ILRI MANUAL

24

RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security

CGIAR

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Smallholder dairy farmer training manual

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Smallholder dairy farmer training manual

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International Livestock Research Institute (ILRI)

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Foreword

Improving milk production in East Africa faces multiple constraints, however lack of farmer understanding of the productive cows' nutritional needs – and how to satisfy them – are frequently a "first-limiting" consideration. In recognition of this an intensive, four week training has been developed to improve farmer understanding and ability in this critical area. This manual forms the underlying learning material for this course and is also designed as a reference resource for all course participants.

The original material has been sourced from many places. John Moran of Profitable Dairy Systems, was the major contributor to the sections on Husbandry and Nutrition. Work of various NGOs and CGIAR centres, engaged with African farmers have contributed strongly to this manual and these are acknowledged below:

Feeding dairy cattle in East Africa (Lukuyu, B (Ed.) Dairy Development programme) – International Livestock Research Institute (ILRI).

Feeding dairy cattle (Lukuyu, M (Ed.) Kenya Dairy Development Programme) United States Agency for International Development–International Livestock Research Institute (ILRI).

A Primer on Planting and Managing'Push-Pull' Fields for Stemborer and Striga Weed Control in Maize (Khan, Z.R. and others) – International Centre of Insect Physiology and Ecology (ICIPE).

Improve the quality of your milk and please your customers: training guide for trainers of small-scale milk traders in Kenya (Smallholder Dairy Project) – International Livestock Research Institute (ILRI).

Doubled-up legume technology: Boosting land productivity by intercropping two grain legumes with different growth habits – Africa Rising.

Grassland Database – Food and Agriculture Organization of the United Nations (FAO).

Making High Quality Sweet potato Silage An Improved Tube Silage Making Method – The International Potato Center (CIP).

Additional editorial support on Fertility and fertilizer from David Pelster, Sonata Learning.

Acronyms, terms and measurements convertion factors

AI	Artificial insemination
BSC	Body condition score
CIP	Cleaning in place
CMR	Calf milk replacer
CP	Crude protein
DM	Dry matter
DMI	Dry matter intake
ICIPE	International Centre of Insect Physiology and Ecology
ICIPE-TOC	International Centre of Insect Physiology and Ecology-Thomas Risley Odhiambo Campus
ILRI	International Livestock Research Institute
LW	Live weight
MY	Milk yield
NSD	Napier stunt disease
TDN	Total digestible nutrients
TMR	Total mixed ration
UMMB	Urea mineral molasses blocks

The conversion factors for pounds and kilograms are below:

To convert lb to kg:

1 lb = 0.454 kg

10 lb * 0.454 = 4.54 kg

To convert kg to lb:

1 kg = 2.2 lbs

10 kg * 2.2 = 22 lbs

The conversion factors for inches and centimetres are below:

To convert in to cm:

1 in = 2.54 cm

10 in = 25.4 cm

To convert cm to in:

1 cm = 0.39370079 in

10 cm = 3.9370079 in

Livestock husbandry

Live weight

- Can be measured directly using cattle scales or estimated from chest girth using an ordinary tape measure and a table (Tables 1.1 and 1.2) which will give an estimate of live weight.
- Puberty occurs in dairy heifers at 35–45% of mature weight, while conception can occur at 45–50% of mature weight.
- A dairy cow will attain her mature live weight in about the fourth lactation and the objective of rearing heifers is to produce an animal 80–85% of mature live weight by first calving.
- Chest girth tapes are an alternative to scales they are not as accurate, but much better than estimating weight from simply looking at animals.

The occurrence of the first oestrus in yearlings depends on live weight.

Table 1.1 Target weights for Friesian and Jersey heifers at different ages.

Age (months)	Friesian live weight (kg)	Jersey live weight (kg)
2-3 (weaning)	90-110	65-85
12	250-270	200-230
15 (mating)	300-350	250-275
24 (pre-calving)	500-520	380-410

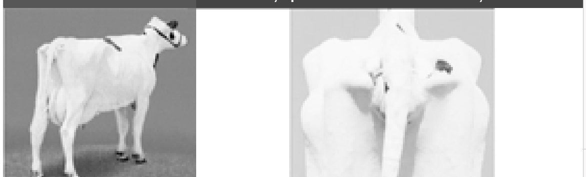
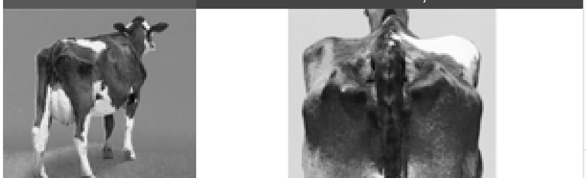
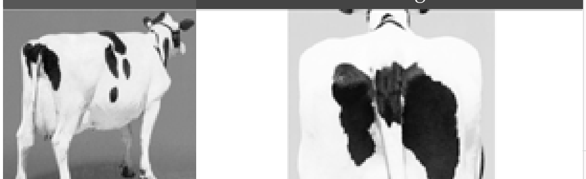
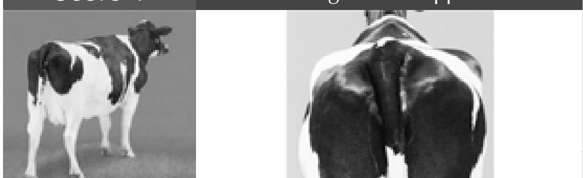
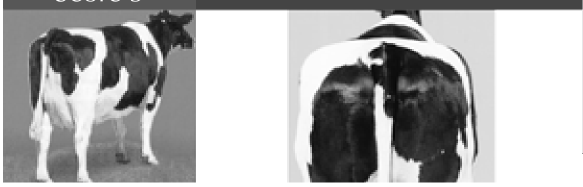
Table 1.2 Heart girth measurements with corresponding approximated live weights.

Heart girth (cm)	Live weight (kg)	Heart girth (cm)	Live weight (kg)
94	64	142	225
96	69	144	234
98	74	146	243
100	79	148	252
102	84	150	261
104	89	152	271
106	95	154	280
108	101	156	290
110	107	158	300
112	113	160	310
114	119	162	321
116	125	164	331
118	132	166	342
120	139	168	353
122	146	170	364
124	153	172	375
126	160	174	386
128	168	176	398
130	175	178	410
132	183	180	421
134	191	182	434
136	199	184	446
138	208	186	458
140	216		

Body Condition (What is it? Why is it important? How to measure it?)

- Condition scoring is the visual evaluation of the amount of muscle and fat covering the bones of an animal.
- It can be assessed independently of live weight, gut fill and pregnancy status and involves observing specific points on the animal.
- Body condition affects milk production and reproductive performance.
- Enables farmers to compare the condition of their cows with recommended targets.
- Knowledge of condition scoring enables farmers to manage their feeding programs better.
- A very useful tool to monitor feeding management by providing a subjective estimate of the amount of muscle and subcutaneous fat between the pin bones and the tail head, over the hip and covering the lumbar vertebrae.
- Increases when energy intake exceeds energy output and decreases when energy output exceeds energy intake.
- For an overweight cow, there is a risk that around the time of calving and in early lactation, she will consume too little feed.
- A thin cow has a poor immunity against disease.
- Sharp falls in condition may also lead to fertility problems e.g. poor or non-existent heats.
- Body condition scores can be based on a 1 to 5 system as in Table 1.3 with pictorial standards presented in Figure 1.1.

Table 1.3 Descriptors for condition scoring of dairy cows for the 5 point body condition scoring system.

