction in the quality of the overall product.

Fig. 29: *Legume hay is dried on plastic sheeting in Mbay, Nagakeo district, Flores.*

Estimating safe storage moisture

Hay is considered sufficiently dry to bale when the stems bend and snap when twisted between the hands, and some leaves fall when the hay is turned. Drying will usually take 3–5 days but may take longer when humidity is high. Under these conditions harvesting and drying should be done in small 'lots' of forage to reduce the chance of spoiling large amounts of hay. Drying under cover with reasonable air flow can minimise the risk of spoilage by rain.

Hay can be stored as a loose stack but is better stored as compacted bales, which take up less space and are easier to stack and transport. A hand-operated press has been developed that can produce a 10–12-kg bale in less than 5 minutes (Figs 30, 31 and 32)—plans are available from the Assessment Institute for Agricultural Technology (BPTP–NTT) in Naibonat. Using bales of a known weight allows for the easy management of animal feed intake over time.

Fig. 30: *Legume forage is placed into the compression box of a hand-operated hay press.*

Fig. 31: *A pressed bale is ready for storage.*

Fig. 32: *Each bale of hay weighs 10–12 kg, a good weight for transport and feeding.*

CASE STUDY

Successful dry-season production in Betun, West Timor

Andreas Bisik, a farmer from Betun in Belu district, was interested in growing legumes for baling and sale as animal feed. With support from Paulus Fahik, the local Dinas Belu extension officer, he successfully established over 2 ha of *Clitoria ternatea* and *Centrosema pascuorum* during the 2008 dry season. Belu's bimodal rainfall pattern meant that 514 mm of rainfall was recorded between the end of February and July. As a result Andreas was able to grow highly successful crops of both legumes, with the *Clitoria ternatea* yielding a total of 7.6 t/ha dry weight (DW) from harvests at 90 and 150 days, respectively, after sowing (in May and July). The yields of *Centrosema pascuorum* were not recorded. Large quantities of biomass from both species were then dried, baled and sold for animal feeding. Over 100 kg of seed of both species were produced from the area and used to expand production in other parts of West Timor.

Andreas proudly shows off his commercial area of Clitoria ternatea *at Betun, Belu district, West Timor, which yielded 7.6 t/ha dry weight from two harvests.*

Paulus inspects Centrosema pascuorum, *which was dried before baling for animal feed in Betun, Belu district, West Timor.*

5. LEGUME PRODUCTION IN CEREAL-BASED SYSTEMS

The quantity of legume biomass that can be produced in a particular location and season depends on the agroecological environment, the way in which the legume is used within the farming system and the agronomic management. The species recommended in this manual have been assessed across a wide range of environments in ENT and evaluated by farmers and extension agencies for use within particular farming systems.

Rainfed legume production

Yields of *Clitoria ternatea, Centrosema pascuorum* and *Lablab purpureus* planted during the mid wet season and grown in rotation with cereals can be expected to range between 1.5 and 5 t/ha DW. Variability in yield is a result of seasonal variation in temperature and rainfall, agronomic management and soil type, with higher yields more likely to occur on the heavier clay soils and where the rainy season is longer (such as in bimodal regions). The highest recorded rainfed yield of 7.6 t/ha DW occurred in Belu district, where *Clitoria ternatea* benefited from the longer bimodal wet season (see case study on page 70).

Yields from legumes planted in relay with maize or rice at around the time of crop flowering tend to be lower and more variable. While yields as low as 50 kg/ha DW have been recorded, they are more generally in the range 1–3 t/ha for *Clitoria ternatea, Centrosema pascuorum* and *Lablab purpureus*. Higher yields are usually achieved when unseasonal rainfall occurs during the dry season or in bimodal regions.

Why is there a difference in yield between relay and rotation?

A legume planted in relay with maize (Fig. 33) competes with the cereal for light, thus slowing the establishment and development of the legume. While it may be thought that competition for water is the main constraint, research suggests that soil water often remains unused during the time that the legume and cereal grow in relay. Legumes grown in rotation do not compete with another crop for light or moisture and therefore have a greater capacity to achieve their potential. Recent research shows that the majority of biomass production occurring in legume crops planted in relay occurs after the cereal crop has been harvested, with biomass production dependent on late wet-season rainfall and available stored water.

Fig. 33: Centrosema pascuorum *is grown as a relay crop with maize.*

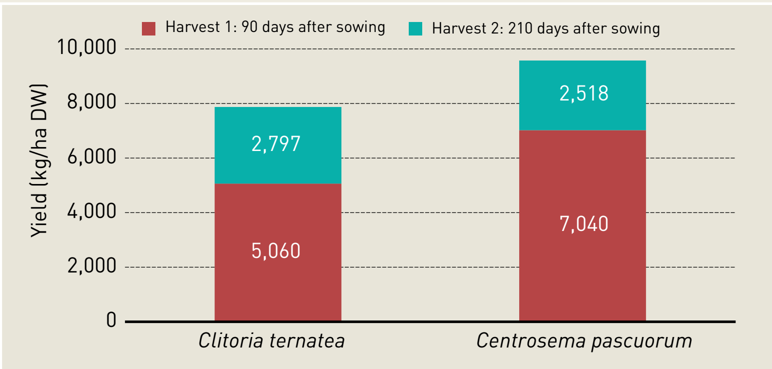
CASE STUDY

Is irrigated legume production an option?

In Mbay, a lowland rice-growing area in Flores where cattle production is increasing, *Centrosema pascuorum* was grown in rotation with lowland rice and was irrigated twice. It was harvested at 90 and 210 days after sowing and produced 9.56 t/ha DW biomass. *Clitoria ternatea* produced 7.86 t/ha DW over the same period. Biomass from both species was dried, baled and sold as animal feed. These results provide an example of how herbaceous legumes may be integrated into an irrigated rice production system, where a portion of each farm is set aside for the production of forage either to feed cattle for fattening or for sale to farmers who require high-quality forage for fattening or breeding but don't have the resources to produce sufficient for their needs.

Irrigated Centrosema pascuorum *is pressed into 12-kg bales in Mbay, Nagekeo district, Flores.*

Forage legume hay for feeding to goats is offloaded in Ulupulu, Nagekeo, Flores.



Biomass yield is shown for Clitoria ternatea *and* Centrosema pascuorum *under irrigated conditions in rotation with rice in Mbay, Nagekeo district, Flores.*

6. THE BENEFITS OF LEGUMES IN CEREAL SYSTEMS

While it is likely that the primary reason for farmers to grow legumes would be to supply high-quality forage for cattle feeding, herbaceous legumes can also benefit a cereal crop being grown in relay or rotation with it. Through the fixation of atmospheric N and release into the soil, legumes can contribute to the growth of cereal crops (Figs 34 and 35).

Fig. 34: *This maize was grown in Usapinonot, North Central Timor district, West Timor, without the addition of fertiliser. Plants are yellow and shorter than those in Fig. 35.*

Fig. 35: *This maize was grown after a 152-day rotation of* Centrosema pascuorum. *The crop is deeper green in colour and taller in stature. This crop benefited from legume N fixation and leaf drop.*

Do legumes need to be inoculated for maximum production?

The achievement of optimal legume biomass yield and N fixation requires the presence of appropriate bacterial strains with which the particular legume is compatible. Many legumes can use local bacterial strains already present in the soil, while others require inoculation with particular strains. *Centrosema pascuorum* appears readily colonised by local rhizobial strains and should achieve optimal biomass yield (as determined by the status of other nutrients, climatic conditions and management) as well as N fixation. In comparison, *Clitoria ternatea,* which grows well under most conditions in ENT, has been shown to achieve maximum biomass yield when inoculated with commercial bacteria sourced from Australia. This indicates that, while current yields from this legume are satisfactory, there may be an opportunity for further improvement in both yield and N fixation if appropriate bacterial inoculants are available. As there is no information available for the other recommended legumes in ENT, and observation over a number of seasons indicates that they grow well, it is generally considered that local soil bacteria are present in sufficient numbers and inoculation with specific bacterial strains is unnecessary.

Do legumes contribute to cereal crop yield?

In the situations where maize was sown after *Clitoria ternatea*, *Centrosema pascuorum* and *Macroptilium bracteatum* and all legume biomass remained in the field (similar to a green manure crop without the incorporation of the material), maize grain yield increased by 1,800–2,700, 1,400 and 660–1,900 kg/ha, respectively, compared with an area with no legume. However, where the legume is removed as hay or cut fresh for feeding, the amount of N returned to the system is significantly reduced. This often results in no or only a small response in subsequent maize grain yield although increases in stover (straw) production have been observed. While no research has been conducted, it can be assumed that, where cattle are tethered in the field and fed the legume forage and the urine and manure are returned to the soil, intermediate responses would occur.

Optimising the nutrient supply to cereals

The benefit of legumes to subsequent cereal crops is severely reduced when the biomass is fed to livestock. At best, where biomass is being removed from the field for animal feeding, legumes may contribute to small increases in grain yield and slightly larger increases in stover production. While these small increases will benefit a smallholder farmer, they are unlikely to have a major impact on livelihood.

What are the options for the farmer?

Using organic fertilisers: the use of animal manure as an organic fertiliser is widespread in food crop production in ENT. While it is an important source of both macro and micro nutrients, they are generally present at low concentrations when the material is applied at the recommended rates of 5–10 t/ha. As a result it is more likely that manure will contribute to the longer term maintenance of nutrient supply rather than provide a significant boost to yield in a particular season.

Using inorganic sources of nitrogenous fertiliser: although potentially beneficial to cereal yields, the use of inorganic nitrogenous fertiliser is limited in ENT. Comparatively large rates of fertiliser (>100 kg/ha N) and improved agronomic management are required to increase maize grain yields from the current provincial average of 2.3 t/ha to the >4 t/ha yield achieved in research trials (with the open-pollinated bred line, Lameroo—see case study on page 78). Understandably, farmers see the required financial investment as being too risky and are unwilling to invest.

If organic fertilisers contribute more to long-term nutrient supply, and inorganic fertilisers are too expensive, what is the solution?

Combining the sources of fertiliser for increased yield: improved N nutrition can be achieved through a multifaceted approach using all three fertiliser sources available to the farmer: inorganic, organic and legume 'fixed' N. While it is unlikely that farmers will invest in high rates of inorganic fertiliser, they may consider a smaller investment if it were to be recommended at a lower rate of 20 or 30 kg/ha N. When combined with manure and legume 'fixed' N, this should result in yields significantly higher than those obtained through the sole use of manure or legume 'fixed' N, or where no additional nutrition is used.

This strategy should be possible without exposing the farmer to significant additional financial or production risk, but it requires a systems approach in which legumes are seen as part of the longer term cropping system.

While this discussion has focused on N, which is the most limiting nutrient in cereal production, it should also be noted that other nutrients including P, K and S may also limit productivity and may require replenishment to achieve optimal yield.

CASE STUDY

The application of nitrogenous fertilisers can have significant impact on farmer livelihoods

In the village of Oebola, Kupang district, West Timor, a farmer-managed trial crop of Lameroo maize achieved a grain yield of 4.96 t/ha with the application of 100 kg/ha N. Given that an adjacent non-fertilised crop achieved a yield of 2.60 t/ha, the difference (2.36 t/ha) was achieved at a N-use efficiency rate of 23.6 kg grain/kg of applied N.

Assuming a linear response between N supply and yield, and an N-use efficiency rate of 23.6, a farmer investing in 20 kg/ha of N (43 kg/ha urea) would increase yield by 472 kg/ha, while an investment in 40 kg/ha of N (86 kg/ha urea) would result in a yield increase of 944 kg/ha.

While this example is based on limited data, it does provide an example of the potential for significant financial returns from a small investment in fertiliser. Also, further value could be added through the use of herbaceous legumes to fix N and the application of organic fertilisers.

Oebola farmers managed a crop of Lameroo maize fertilised with 100 kg/ha N, which yielded 4.96 t/ha of grain.

7. FEEDING HERBACEOUS LEGUMES TO CATTLE

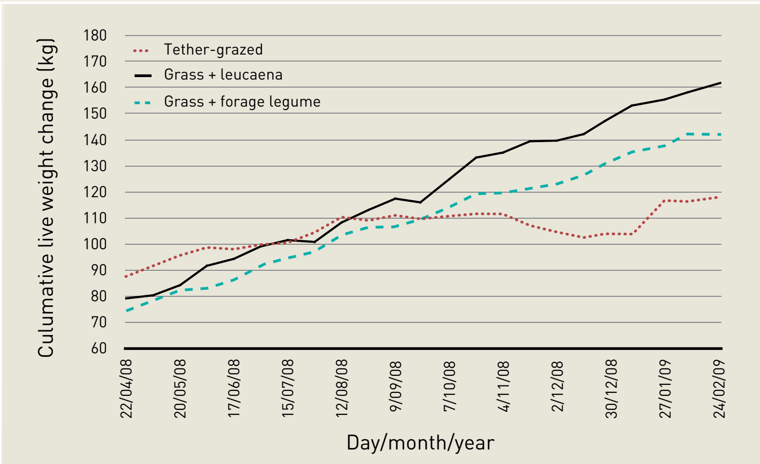
The aim of using herbaceous legumes in cropping systems is to increase animal productivity, particularly liveweight gain in animals being prepared for market. The system being used must meet the individual farmer's requirements in terms of labour availability, overall supply of forage material and number of animals. Herbaceous legumes may be fed directly to animals as fresh material in the late wet and early dry seasons, with browse or tree legumes retained for later dry season feeding, or stored as hay and fed in the late dry or early wet seasons when the availability and quality of local feed is lower. Animal performance on fresh forage is comparable with that of dried material stored as hay; therefore, there does not appear to be a disadvantage in feeding hay in terms of liveweight gain, although there is a risk of spoilage (due to rainfall) during drying and storage if not managed carefully. Using either of these systems will benefit the animal, although evidence from on-farm research suggests that using legume material to fill the feed gap in the late dry and early wet seasons may be a more efficient use of this high-quality material (see Usapinonot case study on page 80).

CASE STUDY

Cattle production in Usapinonot, West Timor

In the village of Usapinonot, West Timor, the dry season feeding (April to September) of weaned Bali cattle (70–80 kg liveweight) with a balanced ration of local grasses and forage legumes—a mix of dried and baled *Clitoria ternatea* and *Centrosema pascuorum*—resulted in an average daily liveweight gain over 151 days of 242 g/head/day compared with tether-grazed animals, allowed to self-select their feed, which gained an average of 237 g/head/day. Animals fed *Leucaena leucocephala* in a balanced ration gained an average of 308 g/head/day.

In the late dry and early wet seasons (109 days, from early September until the end of December) the average daily liveweight gain by animals supplemented with either forage legume or *L. leucocephala* was 220 and 273 g/head/day, respectively, while tether-grazed animals, on average, lost 65 g/head/day over the same period. The results clearly demonstrate that the inclusion of forage or browse legumes in the diet of weaned cattle will maintain good liveweight gains in the late dry and early wet seasons when cattle would normally be losing weight.



This chart and table compare the cumulative liveweight gains of three groups of weaner cattle in Usapinonot, North Central Timor district, West Timor (2008–09): tether-grazed and allowed to self-select their own feed, fed a balanced ration of grass and herbaceous legume, and fed a balanced ration of grass and Leucaena leucocephala. *Animals were fed for a total period of 320 days.*

continued over

CASE STUDY

1. Early to mid dry season—April to September (151 days)			
	Liveweight gain	Increase in liveweight over period	Increase in liveweight over period
	(g/day)	(kg)	(%)
Tether-grazed	237	36	47
Grass + herbaceous legumes	242	37	52
Grass + *L. leucocephala*	308	47	66

2. Late dry to mid wet season—September to December (109 days)			
	Liveweight gain	Increase in liveweight over period	Increase in liveweight over period
	(g/day)	(kg)	(%)
Tether-grazed	–65	–7	–6
Grass + herbaceous legumes	220	24	22
Grass + *L. leucocephala*	273	30	25

Summary for total feeding period—April to February (320 days)			
	Liveweight gain	Increase in liveweight over period	Increase in liveweight over period
	(g/day)	(kg)	(%)
Tether-grazed	132	42	56
Grass + herbaceous legumes	225	72	102
Grass + *L. leucocephala*	284	91	128

How much legume should be fed?

A crude protein concentration in feed of about 12.0–12.5% is recommended for growing animals and about 11.0% when they reach the fattening stage. These diets can be achieved by providing an appropriate grass:legume ratio in the ration. A mixture of about two-thirds grass and one-third legume should provide the most efficient use of the legume forage. Supplementing Bali cattle with legume forage at 10 g dry forage per kg liveweight each day should provide sufficient protein to the animal for growth. Table 6 shows recommended feeding rates for legume, grass, rice or maize straw to meet animals' nutrient requirements to gain weight. The 'Balancing the feed ration' box provides examples of the calculations required to determine balanced rations for two classes of cattle. It is important to note that fresh forage may contain 80% water in the growing season, which reduces to 60% in the dry season. Amounts fed need to be adjusted to account for this.

Freshly weaned animals of 50–70 kg liveweight can also benefit from being fed a legume supplement. In feeding studies tethered animals fed on native grasses gained 42 kg over 320 days, while those fed a supplement of herbaceous or tree legume forage together with native grasses gained 72 kg and 91 kg, respectively, over the same time. Clearly, the animals supplemented with legume forage will reach target liveweights much sooner than those without.

Table 6: *Recommended daily feeding rates (kg, based on forage moisture content) of legume and roughage (grass or crop residues) to maintain a well-balanced ration across a range of cattle liveweights. The diets are based on feeding two-thirds roughage and one-third legume.*

		Daily animal feed requirement							
		Legume				Grass or straw			
Cattle live-weight (LW)	Daily legume requirement	Oven dry	Hay[a]	Fresh[a] (dry season)	Fresh[a] (wet season)	Oven dry	Hay[a]	Fresh[a] (dry season)	Fresh[a] (wet season)
		(100% DM[b])	(90% DM)	(40% DM)	(25% DM)	(100% DM)	(90% DM)	(40% DM)	(25% DM)
(kg)	(g/kg LW/ day)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)
100	10	1.0	1.1	2.5	4.0	2.0	2.2	5.0	8.0
150	10	1.5	1.7	3.8	6.0	3.0	3.3	7.5	12.0
200	10	2.0	2.2	5.0	8.0	4.0	4.4	10.0	16.0
250	10	2.5	2.8	6.3	10.0	5.0	5.6	12.5	20.0

[a] If actual moisture concentrations in a particular feed source appear different from those stated, moisture levels should be checked before feeding and appropriate adjustments made

[b] DM = dry matter

Example 1: How much legume hay and fresh grass are needed to supply a balanced daily ration for a 150-kg bull during the dry season?

At a rate of 10 g legume dry matter (DM)/kg animal liveweight/day, a 150-kg bull requires 1,500 g/day legume DM.