Five point scoring system	Condition	Descriptors*
1 Score 1 — Very poor condition (very thin) 	Very poor	Very thin Spine like teeth on a saw Transverse processes prominent with more than half the length visible Pin bones are very prominent, with a deep V shape cavity below the tailhead and no fatty tissue under the skin
Score 2 — Skeleton clearly visible 	Moderate	Skeleton clearly visible Individual vertebrae can be identified on the spine Transverse processes are 1/2 to 1/3 visible with the ends rounded and can be identified individually Pin bones are prominent with a U cavity below the tailhead and some fat under skin
Score 3 — Skeleton and covering well balanced 	Good	Skeleton and covering are well balanced Spine form a sharp ridge Transverse processes are 1/4 visible and individual vertebrae can still be identified but only by pressing on them Pin bones are rounded and smooth, with a shallow cavity below the tailhead and fat cover over whole area, skin smooth, pelvis can be felt
Score 4 — Covering has the upperhand 	Fat	There is excess fat covering Individual vertebrae cannot be identified Transverse processes have a smooth and rounded edge Pin bones are covered in fat with a shallow cavity below the tailhead and patches of fat evident
Score 5 — Obese 	Grossly fat or obese	Spine is covered with fat The ridge of transverse processes is barely visible Pin bones are completely covered in fat with the cavity filled with fat rolls The pelvis is impalpable, even with firm pressure

** The spine is assessed over the lumbar vertebrae. The transverse processes are the horizontal parts of the lumber vertebrae. The pin bones are the bones on either side of the tail head.*

Target body condition scores for cows and heifers are as follows:

Situation	Cows	Heifers
Pre-calving	2.5–3	2.5–3
Pre-service	2–3	2–2.5
Drying off	2.5–3	

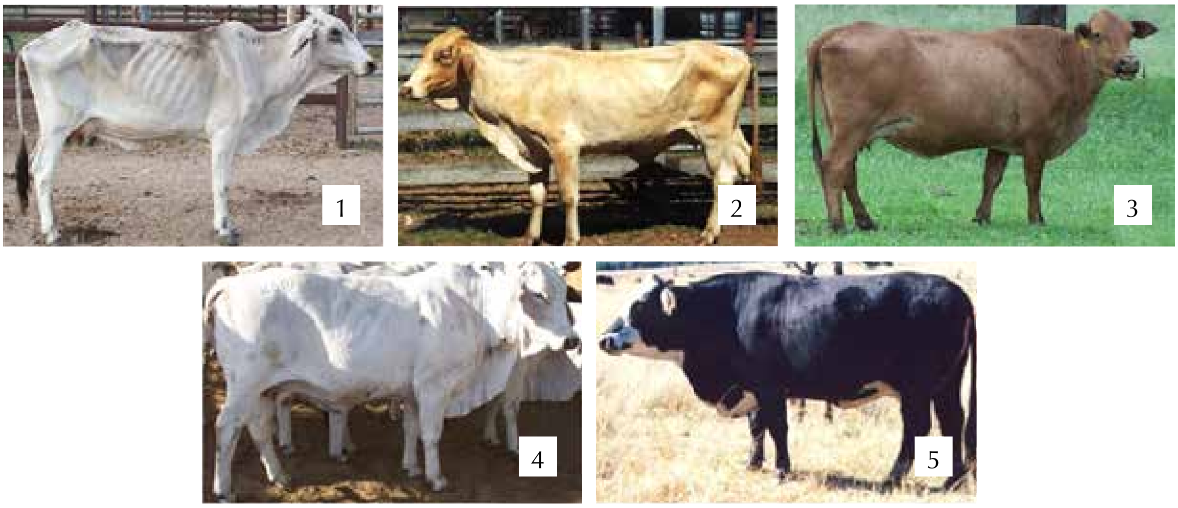
If the average body condition score is:

- Within the normal range, the cows are receiving sufficient energy in their ration.
- High, there is a risk that feed intake will be depressed at the beginning of the next lactation, so ensure cows are not too fat at the end of the current lactation.
- Low, energy intake has been insufficient and resistance to disease could be adversely affected, so increase feed intake and/or energy density of the ration.

Cows should be condition scored repeatedly to assist with feeding decisions. They can be interpreted as follows:

- If the score is within the normal range, then feeding management is correct.
- If the score is below the normal range and changes by less than 0.75 points, then feeding management throughout lactation is correct but overall condition can be improved.
- If the score decreases by more than 0.75 points during early lactation, then energy intake is too low hence dry cow, transition and early lactation feeding should all be reassessed.
- If cows become over fat towards the end of lactation, then the energy: protein balance in the milking ration should be fine-tuned.

Figure 1.1 Pictorial standards of body condition scores in milking cows.



Milk production and body condition

- Cow body condition has a large effect on milk production and fertility. The cow either stores body fat or mobilizes it, depending on the level and type of feed and the stage of lactation. Figure 1.2 depicts the changes during lactation of the partitioning of feed nutrients between the udder and body reserves.
- Adequate body reserves enable high production peaks to be achieved, which contributes to high milk production for the whole lactation.

Body condition in early lactation

- If cows are fat enough at calving—this is an important source of energy at a time when cows are trying to achieve peak milk production and their appetites have yet to reach 100%. Cows in higher condition at calving also have better fertility.
- If cows are low in body condition at calving and are underfed in early lactation, their peak milk production will be depressed and they will partition less feed to milk and more towards body condition over the whole lactation.
- Rapid loss in body condition during early lactation can adversely affect cow performance, through metabolic problems and delayed conception.

Body condition in late lactation and the dry period

Milk production falls in late lactation because:

- Cows are using (partitioning) more of their intake to build body condition rather than to produce milk, their intake ability has decreased or they are being offered less feed or lower quality feed.
- Cows with high genetic production potential tend to continue partitioning nutrients to milk rather than to body condition during late lactation. They must then be fed very well at this time to put on body condition ready for their next calving.
- The dry period may be the only opportunity for cows to put on condition. However cows use feed energy more efficiently to put on body condition while still milking compared to when dry.

Therefore, it is better to plan feeding management to replace body condition during late lactation, rather than during the dry period.

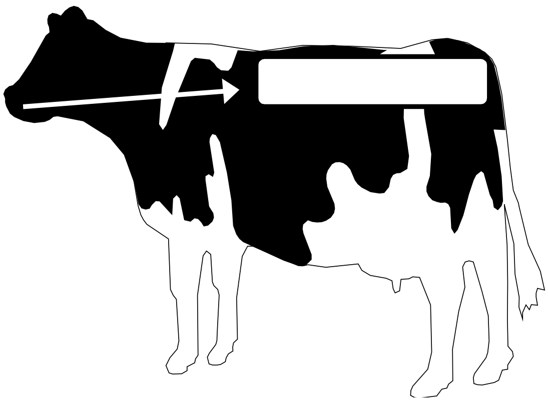
Figure 1.2 Changes in partitioning of feed nutrients over the lactation cycle.

Dry period

Nutrient intake partitioned towards body condition

No milk but developing foetus

Increasing body condition

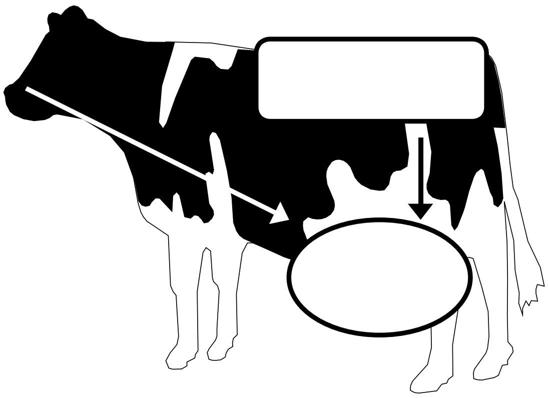


Early lactation

Nutrient intake and body condition both directed towards milk

Milk production high

Body condition high but decreasing

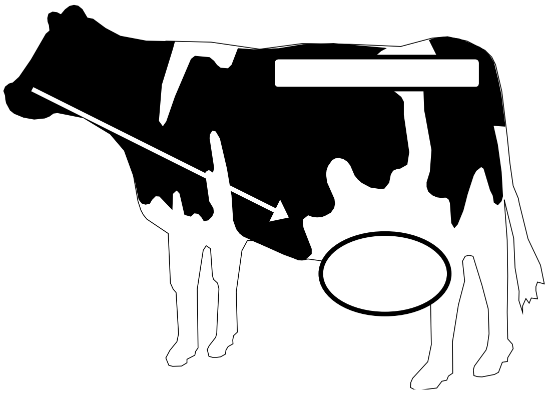


Mid lactation

Nutrient intake partitioned towards milk

Milk yield is less than peak

Body condition low but stable



Late lactation

Nutrient intake partitioned towards body condition and milk

Milk yield decreasing

Condition increasing

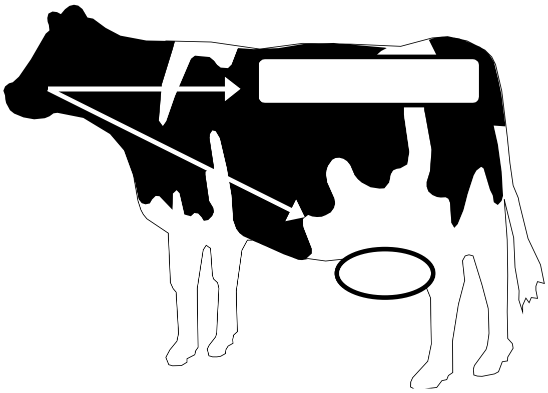


Figure 1.3 Lactation curve.