As legume DM is one-third of the ration and grass DM two-thirds, the daily amount of grass DM is twice the legume amount, or 1,500 x 2 = 3,000 g/day.

The legume is fed as hay, which has a DM level of 90%, while the grass is fresh and has a DM level of 40% (Table 6).

Amount of legume hay to feed is 1,500 g x 100/90 = 1,666 g/day.

Amount of fresh grass to feed is 3,000 g x 100/40 = 7,500 g/day.

Therefore, a ration of 1.7 kg of legume hay and 7.5 kg of fresh grass would provide the correct balance in the daily ration for the 150-kg bull.

Example 2: How much fresh legume and grass are needed to supply a balanced daily ration for a 200-kg bull during the wet season?

At a rate of 10 g legume DM/kg liveweight/day, a 200-kg bull would require 2,000 g/day legume DM.

As legume DM is one-third of the ration and grass DM is two-thirds, the daily amount of grass DM is twice the legume amount, or 2,000 x 2 = 4,000 g/day.

As the legume and grass are being fed fresh during the wet season, both have a DM level of 25% (Table 6).

Amount of fresh legume forage to feed is 2,000 x 100/25 = 8,000 g/day.

Amount of fresh grass to feed is 4,000 x 100/25 = 16,000 g/day.

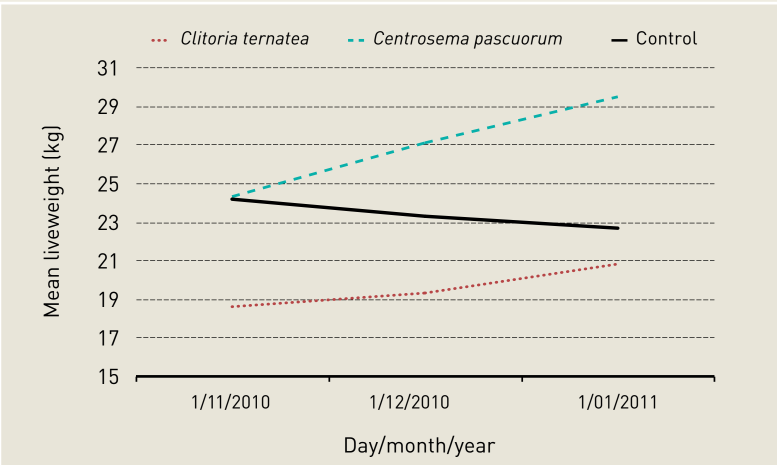
Therefore, a ration of 8 kg of fresh legume and 16 kg of fresh grass would provide the correct balance in the daily ration for the 200-kg bull.

CASE STUDY

Growing legumes for feeding cattle in Marapokot, Flores

The Tunas Baru Farmer Group in Marapokot, Nagekeo district, Flores, grew forage legumes in rotation with maize. The legume biomass was fed fresh to the cattle as it became available. Farmers were also able to access legume hay grown in rotation with dry-season irrigated lowland rice. This resulted in both fresh and dried legume material being available for animal feeding throughout the dry season. The combination of local grasses, rice or maize straw, and legume made an excellent feed and resulted in high animal liveweight gains.

Goats were fed a sole diet of Clitoria ternatea *in Ulupulu, Nagekeo district, Flores.*



This chart shows liveweight gains for goats fed Centrosema pascuorum *and* Clitoria ternatea *compared with native grass (control) over an 8-week period at Ulupulu, Nagekeo, Flores.*

CASE STUDY

Feeding goats in Ulupulu, Flores

Herbaceous legumes can be fed as the sole diet to goats, either as hay or fresh biomass, to improve liveweight gains above that of goats fed native grass. Goats that were fed *Clitoria ternatea* and *Centrosema pascuorum* for 2 months (November to January) had liveweight gains of 33 and 58 g/head/day, respectively. Goats fed native grass *ad libitum* showed a liveweight loss of 33 g/head/day over the same period. Note: This experiment was conducted through the early wet season when the native grass was young and contained high levels of moisture, which may have caused scouring in the control animals.

Edmundus Bata, the leader of the Tunas Baru Farmer Group, inspects his Centrosema pascuorum *fodder bank. The legume material was fed fresh to his cattle in a nearby feedlot.*

During the early dry season farmers in Marapokot supplement their cattle's diet with fresh legume material.

Clitoria ternatea *grown in rotation with irrigated lowland rice was dried and pressed and used to supplement cattle feed at the Marapokot feedlot during the late dry season.*

Legume hay was stored at the Marapokot feedlot and fed to cattle later in the dry season.

8. HOW TO PRODUCE SEED FOR PLANTING OR SALE

A major limitation to the broadscale use of herbaceous legumes is the availability of seed at a reasonable cost. Seeds of the legumes can be grown in ENT, but it is important to choose a suitable seed-production strategy that makes best use of the available resources and meets the demands of users. Systems can range from low-cost and labour-intensive to large-scale and mechanised with costly inputs. The small-scale approach would normally be used to grow seed for village use, while more mechanised systems might be used to produce large quantities for sale.

Seed production is a specialised operation and should be treated like a crop. Legumes vary in flower, pod and seed size and shape, and in how they grow. Temperature and soil moisture must match the needs of the legume as it grows, flowers and sets seed. In general, growth should occur in the wet season, with seed set in the dry season to allow easy harvesting and lower risk of flower and pod diseases. This means that certain regions are more suited to seed production of particular legumes than others. Whereas small-scale seed production can generally be completed in most locations in ENT, areas for large-scale seed production should be more carefully considered.

Other important questions to ask before undertaking large-scale seed production are:

- Is suitable land available to produce seed and can it be spared from other production?
- Is labour available, especially when preparing land, sowing and harvesting?
- Are funds available to purchase seed, fertiliser, herbicide and insecticide?
- Are equipment and machinery (and the skills to use them) available to increase production over time?
- Is a market available for the sale of seed?

It is important to carefully plan the management of a seed crop. Activities and decisions to be performed at critical stages of the seed production process are shown in Table 7.

Table 7: *Critical stages and management actions for legume seed crops*

When	Decision or action	Reason
2–3 months before sowing	Site selection	To check suitability for vigorous plant growth
	Seed quality and treatment	To calculate sowing rates to achieve suitable plant populations
Last 4 weeks before sowing	Site preparation	To reduce weed competition and prevent establishment failure
Sowing	Good sowing practice	To prevent establishment failure
1–4 weeks after sowing	Monitoring emergence	To determine if resowing is required
	Pest control (if needed)	To eliminate seedling-damaging insects
	Weed control	To reduce competition for nutrients and moisture
6–8 weeks after sowing	Installing trellises (if used)	For twining plants
Before flowering	Weed control	To reduce competition for nutrients and moisture
	Pest control (if needed)	To eliminate leaf-damaging insects
Flowering and early pod development	Pest control (if needed)	To eliminate flower and pod-boring insects and seed-sucking/chewing insects
After first mature seed found	Monitoring for crop maturity and shedding of seed	To optimise seed yield and quality

Timing of seed crops

Failure to match the growing environment, particularly temperature and soil moisture, to the reproductive development of the legume will often result in poor seed yields. Plants need to grow vigorously to develop a framework large enough to provide a large number of flowering sites. To achieve this, growth before flowering is planned to occur during the warm months when there is sufficient soil moisture. The seed production phase occurs best when conditions become dry, allowing for easy harvesting and lower risks of flower and pod diseases. In ENT, therefore, sowing is usually best undertaken during December–January in areas with an early end to the wet season (April). Sowing can occur later (February–March) in areas where rainfall maintains soil moisture further into the year (June–July). Growth will likely slow during June–July in upland areas (>700 m ASL) due to cool temperatures.

The second consideration is the transition to flowering, particularly as influenced by seasonal conditions. All legumes must pass through a juvenile phase, usually 2–3 months, before they will flower. Some also flower more strongly as days become shorter (short-day plants), providing an opportunity for larger seed yields in the mid dry season. Late sowing of these legumes can result in poor crop development before flowering begins and low seed yields. The day-length effect becomes stronger in areas further from the equator and appears relatively weak for some legumes in ENT compared with countries at higher latitudes. This may result in flowering that is less vigorous, but occurring over a longer period, in ENT than for high-latitude countries. Further experience is required to better understand these flowering responses.

The flowering responses of many legumes mean that late season (after August), or second, crops can be achieved if there is sufficient soil moisture and the legume can regrow and flower. Legumes with weak short-day flowering responses, such as *Clitoria ternatea* and *Centrosema pascuorum,* can produce good late-season crops in ENT provided the conditions are suitable for growing a new plant framework. The management of second crops is discussed on page 107.

Flowering responses, times and opportunities for second seed crops in ENT are presented in Table 8. These are based on small demonstration crops at upland and lowland sites in Flores and West Timor over a few seasons only, and should be treated as an approximate guide in the absence of further experimentation and experience.

Table 8: *Approximate flowering times for January-sown crops in East Nusa Tenggara (ENT)*

Species	Level of short-day flowering response	Typical flowering time	Opportunity for a late-season crop if sufficient soil moisture
Clitoria ternatea	None	Early (March)	High
Centrosema molle	Likely[a]	Late (June)	Low
Centrosema pascuorum	None or weak	Mid (April/May)	High
Lablab purpureus	Likely	Late (May/June)	Low
Macroptilium bracteatum	None or weak	Mid (April/May)	Moderate
Stylosanthes guianensis	Likely	Late (May/June)	Low
Stylosanthes seabrana	None or weak	Mid (April/May)	Moderate

[a] Flowering in first season at some sites in ENT indicates that plants may need to be exposed to long days before they will flower under short days.