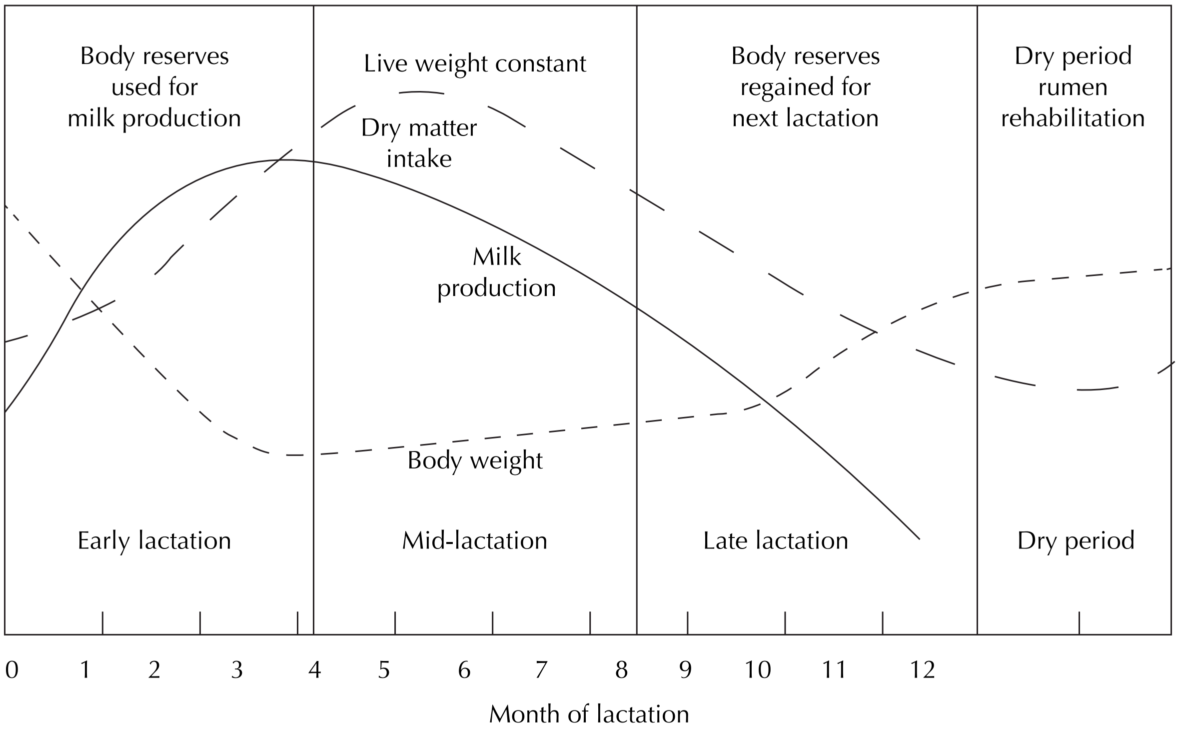
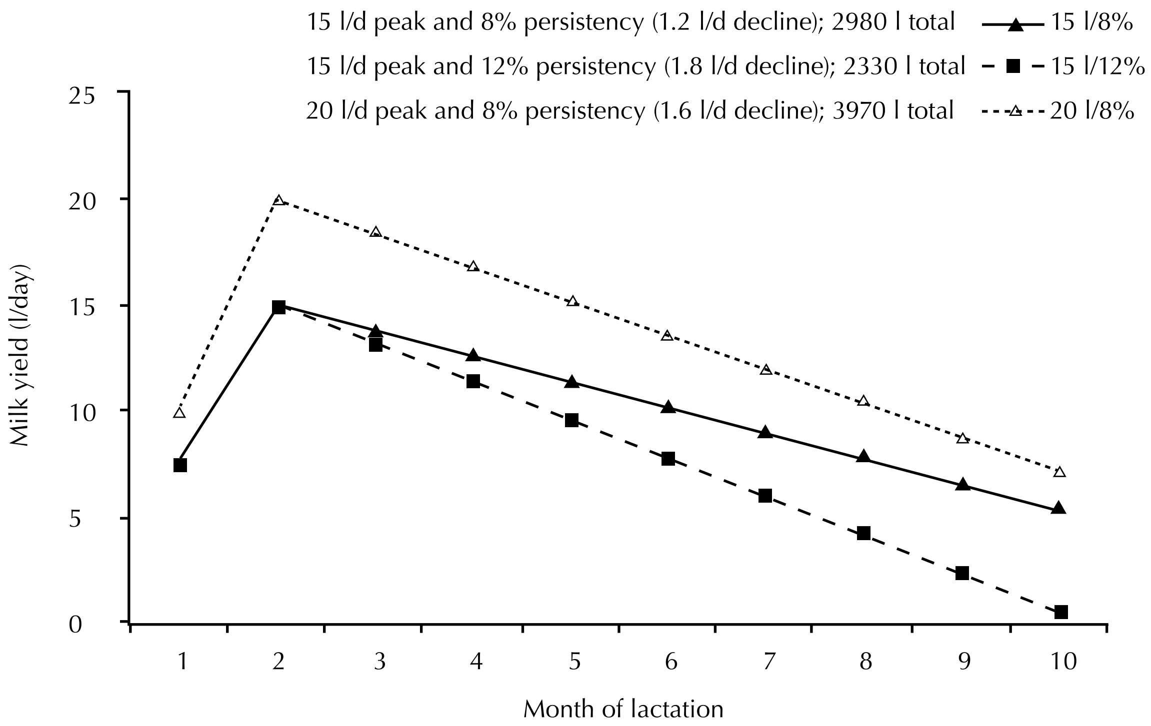


Figure 1.4 Milk persistency curve.



Age determination

- It is easy to estimate the approximate age of a heifer by inspecting the state of her teeth.
- A calf may be born without teeth with the temporary cheek teeth erupting within a few days and the temporary incisor teeth within two weeks.

The age at which the pairs of permanent incisor teeth erupt is as follows:

First incisor teeth	18–24 months
Second incisor teeth	24–30 months
Third incisor teeth	36 months
Fourth incisor teeth	40–48 months

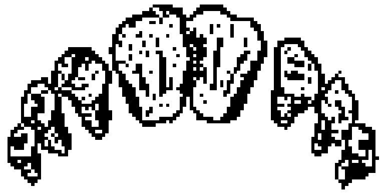
- This is a very useful guide when objectively assessing the feeding management of young stock because poorly fed heifers may look healthy and relatively well grown, but if their first (or even second) incisor teeth have erupted they are likely to be much older than at first glance.
- At approximately age 4–5 years the last of the cow's permanent incisor teeth (the "corner" incisors) are cut, and are typically fully developed by age 5 years. Therefore, at age 5 years, cows typically have all eight permanent incisors erupted and in use. At this age the incisors are tall, relatively flat across the front (when compared to older ages), sharp at the top, and close together.
- From age 6 years or more, estimating cattle age by their teeth is based on their degree of wear and becomes more difficult.

Figure 1.5 Dentition chart.

At birth to 1 month

Two or more of the temporary incisor teeth present. Within first month, entire eight temporary incisors appear.

2 years

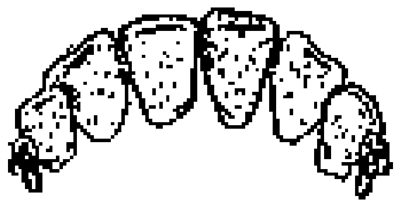


As a long-yearling, the central pair of temporary incisor teeth or pinchers is replaced by the permanent pinchers. At 2 years, the central permanent incisors attain full development.

2–2.5 years

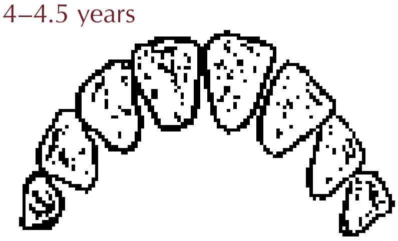
Permanent first intermediates, one on each side of the pinchers, are cut. Usually these are fully developed at 3 years.

3–3.5 years



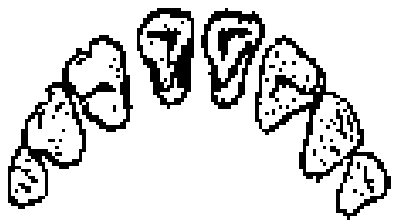
The second intermediates or laterals are cut. They are on a level with the first intermediates and begin to wear at 4 years.

4–4.5 years



The corner teeth are replaced. At 5 years the animal usually has the full complement of incisors with the corners fully developed.

5–6 years

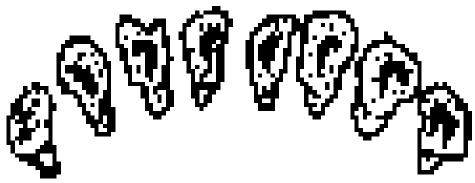


The permanent pinchers are levelled, both pairs of intermediates are partially levelled, and the corner incisors show wear.

7–10 years

At 7 or 8 years the pinchers show noticeable wear; at 8 or 9 years the middle pairs show noticeable wear; and at 10 years, the corner teeth show noticeable wear.

12 years



After the animal passed the sixth year, the arch gradually loses its rounded contour and becomes nearly straight by the twelfth year. In the meantime, the teeth gradually become triangular in shape, distinctly separated, and show progressive wearing to stubs. These conditions become more marked with increasing age.

Pregnancy and heat detection

Heat detection in herds

- Observations of oestrus are more difficult in the tropics due to anoestrus resulting from poor nutrition and/or intensive suckling. Furthermore, the oestrus period is shorter (10–12 hr), signs are less pronounced or mainly shown at night (in buffaloes or local cattle) when farmers are less keen on, or active in, heat detection.
- The average duration of heat is about 14 hr in normal weather conditions. Heats can be as short as 2 hr and as long as 28 hr. Twice daily observations are then essential to catch short heats.
- Observations in the cool of early morning are more likely to detect heat than those in the heat of the day.
- The best conception rates occur following insemination 4–12 hr after the first signs of heat are observed.
- However the problem is knowing at what stage of oestrus the particular heat was first detected.

Cows show signs of heat when:

- They are 18–24 days after their last heat (if they are still non pregnant).
- They stand to be mounted.
- They attempt to mount other cows.
- They are restless and bellow.
- Their feed intake is reduced.
- They have poor milk let down.
- Stringy mucus is seen exuding from their vulva.
- Their vulva is red and swelling.

Heat detection can be improved with:

- Routine night observations.
- Interpreting cow behaviour.
- Checking records for days since previous heat (for closer observation).
- Using heat detection aids in larger herds, although tail paint is a cheap effective aid for most farmers.
- Using oestrus synchronization as a management aid.

Each month farmers need to identify cows which have calved more than 80 days before, but have not been detected on heat, and examine them. This is important if more than 60% of the herd are in this category. Some of these cows may have had an undetected heat, whereas others may not have been on heat and can be treated as non-cycling cows. If most of these cows are in low body condition, their feeding management should be improved. Others may be suffering disorders such as cystic ovaries, infected uterus, and lameness, thus requiring veterinary attention.

Improved reproductive performance provides many benefits to farmers such as:

- Higher average milk yields each day. Cows with poor reproductive performance will spend more of their time in late lactation, when daily milk yields are lower.
- Fewer cows that have become excessively fat because they have failed to conceive.
- Less compulsory culling of cows failing to become pregnant.
- Fewer cows with long dry periods.
- Reduced insemination and semen costs.
- Heifers calving at a younger age.
- Increased number of calves produced each year, thus providing more animals for sale or as replacements for the milking herd.
- More efficient feed utilization as a result of the above benefits.
- More profits, less work and less worry.

The fertility timetable for the milking cow

The fertility cycle can be best understood by following the recommended reproductive timetable as follows:

- Calving, with minimum difficulty.
- Involution (shrinking) of uterus takes 21 days.
- Follicular development commences 14–21 days after calving, in a well managed cow.
- Voluntary waiting period, open days or days after calving with no insemination, should not exceed 50 days.
- Cycling occurs every 18–24 days.
- First insemination should be 50–80 days post-calving.
- Pregnancy takes 282 days.
- Dry off cow 50–60 days pre-calving.
- Transition period to calving for 14–21 days.

There are six key factors which have large influences on herd reproductive performance. Three are non-nutritional and three are nutritional. They are:

- The length of the voluntary waiting period, that is the number of days delay after calving before farmers begin inseminations. This is 50–55 days in the herds with the best fertility.
- Heat detection. Farmers can make two types of mistakes, they can diagnose heat in cows not on heat (called a false positive) or miss a heat identification (undetected heat). Missed heats are more common. The higher the heat detection rate, the higher the submission rate. Farmers with over 80% heat detection rates had 73% 80-day submission rates.
- Artificial insemination (AI) practices. There are many skills in AI. Good first insemination rates were 45–48%.
- Body condition. Cows calving at condition scores of 3 (out of a maximum of 5) had the best fertility. Cows calving in very high condition scores may lose condition more rapidly after calving and can suffer reduced fertility.
- Feed intake. Better fed cows have higher fertility.
- Heifer live weight. The occurrence of the first oestrus in yearlings depends on live weight. So better feeding practices in early life will lead to younger age at first calving in virgin heifers. These heavier animals will also cycle earlier after calving.

Calf rearing—healthy, profitable calves

Well-grown dairy heifers are a good investment in the milking herd. To ensure they grow to become productive and efficient dairy cows, their management must be carefully planned and begin the day they are born.

A well-managed heifer rearing system aims for:

- Good animal performance with minimal disease and mortality.
- Optimum growth rates to achieve target live weights.
- Minimum costs of inputs, such as feed (milk, concentrates and forages), animal health needs (veterinary fees and drugs) and other operating costs (milk-feeding equipment) to achieve well-reared heifers
- Minimum labour requirements.
- Maximum utilization of existing facilities such as sheds for rearing and quality forages for feeding.

The first 3 months are the most expensive period in the life of any dairy cow. During that time, mortality rates are high, up to 10% in many cases. Calves need protection from the extremes of sun, wind and rain no matter what the rearing system. Disease prevention and treatment can be costly during early life.

Rearing the milk-fed calf

- With their undeveloped digestive tract, calves require the highest quality and the most easily digestible source of nutrients, namely, whole milk or calf milk replacers.

- Unfortunately, these are also the most expensive feeds. The most effective way of minimising the high feed costs of calf rearing is through early weaning and reduced milk feeding.
- Good calf rearing depends on two major nutritional factors.
  - Adequate intake of high quality colostrum within the first day of life.
  - Feeding management to encourage early rumen development.

Colostrum feeding

- Calves are born with no immunity against disease. Until they can develop their own natural ability to resist disease, through exposure to the disease organisms in their surroundings, they depend entirely on the passive immunity acquired by drinking colostrum from their dam.
- Colostrum contains the antibodies necessary to transfer immunity onto their calves. It also contains a chemical allowing newborn calves to utilize their own fat reserves to immediately provide additional energy.
- The chances of calves surviving the first few weeks of life are greatly reduced if they do not ingest and absorb colostrum into their blood stream.
- The term colostrum is generally used to describe all the milk produced by cows up to five days after calving, until it is acceptable for use by milk factories. However a more correct term for milk produced after the second milking post-calving is transition milk. This milk no longer contains enough of the factors to provide maximum immunity to calves, but still contains other components, which reduce its suitability for milk processing.

Recommendations on colostrum feeding

- Farmers to ensure all calves drink from their dam within the first 3–6 hours of life and if not, to provide additional colostrum from its mother or another freshly calved cow.
- Two feedings during the first day, 6–12 hours apart, and each of two litres of good quality colostrum used to be considered sufficient to provide passive immunity, mainly because of concern about the small capacity of the abomasum in new born calves.
- Remove the calf as soon as possible after birth (within 15 min) and feed it colostrum. This can be via teat, bucket or stomach tube.