Establishing a seed crop

Choosing a site

The ideal site should have the following properties to support vigorous plant growth:

- well drained soils, but not rocky
- slightly acid to slightly alkaline soils (pH 6–8)
- flat or gently sloping
- exposed to sunlight—avoid areas with heavy shade.

Using areas that have not grown legumes before will reduce the chance of a carryover of soil-borne diseases or pests; for example, select an area where maize has been grown for a number of years.

Preparing the site

Thorough soil preparation will increase the chance of good seed yields:

> Remove or kill weeds to expose soil for cultivating and reduce competition for seedlings.

> Plough or hoe the soil to at least 20 cm depth and level the area to give an even surface of soil particles mostly less than 2 mm diameter, especially if planting small seeds.

> Start ploughing at least 6 weeks before sowing. Repeated cultivations help to exhaust the supply of weed seed in the soil.

> An alternative is to use the 'zero-till' method and spray with glyphosate using a knapsack (Fig. 25) before sowing directly into uncultivated soil. This is most appropriate on a previously cropped level area.

Is fertiliser needed?

Applying fertiliser is insurance against a lack of key elements (e.g. P, K or S) that may have been exhausted by previous cropping. *Clitoria ternatea, Centrosema pascuorum* and *Lablab purpureus* can produce useful seed crops without applied fertiliser. If large commercial crops are being grown, application of fertiliser (15 kg S/ha and 20 kg P/ha) would safeguard against crop failure. Fertiliser should be applied at least every 3 years. On small areas it is wise to apply manure before planting.

Using good seed

Planting good-quality seed will ensure adequate plant numbers to produce high seed yields and reduce weed competition. This can be achieved by the following process:

> Examine the seed before planting.

> Remove seeds that are not plump and appear unhealthy.

- Remove any seeds that have insect frass (droppings) or 1–2 mm holes in them, indicating damage by bruchid insects.
- Conduct a germination test on a sample of the remainder. If less than 40% of these seeds germinate, perform a test for hardseededness on the seed (see section 4 for these techniques).
- If a significant percentage of seeds have hard coats, treat the seeds by one of the techniques mentioned earlier (section 4)—for example, rubbing with sandpaper—to break the dormancy.
- Remove impurities from the seed before sowing—for example, weed seed, chaff and small or shriveled seeds—and store it out of the sun in a cool, dry place.
- Inoculation with N-fixing bacteria should not be necessary as the legumes listed in this manual have grown well in the region without additional inoculation.

How to sow seed

Seeds should be sown into a moist seedbed and covered with soil to get good soil–seed contact. As a general rule, sow seed at depths about three to four times their length, as large seed can emerge from greater depths than small seed. Usually, viable large seed will produce a higher percentage of seedlings (say 80+% establishment) than viable smaller seed (say 50% establishment).

The appropriate sowing method will depend on the size of the seed and the equipment available. Any method that achieves an appropriate and consistent depth of sowing, preferably with gentle compaction over the seed (to improve seed–soil contact), will give good results. The methods used for field crops such as maize or mungbeans will work well. Dibbling gives good results on small plots, while row planting by hand into furrows or with machinery is recommended on areas bigger than 1 hectare. Planting in rows allows easier identification of seedlings and inter-row weeding.

Seedlings of legumes with large seeds (e.g. *Lablab purpureus*) should emerge 4–7 days after sowing, while seedlings from smaller seeds (e.g. *Clitoria ternatea* and *Centrosema pascuorum*) tend to take 7–14 days and very small seed (e.g. *Stylosanthes* spp.) may take even longer. If possible, the top 5 cm of soil should be kept moist during the germination and emergence stages to improve establishment.

What sowing rate should be used?

The following target plant populations should produce satisfactory seed yields:

> *Lablab purpureus:* 10–15 seedlings/m^2

> *Centrosema molle, C. pascuorum, Clitoria ternatea* and *Macroptilium bracteatum:* 20–40 seedlings/m^2

> *Stylosanthes guianensis and S. seabrana:* 40–60 seedlings/m^2

The sowing rate to obtain these populations is determined by the size and the expected germination percentage of the seed. Overall, sowing small and medium legume seeds at 5–15 kg/ha and large-seeded legumes at 20–30 kg/ha should give satisfactory stands. Using a spacing of 40–60 cm between rows will allow inter-row cultivation to control weeds, while the crop can fill the spaces over time.

Note that the sowing rates quoted for seed production may vary from those indicated for general legume biomass production provided in Table 5.

Are trellises useful?

Using a trellis (Figs 36, 37 and 38) can increase seed yields of climbing and twining legumes on small areas by increasing the surface area of the crop and exposing more of the stem to sunlight. It also positions seed at a more comfortable height for picking. The benefits are greater for earlier planted seed crops, particularly if the crop flowers under dry-season (winter) day-lengths.

A-frame trellises made from bamboo or gliricidia *(Gliricidia sepium)* poles are effective although simple vertical trellises made of poles also work. The frames should be about 1.5 m tall and 1 m wide at the base. Legumes seem to climb best if vertical poles are 0.5 m apart. It is best to erect trellises after the seed crop has established and been weeded but before the twining stems emerge (about 6–8 weeks after sowing).

A cereal crop with strong stems can be used as a living trellis for the legume—for example, maize and *Clitoria ternatea* planted as a relay. The legume can be harvested for fodder while the maize is growing, and allowed to grow over the maize stalks once the maize has been harvested. The legume seeds can then be harvested later.

Fig. 36: *A-frame trellises, constructed from gliricidia poles, are used to support* Clitoria ternatea.

Fig. 37: *Simple pole trellises are made from gliricidia poles.*

Fig. 38: Clitoria ternatea *pods develop on a pole trellis.*

Controlling weeds

Weeds will compete with the legume plants for moisture, nutrients and sunlight, which can lower seed yields and contaminate the harvested crop with weed seeds. It is important to start controlling weeds at crop establishment, especially annual grasses, which grow rapidly and compete strongly for nutrients. Seedlings of small-seeded legumes, such as *Stylosanthes guianensis,* grow slowly and compete poorly with other plants, so weed control in the early stages is critical for these crops (Fig. 39). However, vigorous twining legumes such as *Lablab purpureus* can compete well and smother many weeds, so weed control is less important.

The methods used to control weeds should be similar to those for other legume crops grown locally (e.g. mungbean). The choice of method for a particular species depends on the size of the crop and the resources available. Hand-weeding, inter-row cultivation and inter-row spraying with glyphosate using a covered sprayer are useful options. These methods are described in section 4, 'How to grow legumes'. Selective herbicides can be used to control weeds in seed crops, especially on large areas, but are not described in this manual. If weeds are a problem later in crop growth, hand-weeding is often the best approach.

Fig. 39: *A well-established row-planted crop of* Clitoria ternatea *grown in Kupang district, West Timor. Row planting provides options of weed control by hand or using inter-row cultivation and (careful) use of herbicides.*

Managing insect pests

While both larvae and adult insects can attack leaves, flowers and seeds of legumes, only minor damage has been seen in ENT and control is probably not normally required in smaller seed crops. However, insect damage with loss of seed can occur in susceptible crops such as *Lablab purpureus*. Growing legume seed crops away from other legume crops can reduce the risk of insect damage. Since adult insects are quite mobile, it is almost certain that insects will attack seed crops to some extent and some damage should be accepted.

On small areas caterpillars and adult beetles can be removed from crops by hand to reduce damage. The critical time to do this is during early flowering and when pods are small and green. On large areas pesticides can be used to control insects such as bean fly during establishment, flowering and green pod stages. It is important to take care when using pesticides to ensure personal safety during preparation and application. Always apply as stated on the label (see page 63, 'Using pesticides').

Based on experience in ENT and tropical Australia, problem insects that could infest seed crops are discussed on page 96:

During establishment

In Australia bean fly *(Ophiomyia phaseoli)* commonly kills large numbers of seedlings of legumes, such as *Clitoria ternatea*, *Centrosema pascuorum*, *Lablab purpureus* and *Macroptilium bracteatum,* shortly after the seedlings emerge by damaging the stem, but there have been no significant problems to date in ENT.

During growth

Chewing insects such as grasshoppers and caterpillars often cause minor damage to herbaceous legumes in ENT with little obvious impact on seed production (Fig. 40). However, the larvae of *Catopsilia* sp. have completely defoliated *Clitoria ternatea* plants during March–May at both upland and lowland sites in ENT, ruining some seed crops (Figs 26, 27). If increasing numbers of the yellow butterflies are seen during March–May, the legume should be harvested for forage by cutting at 10 cm above the ground and letting the crop regrow for seed. The seed yield will depend on the amount of soil moisture available to produce regrowth and then a seed crop. While insecticides may control the larvae, no testing has yet been conducted.

A leaf-mining insect also caused significant damage to leaves of *Centrosema pascuorum* under very wet, partially shaded conditions in upland areas of Flores (Fig. 28). The poor regrowth of plants may have resulted either from this leaf damage or from problems arising from the poor growing conditions.

During flowering and seed development

The most damaging insects during these stages are a variety of flower- and pod-eating caterpillars (Fig. 41) and the green vegetable bug *Nezara viridula* (Fig. 42a, b), which sucks the contents from young seed. While these can affect all species of legumes, *Lablab purpureus* is usually damaged the most and the *Stylosanthes* spp. the least. Pod-boring insects are found in ENT but serious damage has been seen only once in *Lablab purpureus* grown on a lowland site.