3 Q's principles behind colostrum feeding:

  - Quality is providing good quality colostrum.
  - Quantity is ensuring calves ingest sufficient antibodies.
  - Quickly is timing the first feed to ensure efficient absorption of the antibodies into the blood.

Colostrum quality

- Colostrum is produced by the pregnant cow up to five weeks before she calves down. If cows are not well managed, colostrum quality could be reduced.
- Good management includes providing a good quality diet for dry cows, ensuring they are in good general health and minimising stresses such as climatic or overcrowding during late pregnancy.
- Older cows will generally produce better quality colostrum, containing more antibodies for those diseases existing on that farm. First-calf heifers are likely to have the lowest levels of antibodies in their colostrum because they have had less exposure to these diseases.
- After their first milking, dairy cows begin to reabsorb the immunity factors back into their udder tissue. For this reason, colostrum from the second milking contains only half the immunity factor content as that from the first milking.
- The protection from the passive immunity passed onto the calf peaks one to two days after effective colostrum transfer and then it declines. By two weeks of age, it has declined enough to increase the calf's susceptibility to bacteria, viruses and other pathogens, before the calf's own immunity increases to an effective level. Therefore the calf can be quite vulnerable to pathogen invasions coming from dirty feeding equipment or other sources between 14 and 21 days of age.

In summary, the important principles of good colostrum management are:

- Use colostrum from mature cows that produce less than eight litres at their first milking.
- Use only first milking colostrum.

- Feed four litres to large calves or three litres to smaller calves at first feeding.
- Feed colostrum as soon as possible, at least within the first three hours after birth.
- Do not let calves suckle their dams.

Milk feeding the calf

- Provided the calf milk replacer (CMR) is formulated correctly from good quality ingredients and fed according to the instructions, which are usually on the CMR bag, calves can grow equally well when reared on CMR and their rumens can develop just as well as they would on a diet of whole milk.
- Calf milk replacer should be fed less frequently than whole milk. Too frequent feeding of too much milk replacer can lead to abomasal-induced milk bloat.

A successful early weaning recipe for calf rearing

- The rumen is non-functional in newborn calves; hence, all digestion must take place in the abomasum (or true stomach) and the small intestine. The weaned calf needs a fully functional rumen in order to be well adapted to a forage-based diet. Before weaning, it is important to promote rumen development, so as to avoid growth checks when calves are weaned.
- Rumen development occurs through the digestion or fermentation of feeds (roughages and concentrates) by the rumen microbes.
- Calves should be encouraged to eat solid feeds at an early age, mainly through limiting their access to milk to four litres/ day. From the first week, small amounts of roughage such as clean straw should be offered in combination with high-quality concentrates specially formulated for rearing calves.
- Fresh forages are not good sources of roughage for milk-fed calves. Such forages contain too little fibre, and their very high water content prevents high intakes of feed energy in each mouthful. This limits the feed energy available for rapidly growing animals. Until their rumen capacity is larger, young calves just cannot eat enough fresh forage to sustain high growth rates.
- All calves must be given the opportunity to nibble on the straw even though they will eat very little of it. Straw will encourage rumen development rather than provide nutrients.
- Clean drinking water must be available at all times.
- It is concentrate rather than milk that should provide the bulk of nutrients to develop the rumen as well as keep the calf growing.
- Calves can be weaned off milk once they are consuming 0.75 kg/day of concentrates for two or three consecutive days. This usually occurs by about 6–8 weeks of age.

Weaning age. The age when milk is no longer fed should depend on the quality of feeds available. For example, suggested calves should be weaned at:

- Two months, when quantity and quality of roughage and concentrates are good.
- Four months, when quantity and quality of roughage and concentrates are average.
- Six months, when quantity and quality of roughage and concentrates are poor.
- Eight months, when suckling and cows are dried off.

Concentrate quality. Milk fed and weaned calves require concentrates containing higher protein levels (18-20%) than do milking cows (16%). Low protein concentrates will not promote the same rate of rumen and body development in milk fed calves.

- For farmers receiving KES 35/kg for their milk spend four times more per unit of energy by continuing milk feeding beyond the 6–8 weeks required for normal rumen development in a well reared calf.
- With high milk feeding there is increased likelihood of disease problems. Once milk is removed from their diet through weaning, calves are more resistant to scours. Unless a strict cleaning and sterilising routine is enforced in the calf shed, flies and other disease carrying agents will thrive on residual milk left in buckets, on floors and in other equipment used with milk feeding.
- Scours is the single most important cause of death in milk-fed calves. Even when calves survive, the increased labour requirements for their caring, together with veterinary and drug bills, make scours a costly problem with calf rearers.

What is scours?

It is an increase in the frequency and quantity of faeces, which has a higher than normal water content. In some cases, blood and mucus may also be present. Whatever the cause of scours, farmers will see some or all of the following:

- bright yellow or white faeces.
- depressed calves which are reluctant to feed or suck.
- calves with sunken eyes and/or a temperature.
- skin remaining peaked or tented when lifted, indicating dehydration.
- weight loss and weakness.
- if severe cases, calves will collapse, become comatose and die.

Scours can be classified into two types, nutritional and infectious. Nutritional scours is usually caused by stress to the calf due to a breakdown in management routines. Nutritional scours often progresses to an infectious scour, which is caused by a high population of pathogens.

Causes of nutritional scours

- Scours can be traced back to two major causes, poor colostrum feeding management and stress. One of the first effects of stress in calves is a reduction of acid secretion into the true stomach (or abomasum). This reduces both the ability of the clot to form, and digestion of milk protein.
- Stress can result from a wide variety of causes. It could be due to inappropriate milk feeding programs (eg overfeeding or irregular feeding), sudden changes in the concentration of milk replacers, incorrect milk temperatures or a poor quality milk powder. Calves reared on milk replacers are more prone to scours than those reared on whole milk.
- Environmental stress is also a common cause of scours, such as sudden changes in the weather (for calves run outdoors) or cold, damp, draughty or humid conditions inside calf sheds. Overcrowding in calf sheds can result in outbreaks of scours. Even changes in staff can lead to scours through different handling of calves or changes in the standards of hygiene. Combinations of any of the above stresses will greatly increase the likelihood of scours.

The following signs are used to anticipate the onset of scours on the day before it occurs:

- dry muzzle, thick mucus appearing from the nostrils.
- very firm faeces.
- refusal of milk.
- a tendency to lie down.
- a high body temperature (over 39.3°C).

- Scouring calves can lose up to five litres of fluid each day including minerals and salts essential for normal body function. With most infectious scours, it is the dehydration and acidosis, not the infection, that kills the calf.

Treating scours

- The top priority for treating scouring calves is to provide them with sufficient liquid and electrolytes to replace that lost in the faeces. The next priority is to supply additional sources of readily digestible energy, such as glucose (dextrose), but not sucrose.
- If giving both electrolytes and milk, electrolytes should be given at least 30 minutes before a milk feed.
- Treated calves should be back to normal after two days of fluid therapy.
- It is dangerous to withdraw milk for more than 24–48 hours as the intestinal wall will degenerate and lose its capacity to secrete enzymes that digest lactose. Many authorities now recommend withholding milk for no more than 24 hours, or even not at all.

Preventing scours

- Feeding high quality colostrum for the first few days of life is beneficial. Even if some of these antibodies are not absorbed into the blood, they can still provide local protection in the intestines against infectious scours.
- Good hygiene and minimising stress.

Measures that can be taken include:

- Ensure calves are protected from extremes of climate.
- Carefully plan shed designs to avoid overcrowding.
- Minimize stresses associated with routine management practices, such as disbudding and castration.
- Maintain strict hygiene by cleaning and sterilising feeding utensils and facilities during milk rearing.
- Develop a routine milk feeding program, with as few people involved as possible.
- Wean early to minimize the period of milk feeding.
- Quickly respond to early symptoms of scours, isolate sick calves and address the cause.
- Minimize the use of antibiotics and then only under veterinary supervision.
- Keep records of treatment of sick calves to assist in veterinary diagnoses and for withholding periods if the calf is subsequently culled.

Management of weaned replacement heifers

All too often, farmers rear their heifer calves carefully until weaning but neglect them thereafter. Calves that are poorly managed after weaning are disadvantaged for their entire life. Even if they are well fed after mating, their ultimate mature size is restricted and if they do put on extra weight, it tends to be fat. Most of the growth in skeletal size occurs before, not after puberty.

Weaned heifers do, however, require less attention than milk-fed calves and milking cows. Dairy heifers need to be well fed between weaning and first calving. If growth rates are not maintained, heifers will not reach their target live weights for mating and first calving and their lifetime milk production will be reduced.

Undersized heifers have more calving difficulties, produce less milk and have greater difficulty getting back into calf during their first lactation. When lactating, they compete poorly with older, bigger cows for feed. Because they are still growing, they use feed for growth rather than for producing milk. Many studies have demonstrated the benefits of well-grown heifers in terms of fertility, milk production and longevity.

Fertility

The onset of puberty, and commencement of cycling, is related to live weight more than to age. A delay in puberty means later conception. All heifers should achieve their target weight before joining, because lighter heifers have lower conception rates. Calving problems depend more on heifer live weights at mating, than on live weights or body condition at calving. Frame size is determined early, so there is doubtful merit in the practice of feeding older heifers to make up for poor growth earlier in life.

Friesian heifers mated below 260 kg had 34% conception to first insemination compared to 58% for heifers mated weighing 300 kg or more. Of the smaller heifers, 24% had difficult calvings. This declined to 8% in heifers mated at 260–280 kg and was lowest in 340–360 kg heifers. Heifers under-weight at mating required considerable assistance if in difficulty during calving.

Milk production

Increasing calving live weights (LWT) for Friesians from 360–460 kg, increased milk production during the first lactation by 400 l. This production benefit extended into both the second lactation, with an extra 830 l/extra 100 kg LW, and the third lactation, with an extra 840 litres/ extra 100 kg LW. Heifers calving 100 kg heavier can increase their peak production by five litres milk/day during the first lactation.

However there is little point in rearing well-grown heifers then underfeeding them during their first lactation. Bigger heifers have higher maintenance requirements, which must be met before additional nutrients produce milk. Therefore good heifer rearing systems should be considered only after feeding systems for milking cows have been developed. Many Asian and African smallholder farmers do not feed their cows well enough to justify producing bigger heifers.

Heifer wastage

Poorly grown heifers do not last long in the milking herd. They are more likely to be culled for poor milk yield or poor fertility during their first lactation.

Total herd costs can be greatly increased by this high rate of wastage. Producers should aim to lose (through deaths or culling) no more than 20% of their replacement heifers between weaning and their second lactation.

Targets for replacement heifers

Live weight

Traditional target weights are too low to ensure first lactation heifers achieve their productivity potential, particularly on farms where milking cows are well fed. Table 1.4 summarizes recommended live weights for Friesian and Jersey heifers at various ages. Targets for Zebu or local breed heifers would be similar to those for Jerseys.

Puberty occurs in dairy heifers at 35–45% of mature weight, while conception can occur at 45–50% of mature weight. A dairy cow will attain her mature live weight in about the fourth lactation and the objective of rearing heifers is to produce an animal 80–85% of mature live weight by first calving. Chest girth tapes are an alternative to scales but they are not as accurate.

Table 1.4 Target weights for Friesian and Jersey heifers at different ages.

Age (months)	Friesian – live weight (kg)	Jersey – live weight (kg)
2-3 (weaning)	90-110	65-85
12	250-270	200-230
15 (mating)	300-350	250-275
24 (pre-calving)	500-520	380-410

Energy and protein requirements for heifers

Table 1.5 shows the energy requirements (for maintenance and growth) of heifers growing at different rates at various live weights. The growth rates for 500 kg heifers assume a contribution of 0.4 kg/d from the growing foetus.

Table 1.5 Energy and protein requirements for growing heifers.

Live weight (kg)	Energy requirements (units/day)				Protein (%)
	Growth rate (kg/day)				
	0.4	0.5	0.6	0.7	
100	28	30	33	36	17
200	42	45	48	51	16
300	50	60	64	68	15
400	75	79	84	89	13
500	91	95	99	103	13

Growing heifers require a constant source of protein for optimum bone and muscle growth. Table 1.5 also lists crude protein requirements at different live weights.

Feeding heifers to achieve target live weights

Recommendations for grazing and feeding systems will differ between regions. Rather than depend on recipes, producers should regularly weigh their young stock, then vary feeding strategies according to their growth rates. Growth should average 0.6–0.7 kg/day, although that can vary between 0.5 and 1.0 kg/day, depending on available pasture and the supply and cost of suitable supplements.

As fresh forage is the cheapest feed, it should constitute the bulk of the diet, with hay, silage or concentrates used to overcome forage shortages. Fresh forages or conserved hay or silage must be of sufficient quality (at least 10 units of energy/kg DM) to satisfy the requirements for growth and maintenance.

Until calves reach 200 kg in weight, they are not able to maintain the growth rates needed to reach target weights on diets of either average quality forages or even top quality silage. Their capacity is limited and they simply cannot eat enough DM from the forages to meet their nutrient requirements for rapid growth. Forages must be of good quality (at least 11 units or energy/kg DM) if used as the sole feed for heifers less than 12 months of age.

Forage quality and allocation should allow for continuous growth throughout the first two years. Uniform growth is not necessary and may be impracticable with seasonality of quality forage supplies. Yearling heifers have some ability for compensatory gain following periods of mild under nutrition, so long as they have not been grossly underfed. However, heifers should not be allowed to lose weight or to grow very slowly for long periods of time (ie. no more than one month).

Ideally growing heifers should be continuously fed concentrates to supplement the fresh forage, the quantity offered depending on target growth rates and the nutrients provided from the forage.

Key performance indicators for rearing replacement heifers

Key performance indicators for components of heifer management

Poor heifer management is a major problem in many (if not most) Asian smallholder dairy farms. Young stock receive insufficient attention because they do not generate income for many months. In addition, the first three months are the most expensive period in the life of any dairy cow and many farmers are just not prepared to invest in the calves' future. A low calf mortality rate indicates that early milk rearing practices are adequate and allow for greater opportunity for economic and genetic improvement in the herd. When a heifer dies, there are fewer opportunities for culling unprofitable cows.

There are many hidden costs arising from poor management of the replacement dairy herd. The milking potential of small stunted animals that do not calve until three years of age has been markedly reduced, while very high mortality and morbidity rates in calves during their milk feeding period represent an enormous waste of genetic potential in the dairy herd as well as cash outlay.

There are easily quantifiable benefits in having more newly calved heifers available to replace older unprofitable cows as both heifer and reproductive management improve. These benefits are:

- 1–2% more first calf heifers for every month reduction in age at first calving.
- 3–5% more first calf heifers for every 10% reduction in calf mortality.
- 2–3% more first calf heifers for every month reduction in inter-calving interval.

Farmers should aim to rear 20–25% of their milking herd each year as replacements, to calve down for the first time by about two years of age and produce at least five calves during their productive life. Realistic target for tropical dairy systems are:

- Calf mortality to weaning, 4–6%.
- Heifer wastage rate from birth to second calving, 20–25%.
- Live weight at mating, 250–300 kg.
- Live weight at first calving, 400–500 kg (depending on breed type).
- Age at first calving, 28–30 months.

Another good indication of heifer management is first lactation milk yield. This is expressed as % of mature cow production, with a target of 80–85%. If first lactation yields are less than 75% of the mature equivalent, then the heifer rearing program should be reviewed.

On most dairy farms, heifers don't cover their rearing costs until they reach their second lactation. If they are culled or die earlier, they will leave the farm with an unpaid debt. A feed plan for your heifers is as important as having a feed plan for your milking cows. It is easy to let your heifers drop down the priority list. Growing heavier, well framed heifers is an investment in the future on any farm.

Key performance indicators for entire heifer herds

Replacement heifers are bred to allow for the culling of cows no longer suitable for the milking herd. Good heifer management is essential to provide sufficient animals for this to occur on a regular basis. The proportion of heifer calves that survive and grow well enough to become replacements depends on the many factors. These can be quantified as the proportion of:

- Milking cows that actually conceive (the conception rate).
- Those that produce a live calf (namely, do not abort during pregnancy or suffer neonatal death).
- Those that are heifers (usually 50% of the viable calf drop, except when using sexed semen).
- Those that survive until calving (namely, do not die during milk rearing and post weaning).
- Those that conceive as maiden heifers.
- Those that are suitable as milking cows in the herd (for example are not culled because of poor temperament, poor udder conformation or because of lengthy illness).