Fig. 40: *This leaf damage was caused by grasshoppers.*

Fig. 41: *Flower- and pod-boring caterpillars attack legume flowers.*

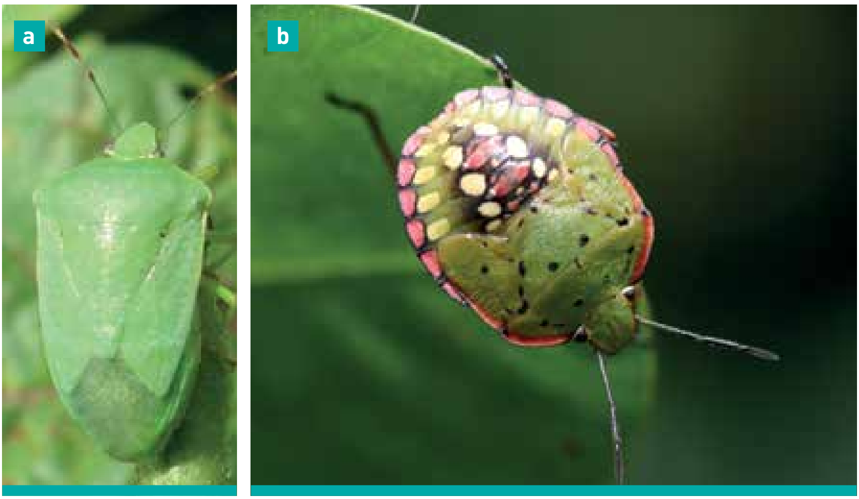


Fig. 42a, b: *The green vegetable bug is shown at different growth stages on a legume crop. (Photos: Bob Martin)*

Is irrigation necessary for seed production?

While insufficient soil moisture can limit the growth of plants and seed yield, too much water can also limit flowering and seed production in some legumes. The legumes listed in this manual were selected because they grew successfully into the dry season in ENT. Therefore, it should not be necessary to irrigate seed crops if the crop is sown at an appropriate time of year, although irrigation could be applied to finish the crop if the wet season ends earlier than usual. If irrigation is required it is best to continue it until most green pods have fully expanded and to water at weekly intervals. Apply water by the most convenient method available and wet the soil to at least 10 cm with each irrigation. Buckets can be used on small areas (e.g. a village trellis area), while pumps, sprinklers or flood irrigation can be considered on larger crops.

When to harvest seed

To ensure high yields of good-quality seed, it is important to harvest at the correct time. Seeds should be harvested when mature, and it is best if they dry on the plant as this ensures a higher proportion of fully developed seeds. Seed colour is a good indicator of the stage of ripeness (Fig. 43).

Flowering and seed development occur over months, and flowers, green pods and mature pods are usually present at the same time. The optimum time to harvest is when most pods are brown/black rather than green. Pods of some legumes (e.g. *Macroptilium bracteatum*, *Centrosema molle* and *C. pascuorum*) readily burst open (shatter) when mature and shed seed, and harvesting must be timed so that losses through shattering are not greater than gains from new pod development. Pod shattering is usually greater on crops that have pods above the foliage and when conditions are warm and dry. **When conditions are hot and dry serious seed loss can occur over just a few days. If these conditions are normal during harvest time, it might be best to collect seed from the ground.**

Fig. 43: *These are mature seeds. Clockwise from the top:* Centrosema molle, C. pascuorum, Clitoria ternatea, Lablab purpureus, Macroptilium bracteatum, Stylosanthes guianensis*.*

To identify the best time to harvest, crops should be examined every 3 or 4 days. On each occasion estimate the proportion of pods that are: small and green, full-sized and green, and brown or black and shattered. Open some full-sized green pods and mature pods to check for insect damage (undeveloped seeds). Look at a number of sites in the crop, especially if the crop is large or variable (e.g. wet and dry areas through the crop). Crops such as *Clitoria ternatea, Centrosema pascuorum* and *Lablab purpureus* continue to produce pods over several months without pods shattering, so the timing of harvest is less urgent. However, pods of *Macroptilium bracteatum* shatter readily and *Stylosanthes guianensis* sheds seed, so the optimum harvest time covers only a few weeks.

Table 9 shows differences between legume species in flowering period, shattering behaviour and pod characteristics to identify the optimum harvest time.

Table 9: *Flowering and pod characteristics and identification of optimum harvest date*

Species	Flowering period	Pods shatter when dry?	Appearance of mature pods and seeds
Clitoria ternatea	Long	No	Pods black, seeds black
Centrosema molle	Short	Yes	Pods brown, seeds brown/ black
Centrosema pascuorum	Long	Yes	Pods brown, seeds brown/ black
Lablab purpureus	Moderately long	No	Pods brown, seeds brown (Rongai) or black (Highworth)
Macroptilium bracteatum	Moderately long	Yes	Pods brown/black, seeds brown/black
Stylosanthes guianensis	Short–moderate	No, but sheds seeds in whole pod	Pods brown/black, seeds black or yellow[a]
Stylosanthes guianensis	Short–moderate	No	Pods brown/yellow or brown seeds

[a] Peak presentation occurs when most seedheads are shedding seeds. If opened many will have two to four mature seeds in them.

Harvesting seed

Many factors determine the appropriate harvest method for different situations and this decision should be made before the crop is sown. Species, size of the crop and availability of labour or mechanical equipment will influence the decision. The following methods are suitable for crops of less than 2 hectares but the same principles apply for larger crops.

Hand-picking: on small and trellised areas mature pods can be removed by hand and placed in a container (bag, bucket, basket). Picking once a week is usually adequate but more frequent picks might be needed on species that shatter readily (e.g. *Macroptilium bracteatum*). For these legumes seeds can be squeezed out of pods as they are picked. With this labour-intensive approach a picker should collect 2–4 kg of *Clitoria ternatea* seed per day by picking in the morning and late afternoon.

After picking, pods are laid out to a depth of 1–3 cm on a plastic sheet, concrete or similar surface in the shade and allowed to dry over 3–5 days. The seed should be turned once a day, especially on the first day, to provide even drying. It is suggested that a barrier be erected around the drying pods to collect seed from species that shatter.

Cut, dry and thresh: this method can be used if pods are within the canopy (e.g. *Centrosema pascuorum*) or a high proportion of seed is ready for harvest and shattering may become an issue. The plants are cut by hand below the pods when most are mature—in some species some pods might have already shattered. Cutting height will vary from about 2–5 cm for *C. pascuorum* to about 10 cm for *Clitoria ternatea*.

The harvested material should be placed in rows of <1 m width and <0.5 m high on a surface where the seeds can be recovered easily by sweeping (e.g. concrete or plastic sheets (Fig. 44)) although clean compacted soil is also acceptable. Smaller harvests can simply be placed on mats. The area can be in direct sunlight but drying during rainy periods should be avoided. The legume material should be turned each day for 3–5 days, allowing seed to fall to the surface beneath. When leaves and pods are brittle, the dried material should be removed and the seed swept up. Any remaining pods on the trash can be encouraged to shatter by walking on the legume material or by hand-rubbing. Mechanical threshing is more economical than hand-picking for large quantities of seed.

Fig. 44: *Using the cut, dry and thresh harvesting method in Betun, Belu district, West Timor, plant material is cut in the paddock and allowed to dry on plastic sheets.*

Sweeping off the ground: for crops with pods that shatter readily (especially *Macroptilium bracteatum*) or inflorescences that release seed in pods (e.g. *Stylosanthes guianensis*), seed is swept from the ground after the crop has shed most of its seed. Other crops may require sweeping after a cut, dry and thresh harvest (Fig. 45). The crop should be planted in rows and on non-cracking soils. Harvesting is later than for the other methods and it is essential that the harvesting period is reliably dry (July–September). Leaves and stems should be cut and removed for feeding to stock or dried and stored. The appropriate cutting height is about 3–5 cm for *M. bracteatum* and 20 cm for *S. guianensis*, especially if the crop is to be used for seed production in the following year. Seed can be recovered from any unshattered pods as described above, while the fallen seed is swept up and sieved to remove most of the soil and dust. The seed should be dry at harvest but it is wise to dry it as described above before storing.

Suction off the ground: a portable vacuum cleaner can be used to recover seed as an alternative to sweeping. Care should be taken that seed is not damaged while passing through the impeller of the machine of some models (Fig. 46).

Recommended harvesting methods for various legumes are presented in Table 10.

Fig. 45: *This site is ready for sweeping fallen* Centrosema pascuorum *seed from the ground. Note the absence of cracks in the soil.*

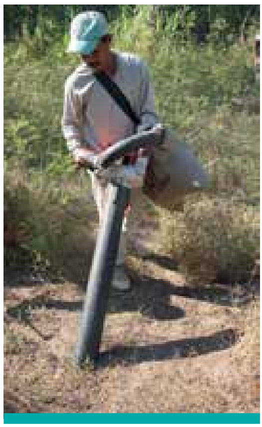


Fig. 46: *Fallen seeds are vacuum-harvested in Betun, Belu district, West Timor.*

Table 10: Some recommended seed-harvesting methods for legumes in East Nusa Tenggara

Species	Small field crop	Small trellis crop	Large field crop
Clitoria ternatea	HP✓	HP✓ CT	HP✓ CT
Centrosema molle	HP CT✓ SP	HP✓ SP	HP CT✓ SP/SN
Centrosema pascuorum	CT✓ SP	–	CT✓ SP/SN
Lablab purpureus	HP✓	HP✓	HP✓
Macroptilium bracteatum	HP✓ CT SP	HP✓ SP	CT SP/SN✓
Stylosanthes guianensis	CT SP✓	–	CT SP/SN✓
Stylosanthes seabrana	CT✓ SP	–	CT✓ SP/SN

HP = hand-picking; CT = cut, dry and thresh; SP = sweep off ground; SN = suction off ground

✓ usually the best method, based on relative cost and availability of labour

Drying seed

Seed must be dry (a moisture content of 12% or less) to prevent damage by insects and fungal diseases and to prolong storage life. Mature legume seed should be ready for storage without further drying. If seed is hard when bitten it is probably dry enough. However, it is best to always dry seed before storage in case there is a significant proportion of immature seeds or other moist plant material. Spreading on concrete or plastic sheeting in a shaded and ventilated area for 3–5 days is appropriate for small crops. The depth should be less than 3 cm and the seeds should be stirred at least once a day. A simple electric fan can be used if there is limited air flow. High humidity will slow the rate of drying.