Reproduction and calf survival in two rearing systems (A and B) Table 1.6 were compared to calculate their relative replacement rates for a dairy herd with stable stock numbers.

Table 1.6 Measures of reproduction and calf rearing to produce replacements for a stable dairy herd.

Rearing system	A	B
Inter-calving interval (months)	12	18
Calving rate (%)	85	65
Still born calves (%)	2	5
Calf mortality from 0-24 months (%)	8	20
Non pregnant heifers (%)	5	10
Heifer calves born (%)	36	15

Assuming cows remain in the milking herd for up to four to five lactations, 20–25% should be replaced each year. From Table 1.6, the supply of 36% heifers from System A allows for the sale of young breeding stock or a higher culling rate to better address genetic improvements in the herd. Only one in every six or seven cows could be replaced annually in System B, which would hardly be enough to maintain herd numbers, let alone allow for much genetic selection. System A could then be considered as a set of Key Performance Indicators.

With high ages at first calving (> 30 months) and long inter-calving intervals (> 15 months), it is very difficult to increase herd size through natural increases. That is why it is so important to seek the underlying causes of herds with high percentages of dry cows or a high proportion of heifers to cows. The most likely cause is poor feeding management but there could be others, such as disease, heat stress or simply poor reproductive practices.

Difficulties with rearing replacement heifers in the tropics

The tropics are not and ideal location to rear young dairy stock for many reasons. The harsh tropical climate introduces many problems to milk-fed calves while the type of dairy farming (generally poorly resourced smallholder farming) and the lack of awareness of the long term implications of poorly reared stock, do not encourage farmers to pay close attention to their calf rearing systems.

The reasons for poorly reared calves are many and include:

- The tropical environment encourages the proliferation of many disease organisms that can reduce calf and heifer performance. These include some diseases that only occur in the tropics.
- Dairy cows are essentially temperate animals, which are most comfortable 6–18^{0}C. The high tropical temperatures and humidities introduce specific climatic stresses that adversely affect calf and heifer feed intakes, growth rates and fertility.
- As ambient temperatures approach body temperatures, stock rely more on cutaneous evaporation to remove residual body heat, and this is less efficient than other forms of heat loss, requiring increasing amounts of water and minerals.
- The stock on many small holdings are multi-purpose, being farmed for manure, meat and even draught, in addition to milk. Young stock management is often not a high priority on such farms.
- Many of the dairy farms are small holdings where farmers often lack the resources to develop the most effective rearing systems for young stock, since most of their attention is directed towards income generation, namely feeding and managing their milking cows.
- The best way to reduce calf mortality is to practice good husbandry. Some common ailments can be treated by the farmer, but once a calf is seriously ill or large numbers are ill, expert veterinary advice should be sought and are not always readily available.
- Levels of shed hygiene are often suboptimal and this can have detrimental effects on young animals such as milk-fed calves.
- The nutritive value of tropical forages is generally poorer than that in temperate areas, so weaned heifers cannot grow as fast as they do in temperate regions without continual access to high energy and protein supplements. As these are generally more expensive than forages, farmers are less likely to provide sufficient amounts.
- Suboptimal feeding regimes, leading to low growth rates, can greatly reduce feed efficiency in replacement heifers.
- In many cases, farmer extension programs place little emphasis on feeding and managing calves and heifers because of the extended time required for such investments to reap rewards.
- Service providers and agribusiness are less able to source the most up to date equipment and farm inputs, such as the latest generations of veterinary drugs or calf milk replacers that are more readily available to farmers in the developed temperate dairy regions.
- Many veterinarians are not fully aware of the most recent treatment and prevention animal health protocols readily adopted by dairy farmers in more developed countries.
- Farmers are not fully aware of the high costs associated with poor management of young stock, arising through firstly, the high wastage rates of calves and heifers and secondly, the detrimental effects on potential milk yields and fertility.
- Delayed calving can greatly increase the total costs of rearing replacement heifers.
- We know less about the constraints to the performance of young stock in the tropics because there has been less research undertaken. Accordingly, there is less relevant extension material available for dissemination to tropical dairy industries.

The “bottom line” is fewer resources are devoted to young stock management in the tropics. Considering all the above, it is not surprising that the performance of young stock on most tropical, or even subtropical dairy farms, is below that observed on temperate farms.

Health and parasites (ectoparasites, worming, vaccinations)

Maintaining animal health of smallholder dairy herds

- Although veterinarians are essential in times of health emergencies, smallholder dairy (SHD) farmers can do much to ensure their stock remain healthy and productive. The three most important disease problems in tropical dairy farms are scours in milk-fed calves, lameness and mastitis in adult stock.

Physical attributes of healthy and sick cows

- Healthy animals are alert, active, have bright eyes, with no discharge, smooth and shiny skin, breathe and urinate regularly and their tail moves to drive flies away.
- Signs of stress include loss of appetite, reduced daily milk yield, increased temperature, high respiratory rate, tongue protruding, open mouth breathing, inability to lie down.

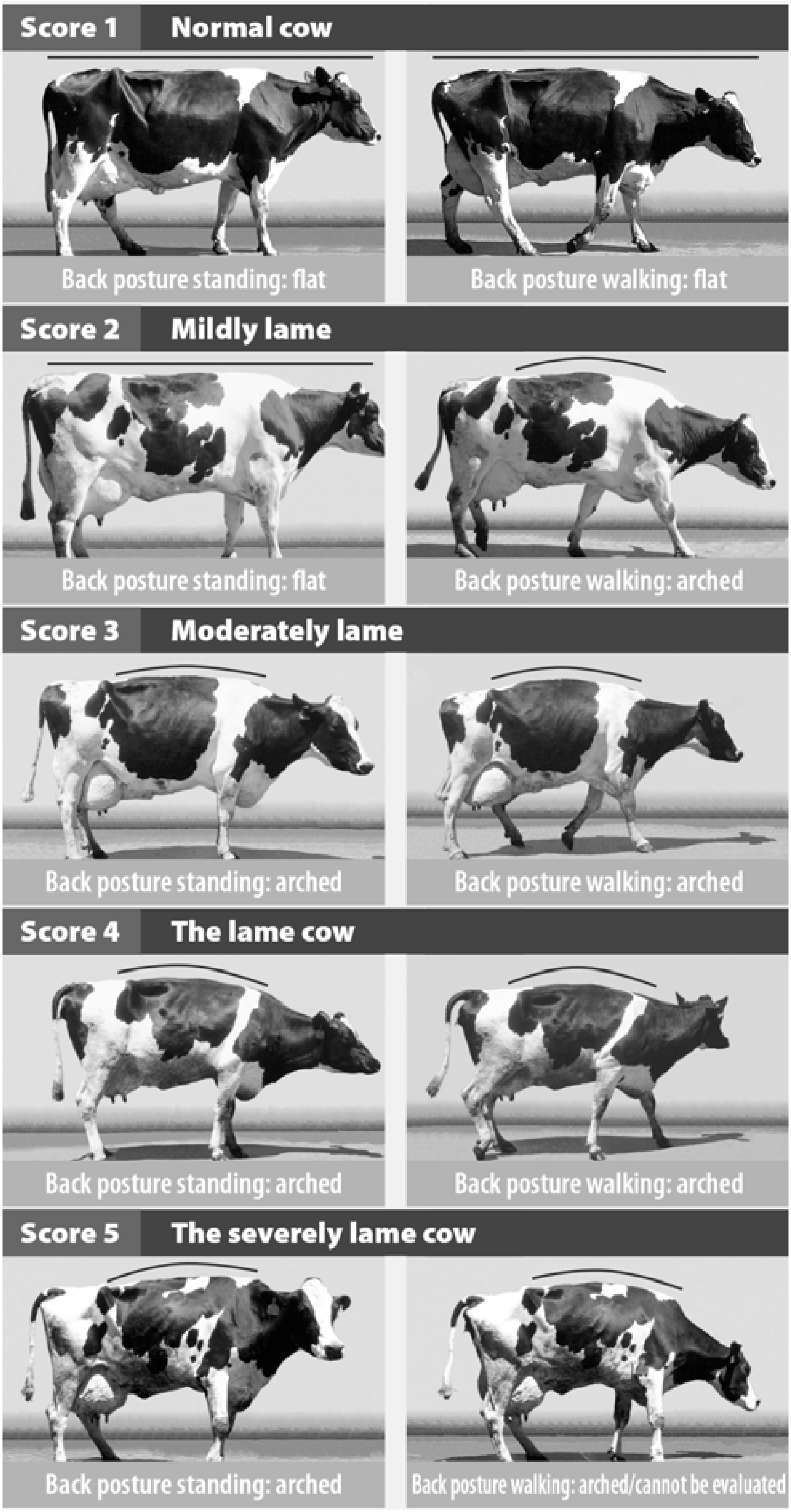
Symptoms of health include:
Nutritional status: sick cows tend to lose weight due to depressed appetite, poor feed digestion or loss of body reserves.