Cleaning seed

Any impurities such as pod and stalk fragments, poorly formed seed and weed seeds should be removed from the harvested seed. Most can be removed by hand-winnowing or the use of sieves (Fig. 47). Hand sieves or baskets with holes small enough to retain seed while the impurities fall through can be used for small lots. Alternatively, baskets can be used for winnowing in a breeze or with a small electric fan (Table 11). Mechanical cleaners can be used for larger seed lots. These can include either air-screen cleaners and purpose-built winnowing boxes or gravity tables, which separate seed from impurities based on differences in seed weight and density; or indented cylinders, which separate the different material on the basis of size and weight.

Soil is often a major contaminant when seed is swept up from the ground or vacuum-harvested. This can be removed by screening and aspirating (in that order). Specialised methods such as gravity tables and decanting using heavy solvents (e.g. tetrachlorethylene) can be used to remove any remaining soil fragments. Safety precautions should be taken with tetrachlorethylene as it is a dangerous chemical.

Fig. 47: Centrosema pascuorum *seeds are hand-winnowed to remove pods and small seeds.*

Table 11: *Some recommended seed-cleaning methods for legumes suited to crop–legume relays*

Harvesting method	Typical contaminants	Useful manual methods	Useful mechanised methods	Other methods
Hand-picked	Small seeds, damaged seeds, pod fragments	Hand-sieving and picking	Air-screen cleaner Fan-winnower	
Cut, dry and thresh	Small seeds, damaged seeds, weed seeds, pod fragments, stem/leaf (dry)	Hand-sieving and picking Air-winnowing	Air-screen cleaner Fan-winnower	
Sweep or suction	Small seeds, damaged seeds, weed seeds, straw/leaf (dry), soil	Hand-sieving and picking Air-winnowing	Air-screen cleaner Fan-winnower	Tetrachlor-ethylene or gravity tables to remove soil

Storing seed

The viability of seed is affected by:

> seed moisture content

> storage temperature

> damage by pests, especially insects and rodents.

In general a one-unit decrease in seed moisture content (between 5% and 14%) or a 5% decrease in storage temperature (between 0 °C and 50 °C) will double the storage life of the seeds. Insects can destroy a seed lot in a few months if not controlled. In practice, if legume seed is harvested in the dry season, enters storage at a moisture content of 12% or less and is stored under dry conditions in a cool, shaded building, it will be suitable for planting in the next wet season. More care is required if longer storage is needed.

Keep seed dry: seed should be dry when entering storage and kept dry during storage, especially in the wet season. Most legumes in this manual (except *Lablab purpureus*) have relatively high levels of hard seed when mature and this helps to keep moisture content low in storage. However, a proportion of the seed lot will absorb water, so waterproof containers are recommended. Clean plastic bottles or tins are ideal for small seed lots, while sealed plastic bags (high-density polythene) and drums are suitable for larger amounts. Paper or woven bags are unsuitable. Seed should be checked every few weeks and redried if it smells musty. **As scarifying** (see section on 'Treating hard (dormant) seeds', page 61) **allows water to be absorbed quickly by seed, do not treat seed until close to sowing time.**

Keep seed cool: storing seed in a cool, dry area is adequate for up to 1 year. Areas with large temperature variations, such as near tin walls or under tin roofs, should be avoided. For longer storage it is important to minimise both temperature and relative humidity. Aim for a storage temperature of 15–20 °C and use sealed containers. Storing in the centre of a building and close to the floor keeps the temperature of the seed low. Do not store near a fireplace. Air-conditioned rooms are appropriate for mid-term storage of larger commercial-scale seed lots. Where seed must be stored for 5 years or more, a controlled environment to maintain temperature at 15 °C and relative humidity at 40–50% should be considered.

Controlling pests

Bruchid beetles are likely to cause problems in some crops by boring into soft seeds. They have been found in *Lablab purpureus* seed in Flores but have not affected other legumes. The adults lay teardrop-shaped eggs on immature seed in the field and the larvae feed on the seed before emerging as adults through 1–2 mm holes (Fig. 48). The adults can remain trapped in containers after the seed has been stored for a few months. While some seeds with holes will germinate, overall germination will be reduced. It is wise to check seed every few weeks and, if there is a problem, sow seed as soon as possible and keep it away from other stored seed. Commercially grown seed should be treated with aluminium phosphide tablets. These are highly toxic and should not be used by untrained operators. Evidence from other countries suggests that exposing seed to naphthalene balls can control bruchids but this has yet to be tested in ENT.

Fig. 48: Lablab purpureus *seeds show signs of bruchid damage (eggs and holes).*

Getting a second seed crop

In most instances vegetative growth for the main seed crop of the year will occur over the wet season, with harvesting during the early–mid dry season. Some legumes will regrow after the first seed harvest and produce a second seed crop in the same season if managed correctly. Legumes such as *Clitoria ternatea* and the *Stylosanthes* spp. will regrow strongly during the later dry season, while others such as *Centrosema pascuorum* and *Macroptilium bracteatum* are unlikely to set a second seed crop unless there is unseasonal rainfall or irrigation is available. Provided there is adequate soil moisture, sowing *Clitoria ternatea* and *Centrosema pascuorum* in December–January can result in a first seed crop in May–June and a second crop in October–November. This situation is most likely to occur in lowland areas with a bimodal rainfall pattern.

To prepare for a second seed crop, the plants from which seeds have been harvested should be cut and leaf and stem material removed. The cutting should be timed to meet the flowering requirements of the particular legume species and anticipated soil moisture through to seed production. Legumes that can resume growth and flowering after the first seed harvest (e.g. *Clitoria ternatea*, *Centrosema pascuorum*) can be cut whenever good growing and harvesting conditions are expected to follow. However, cutting of legumes that flower most strongly during short days (e.g. *Centrosema molle*) is best delayed until the following wet season (December–January) to avoid excess production of leaf and stem before flowering in the following year. These can be cut for hay between the end of the first crop and the start of the crop in the second year.

Different cutting heights are required for different legumes:

- *Clitoria ternatea*, *Centrosema pascuorum*, *C. molle*—5–10 cm above the ground
- *Macroptilium bracteatum*—10–20 cm above the ground
- *Stylosanthes guianensis* and *S. seabrana*—20 cm above the ground.

Annual *Lablab purpureus* is usually best resown each year.

It is important to control weeds after cutting although the regrowing crop should compete well with these. It is generally unnecessary to apply fertiliser to crops regrowing in the same (dry) season (e.g. *Clitoria ternatea*, *Centrosema pascuorum*) but fertiliser should be considered for any crops started in the following wet season.

RESEARCH METHOD

Using weed mats for seed production in high-value seed crops

Weed mat is a densely woven polypropylene mat used to suppress weeds while allowing crop plants (such as legumes) to grow through holes cut into the mat. Water (irrigation and rainfall) is able to pass through the mat surface.

When new plant cultivars become available it is often useful to use weed mats to increase the amount of seed recovered from seed production areas. This enables rapid multiplication of seeds with a low risk of failure. The use of mats is particularly important with legumes that display high levels of pod shattering (e.g. *Macroptilium bracteatum* and *Centrosema molle*), especially if they are grown on cracking soils. Using mats in these situations can double recovered seed yields. For legumes that do not shatter, mats are often not feasible as they are relatively expensive and may be difficult to obtain. Shadecloth might be a suitable alternative but has not been tested.

*A shattering legume (*Macroptilium bracteatum*) grown on weed mat is harvested.*

Fallen seeds are swept up (sweep method).

continued over

Using weed mat:

- Source the weed mats—the best for increased seed yields are 3 m wide and come in 50 m or 100 m rolls.
- Prepare seeds for planting, including germination testing and scarification if required.
- Prepare the ground as you would for a row crop and apply fertiliser if necessary.
- Roll out weed mat and peg down the edges and middle of the mat using wire loops (or similar).
- Burn or cut holes in the weed mat, each 5 cm diameter and 50 cm apart. Keep the holes at least 1 m from the edges of the mat.
- Place two to four seeds per hole (see planting guides for dibbling).
- Water and monitor establishment for 2 weeks and replant any empty holes.
- Grow the crop as a normal field crop and allow seeds to fall onto the mat.
- When seeding has almost finished (or the wet season is approaching) cut the plants and remove leaf and stem.
- Sweep up or vacuum the seeds.

Species that might be expected to regrow and produce a second seed crop should continue to be watered and managed as above.

Seed recovery can be mechanised using vacuum machines.

Possible seed yields

Expected seed yields based on experience in Australia and ENT are presented in Table 12.

Table 12: *Seed yields for seed crops grown in Australia and East Nusa Tenggara (2009–10)*

Species	Harvest months	Seed yield (kg/ha)	Harvest method(s)	Typical yield of high-input system (Australia) (kg/ha)
Clitoria ternatea	June–July November–December	500–680 250–1,330	Hand-pick Hand-pick or cut, dry and thresh	700 (direct mechanical harvest)
Centrosema molle	September–October	10[a]	Hand-pick	800 (direct mechanical harvest)
Centrosema pascuorum	June November–December	160 130–870	Hand-pick Hand-pick or cut, dry and thresh	800 (direct mechanical harvest)
Lablab purpureus	June–August	330–1,600	Hand-pick	1,500 (direct mechanical harvest)
Macroptilium bracteatum	September–October	180–470	Hand-pick	900 (vacuum)
Stylosanthes guianensis	September–October	Yet to harvest significant areas	Not harvested, did not grow	450 (direct mechanical harvest)

[a] Weak flowering was possibly due to late sowing.

Planning for a successful seed crop

Table 13 provides an example of the required seasonal planning for the successful production of a seed crop, taking into consideration selection of site, preparation of the land, planting, agronomic management and harvesting. While this example is based on *Clitoria ternatea*, similar methodologies are appropriate for all herbaceous legume species, although the manual should be consulted to confirm specific details.

Table 13: *Required planning for a successful seed crop using* Clitoria ternatea *as an example*

Decision or action	When	Low-input: smallholder	High-input: commercial
Typical area[a]		400 m^2 (10 x 40 m)	2.1 ha (70 x 300 m)
Expected seed yield		30 kg (from first crop) from the planned area	1,000 kg (from first crop) from the planned area
Identify site	October	Where crops grow well, preferably after a maize crop, on a gentle slope and situated away from other legumes; a free-draining soil, pH_{water} 6–8 (e.g. Vertisol). A soil test may be necessary if there is doubt about nutritional status (e.g. if after multiple crops of maize).	
Prepare seed for planting	November	Inspect seed and remove impurities (weed seeds). Do a germination test in soil and a hardseed test. If hardseed percentage is above 40% treat seeds with sandpaper and then retest. Adjust sowing rates if total germination is low (<40%).	
Prepare site	December	Cultivate by hand. Spray weeds with glyphosate if available. Level the soil surface.	Cultivate twice and use glyphosate to reduce weed seed levels. Use tractor-mounted discs/ tynes if available. Level and compress with a roller if available.
Apply fertiliser		Apply manure during cultivation if available.	Apply inorganic fertilisers during second cultivation at rates based on soil tests.
Sow seeds	January	Dibble: 20 x 20 cm spacings, 1–2 cm deep.	Row-plant using mechanical planter or in handmade furrows. Rows 40–50 cm apart, 1–2 cm deep, with fertiliser rate of 10–15 kg/ha.

[a] assuming conservative seed yields

continued over

Table 13: *continued*

Decision or action	When	Low-input: smallholder	High-input: commercial
Check plant population	January	Monitor over 2–3 weeks. Resow empty holes if more than 30% of dibble holes have no plants.	Monitor over 2–3 weeks. Resow if fewer than two plants per metre in a row.
Control pests after establish-ment		No action needed.	Monitor for bean fly. Consider treatment using insecticides if equipment and trained staff available.
Install trellises	January–February	(Optional) 1.5 m-high x 1 m-wide trellises with 1 m between trellis rows.	Not applicable.
Control weeds	January–February	Hand-weed.	Remove weeds, inter-row cultivate or inter-row spray (using glyphosate). Apply selective herbicides only if equipment and trained staff available.
Control pests—leaf growth	March–April	Little can be done if *Catopsilia* sp. caterpillar attacks plants. Cut back (make hay) and restart crop.	Watch for yellow butterfly (*Catopsilia* sp.) and monitor damage to leaf. Cut, bale for hay and restart crop.
Control pests—flowering	April–May	Tolerate some losses. However, it may be necessary to remove caterpillars.	Control warranted on a commercial scale only with suitable equipment. Spray insecticides to control green vegetable bug and flower-/pod-boring caterpillars as required.
Identify time of harvest	May	Check pods for insect damage as they mature. Both pods and seeds are mature when black.	

continued over

Table 13: *continued*

Decision or action	When	Low-input: smallholder	High-input: commercial
Undertake harvest 1	May	Hand-pick once per week as pods mature.	Contract harvest hand-picking or cut, dry and thresh.
Dry seed		Dry on a tarpaulin or on concrete in the shade (3 days).	Dry on a tarpaulin or on concrete in the shade (3 days), or in a specialised drier (at 35 °C).
Clean and store seed		Hand-sieve and winnow. Store in sealed plastic bags or containers in a cool dry place.	Hand-sieve and winnow or air-screen clean. Fumigate for insects before storing. Store in sealed plastic bags or drums if in ambient temperature storage, or in low temperature/ humidity store if possible.
Manage-ment of a second crop	June	Cut plants to 10 cm. Remove trellises. Feed off hay. Replace trellises.	Cut plants to 10 cm. Remove trash and bale.
Harvest 2	November	As above.	As above.

9. INCREASING ADOPTION OF LEGUMES

The agronomic aspects of forage production in cereal-based farming systems are well understood. For farmers to consider growing significant areas of herbaceous legume forage they will require appropriate support from government and non-government extension staff. The following aspects of the system will have significant impact on farmer uptake and should be considered when identifying new areas for possible expansion of the technology.

Animals as part of the farming system

The main reason for growing herbaceous legumes is to improve the productive performance of animals, predominantly cattle but also goats. Therefore, any effort to increase adoption should focus on farmers who personally own animals. This group is most likely to plant the legumes, as the first benefit they will see is improvement in the performance of their animals. As time goes on they might also achieve improved crop yields and derive cash from selling forage seed. While farmers without animals will also derive benefits through increased crop yields, they may not be as rapid or obvious.

Land and labour availability

In most areas there is land available to grow legumes, but competition for labour, which is also required to produce food security crops, is a problem. It is therefore necessary to develop legume production strategies that ensure that labour demands are offset with those of crop production. This could include a change in the planting date of the legume or alternative methods of weed control (e.g. herbicide use instead of hand-weeding) and seed harvesting (e.g. mechanised or cut, dry and thresh instead of hand-picking). Many farmers have a number of small areas of land and it is difficult to manage all areas adequately. Areas close to the house are usually better managed than those further away, as the more remote areas are harder to access and are less secure. Those farmers with adequate land close to home are more likely to plant legumes and manage them effectively.

Seed supply

Unless there is sufficient seed available for sowing, farmers will not plant herbaceous legumes. Seed production methods must be communicated effectively to farmers, research workers and extension workers. When adequate supplies of seed are available a key limitation to future expansion will be removed.

Extension support

Integration of herbaceous legumes into farming systems will be greatly accelerated if adequate extension support is provided by the appropriate organisations. The following strategies outline the kinds of activities that could be considered, the people involved, the benefits that will accrue and the approaches that could be adopted.

Strategy 1: Village-based extension support to farmers

Who would be involved?	> Government and non-government extension and research officers
Benefits	> Herbaceous legumes producing greater benefits to farmers through improved management and season-long technical support > Support being available in the village for newly interested farmers to integrate herbaceous legumes into their farming systems > Strengthened relationships between farmers and extension officers
Recommended activities	> Ensure that the facilitators or extension officers allot sufficient time to visit farmers regularly to develop a good relationship with them and provide technical support > Provide extension officers with good practical knowledge of herbaceous legumes in terms of cultivation, harvesting, feeding livestock and nitrogen contribution to subsequent maize and other cereal crops > Provide extension officers with resources and technical support to solve problems with which the farmers have no experience > Agencies and farmers need to interact over a number of months, or even years, to ensure that all facets of the system are covered in training and that farmers have continuing support as they trial the new technology

Strategy 2: Village-based plot demonstration of proposed technology

Who would be involved?	>	Farmers plus government and non-government extension and research officers
Benefits	>	A range of interested people and stakeholders (i.e. no restriction on age, gender and numbers) visiting and observing the benefits
	>	A range of organisations and extension officers disseminating the benefits of herbaceous legumes, thus accelerating technology transfer
	>	Participating farmers improving their knowledge and skills relating to the management of herbaceous legumes, and becoming local experts for promoting the benefits of the technology to other farmers and stakeholders
	>	The managing farmer group often having seed available that interested parties can take home and begin using immediately
Recommended activities	>	Ensure that the demonstration is long term or permanent, and the location is readily accessible and suitable for demonstrating the benefits of herbaceous legumes
	>	Involve local farmers in the demonstration at all stages of the production cycle—planting, growth and harvest—to obtain maximum educational effect
	>	Visit the demonstration regularly to provide technical support to the farmers and monitor progress
	>	Organise other farmer groups and extension officers to visit the site at key stages of the production cycle—planting, seed harvest and cutting biomass
	>	

Strategy 3: Using farmer experience cross-visits

Who would be involved?	>	Farmers who are either members of the group or outside the group, from inside or outside the village, or from other regions; plus extension officers
Benefits	>	Farmers expanding their practical knowledge through observation and discussion with farmers who are successfully using herbaceous legumes
	>	Farmers and extension officers viewing the range of system benefits
	>	Visiting farmers, host farmers and extension officers exchanging knowledge and experiences, thus improving relationships between the groups
	>	Visiting farmers being encouraged by the observed benefits to introduce herbaceous legumes into their own farming systems
Recommended activities	>	Identify a farmer group that has successfully integrated herbaceous legumes into its farming systems and is willing to have farmer groups visit the village
	>	Encourage other farmer groups from inside or outside the village to visit the successful farmer group or, preferably, organise one group to visit another group that is successfully using herbaceous legumes
	>	Use successful farmers to convey their knowledge to other farmers
	>	Provide sufficient time during visits for farmers to discuss the technology
	>	Ensure that the majority of farmer group members can attend the cross-visit so that all farmers participate in the educational and motivational experience

Strategy 4: Workshop on proposed/successful technology

Who would be involved?	> Farmers plus government and non-government research and extension officers
Benefits	> Rapid transfer of a wide range of knowledge to workshop participants, increasing stakeholders' knowledge about herbaceous legumes > Participants sharing and discussing their experiences > Improved relationships between all stakeholder groups > Participating farmers being empowered and motivated
Recommended activities	> Organise a suitable time when farmers, extension officers and researchers are available > Invite farmers who already grow herbaceous legumes and wish to learn more about the technology > Present relevant information in a clear and concise manner > Allow sufficient time for all participants to discuss herbaceous legumes, how they are using the technology, and the future extension and research work that is required > Provide reference material to participants

Strategy 5: Posters and other written material

Who would benefit?	>	Farmer groups, extension officers, and high-school and university agricultural students
Benefits	>	Material serving as a ready information resource for all parties
Recommended activities	>	Make material freely available to groups interested in the technology and with a basic understanding of the technical aspects of herbaceous legume production
	>	Ensure that the material uses appropriate language and the text is easily read
	>	Ensure that technical staff are available to provide additional information
	>	Ensure that posters are available from BPTP-NTT

Strategy 6: Practical work experience for high-school and university students

Who would be involved?	>	High-school and university students with an interest in agricultural and livestock production
Benefits	>	Students gaining practical knowledge about the roles of herbaceous legumes in improving soil fertility and providing fodder, and about seed production methods
Recommended activities	>	Invite students to work at a research station (i.e. BPTP-NTT research station) or on trial plots that include herbaceous legumes
	>	Ensure that visits coincide with critical stages of the growth cycle
	>	Ensure that research/extension staff spend sufficient time with students in the field teaching them about herbaceous legumes
	>	Provide both practical experience and reading material for students
	>	Integrate teaching materials about the production and benefits of herbaceous legumes into agricultural high-school curricula

CASE STUDY

Experiences at Soe Agricultural High School

At Soe Agricultural High School in the South Central Timor district of West Timor, crop and animal production systems form part of the curriculum. Teachers identify new technologies and incorporate these into teaching materials. They planted small plots of herbaceous legumes and, together with students, learnt about the growth and management of these plants in the local environment. This has now been expanded to 0.5 ha of *Clitoria ternatea* and *Centrosema pascuorum* (Cavalcade) for seed production. The seed produced will be planted in relay with maize to improve soil fertility as well as provide fodder for livestock.

Realising that horticultural crops could also benefit from the N fixed by herbaceous legumes, students and staff now grow vegetables such as cucumber in rotation with *C. pascuorum*, and harvest the seed for planting out other areas.

Seed is produced by students and teachers at Soe Agricultural High School.

Clitoria ternatea *is grown for seed production on trellises by students at Soe Agricultural High School.*

Strategy 7: Collaboration between government agencies, research centres, NGOs and educational institutions

Who would be involved?	> Tertiary agriculture and animal husbandry students, polytechnic agriculture students, farmers, government and non-government supervisors and extension officers
Benefits	> Opportunities for inter-organisational interaction on areas of mutual interest including seminars, invitations to field days, collaborative research and cross-visits > Improved mutual relationships among government agencies in which farmer welfare is a goal > Utilising the expertise of universities, Assessment Institutes for Agricultural Technologies (BPTPs) and NGOs in legume research and technology transfer
Recommended activities	> Increase collaboration between organisations to develop practical communication materials for use by extension officers and other government agencies > Organise regular seminars or workshops to improve understanding of herbaceous legume production > Encourage regular dialogue among organisations to evaluate herbaceous legume activities and consider requirements for future research and extension

Strategy 8: Developing the skills of extension staff

Who would be involved?	>	Government and non-government extension officers
Benefits	>	More extension officers having technical knowledge about herbaceous legumes
	>	Improved quality of information being communicated to farmers
Recommended activities	>	Explain the benefits of herbaceous legumes to the managers of the extension organisation to ensure that they support their staff in training
	>	In conjunction with organisational management, identify extension officers working with farmer groups who own livestock and plant cereal crops
	>	Provide an activity to initiate interest and train extension staff. Activities may include a visit to a farmer group already experienced in legume production or a meeting with experienced research staff
	>	Provide technical training workshops with reference material on herbaceous legumes, including all aspects and stages of production
	>	Encourage mentoring relationships between experienced staff and trainees to ensure that they have long-term support to develop the required expertise
	>	Formulate a work plan with extension officers including where they can access further information, and how they can plan to identify suitable farmer groups, generate interest and assist farmers in integrating herbaceous legumes into their farming systems

CASE STUDY

Cooperation between farmers and local NGOs finds that 'grass isn't enough'

This is the story of cooperation between the local NGO Oasis and a farmer group in Reworangga in the Ende district of Flores. The NGO works with marginal farming groups to increase their agricultural production. The head of Oasis, Hendrikus Loby, sees herbaceous legumes as one of many important technologies that can be used to increase agricultural production. Hendrikus believes that 'king grass isn't enough' and we 'have to use herbaceous legumes as well'. He also believes that planting forages—both grasses and legumes—before farmers buy cattle is important so that cattle can immediately start eating high-quality feed.

In addition to assisting the Reworangga farmer group meet their cattle's feed requirements, Oasis has established a seed production plot of *Clitoria ternatea* and *Centrosema pascuorum* that will produce seed to be distributed to other marginal farmer groups.

Hendrikus (second from left), the head of Oasis (a non-government organisation), believes that forage legumes can play a role in increasing agricultural production, especially for the most marginal farmer groups.

Clitoria ternatea *being grown at Oasis will be used to increase the growth rates of cattle at the Reworangga feed lot.*

GLOSSARY

Annual plant	one that grows, produces seed and dies within 1 year
Anthracnose	a fungal disease of many legumes caused by the *Colletotrichum* fungus
Anti-nutritional factors	chemicals within an animal feed that can interfere with the capacity of the animal to digest the forage (can be toxic)
Aspiration	using air movement to remove impurities from harvested and (usually) dried seeds
Bimodal rainfall pattern	where significant rainfall occurs in two distinct seasonal periods within 1 year
Bruchid beetles	a group of insects (weevils) that can be a major pest of stored seeds or grains, causing damage as the developing insects eat the inside of the seeds
Cereal	a grass such as maize, rice or wheat, the starchy grains of which are used for food
CLL	crop lower limit—the maximum amount of water able to be extracted by a particular plant from a particular soil type before it senesces or dies
Cut-and-carry	the cutting of specially grown forages or crop residues, or the collection of other plant material, to feed to animals in a confined enclosure
Dibbling	the planting of crop seeds in a small hole formed with a pointed stick or sharp instrument
Dinas Pertanian	Agriculture Services office/agency (Indonesia)
Dinas Peternakan	Animal Production / Livestock Services office/agency (Indonesia)
DUL	drained upper limit—the amount of water that a particular soil holds after drainage has practically ceased
Hand-winnowing	cleaning seeds by hand using wind to remove (usually lightweight) impurities from harvested and dried seeds; a common method is to toss seeds in the air and catch them in a pan/basket while the impurities are removed by a light cross-wind

Herbaceous legumes	short stature, non-woody legumes, e.g. *Clitoria ternatea*, *Centrosema pascuorum*
Inflorescence	a group or cluster of flowers
Insect frass	the droppings or excrement of insects
Intercropping	where two or more crops are grown together in the one area of land during the same season and compete for the same resources (soil, water, light and nutrition) for production; sometimes called multiple cropping
Leaf miner	an insect that removes the green tissue of leaves, leaving the less-digestible structural tissue ('skeleton')
Legumes (as used in this document)	plants of three botanical families that produce seed-bearing pods
Nitrogen fixation	the conversion of atmospheric nitrogen to forms useful to plants through a symbiotic relationship between specialised bacteria and legumes
ENT	East Nusa Tenggara (Nusa Tenggara Timur)—the Indonesian province of which Flores and West Timor form a part
PAWC	plant-available water capacity—the amount of water that a particular soil can hold for the use of a particular crop, described as millimetres of water available to the crop; it varies for individual crop types grown on the same soil type
Perennial plants	those that continue to grow for a number of seasons, often after flowering; those that grow for more than 1 year but die after 2 or 3 years are often described as short-lived perennials
Puckering	buckling of the surface of the leaf, resulting in the leaf having a rough appearance
Relay cropping	where a second crop is planted amid the first crop before it has reached maturity
Rotational cropping	where differing crops (e.g. a legume after a cereal) are grown in the same piece of land in sequential seasons

Ruminants	animals including cattle, sheep, goats and buffaloes characterised by having four compartments to their stomach instead of the one found in most other animals; the rumen, the largest compartment, is used to microbially digest plant material before it passes through the reticulum, omasum and abomasums, where nutrients are absorbed
Saturation	the maximum amount of water able to be held in a particular soil before drainage occurs
Stover	the vegetative component of a mature plant—at maturity a maize plant may be separated into the stover (straw) and grain components
Unimodal rainfall pattern	where significant rainfall occurs in one distinct season annually; rainfall may still fall outside of the designated 'wet' season but is likely to be irregular and of small amounts

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