Walking and standing: The way an animal moves can indicate pain in the body, the result of a traumatic injury or an infected hoof.

Eyes and ears: Eyes have a bright and lively expression with no discharge; sunken eyes indicate dehydration. Ears should be able to freely move around.

Skin, coat or mucous membranes: The skin of healthy cows is flexible and when pinched, should quickly return to normal; a lengthy delay will indicate dehydration, as will a dry nose. The coat should be smooth and shiny. The mucous membranes around the eye, nose and vagina should be pink to reddish in colour and be moist. In sick cows, these membranes can become either too red or too pale, the later indicating anaemia.

Figure 1.6 Visual recognition of lameness.



Healthy cows have a good appetite and eat with eagerness. Faeces and urine are discharged regularly with the faeces having a normal consistency. When digestion is disturbed, the cow's appetite decreases and the faeces is discharged too fast (scours) or too slow (constipation). Cows ruminate frequently when healthy (at least 6 to 8 hours each day), and if she does not ruminate when resting, her digestion is disturbed.

Urine should be thin, yellow and clear; thick, mucous or red urine is an indication of ill health.

In healthy cows, respiration is quiet and regular, whereas in cases of unrest, fever, fatigue or heat stress, respiration rates increase. Coughing, nasal discharge, rapid or slow breathing can all be symptoms of ill health.

When a cow is sick, milk production drops, primarily due to decreased appetite.

Mastitis

Mastitis is an inflammation of the udder caused by a variety of microbes, mostly bacteria, that gain access to the interior of the mammary gland through the teat canal. These microbes live on the cow, its udder and in its environment, including the floor, faeces, soil, feedstuffs, water, plants and milking equipment and utensils. In response to these bacterial invasions, cells move from the blood stream into milk in order to fight the infection. Fortunately these organisms are normally killed by pasteurization and thus seldom cause disease in humans, unless the equipment is faulty or if raw milk becomes contaminated with these organisms.

Microbes that can cause mastitis are grouped into two main types:

- Contagious bacteria that spread from infected quarters to other quarters.
- Environmental bacteria, commonly present in the cow's environment.
  - At low levels of infection, it may go unnoticed in the form of subclinical mastitis. However, it eventually becomes sufficiently severe to be classed as clinical mastitis leading to pathological changes in the mammary tissue and physical, chemical and bacteriological changes in the milk.
  - If the infection is not cleared up, chronic mastitis may result. Infected quarters can lose up to 25% of their potential milk production and produce only poor quality milk.

The economic importance of mastitis:

- reduced milk production.
- treatment costs.
- discarded milk with antibiotic residues.
- possible death of infected animals.
- udder damage and the interruption to breeding improvement programs.

Mastitis may be attributed to:

- poor management.
- improper milking procedures.
- type of housing.
- nutrition and stress.

These all interact with genetic and physiological factors such as stage of lactation, milk yield, milk flow rate and pregnancy.

(More to be covered in chapter 4)

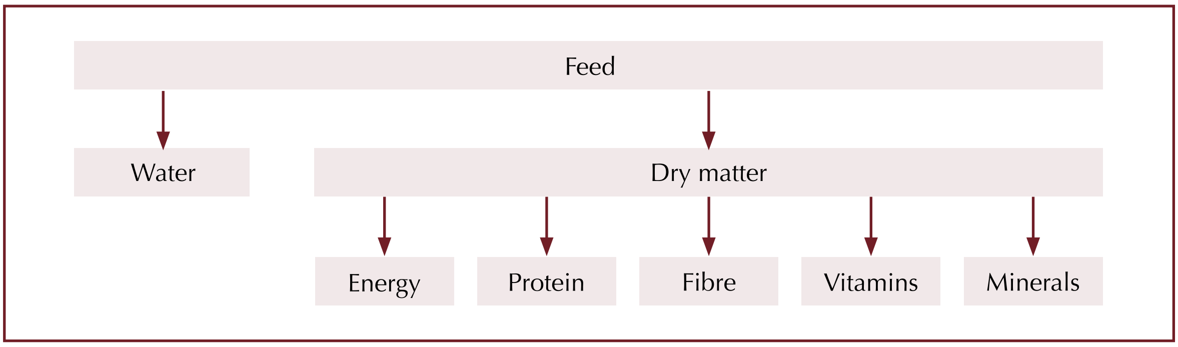
Livestock nutrition

Feeds can be divided into two groups: roughages and concentrates.

Roughages are bulky feeds like Napier grass, maize stover, Leucaena, banana stem, sweet potato vines, hay, silage etc.. These feeds are usually grown on the farm and are the cheapest to feed to the cow.

Concentrates are products like dairy meal, maize bran, maize germ meal, brewer's waste, copra cake, etc.. Dairy meal or cubes are more or less balanced concentrates for milk production.

- The nutrients required by dairy cows are water, energy, protein, fibre, vitamins and minerals. These requirements largely determine how we think about the composition of their feed. Feed contains both water and dry matter.
- The dry matter component of that diet is the part which contains the necessary energy, protein, fibre, minerals and vitamins as depicted below.



The dry matter intake concept

Dry matter intake (DMI) is a factor that must be estimated before an animal's diet can be properly calculated. Yet, DMI is a concept that's commonly misunderstood.

DMI is the level of intake that a cow must consume of a ration that contains the energy concentration recommended for her by nutrient tables.

Consumption controls

Consumption of less-digestible, low-energy, high-fiber diets is controlled by rumen fill and the feed passage rate through the animal. Meanwhile, consumption of highly digestible, high-energy, low-fiber feeds is controlled by the animal's energy needs and by metabolic factors.

How much dry matter will a cow eat?

Depending on the quality of the diet, a mature cow will usually consume 2-4% of her live weight (LW). Consumption of low-quality feeds may be 2-3% of LW, while green pasture may be 3-4%.

The factors that influence the amount a cow will eat include her size, body condition, stage and level of production. Other factors include the quality and availability of forage, amount and type of supplements and her environment.

With diets high in fibre, the rate and level of digestibility will have a large effect on intake. The faster the feed is digested, the faster it passes through the digestive tract and the more it allows for an increase in consumption.

Poor-quality roughage such as straw and maize stover, on the other hand, will have a slower rate of digestion than a high-quality feed such as Lucerne.

With straw, a cow weighing 500 kg l/weight would have to eat about 40 kg. National Research Council (NRC) to meet her energy and protein requirements. This she can't do. We can predict that she would eat only 15 kg. The cow will appear full, but she won't be meeting her nutrient requirements. It's a scenario seen quite often in cattle on corn stalks or other poor quality roughage.

Importance of dry matter intake

Cows have a minimum requirement for protein and energy to maintain normal body functions – known as their 'maintenance' requirement – which is approximately 2% of their body weight.

Maximising dry matter intake provides more nutrients to rumen microbes, which in turn provides more nutrients to the cow for milk production and composition, growth, reproduction and body condition.

Every day, an efficient milking cow needs a dry matter intake equivalent to at least 3% of their body weight.

Estimating dry matter intake

Measure how much of each feed a cow is eating

Weigh daily allocations of grain, protein meals, conserved forages and hay. Intake of pasture and forage crops are more difficult to estimate. However, visual estimation, cutting quadrats and/or using rising plate m are ways of determining pasture/forage intake levels.

Indicators of adequate daily dry matter intake

- Milk yield and composition on target.-Lush pasture allocation not fully eaten.
- Silage, grain or mixed feed being left in troughs.
- Cows not standing around 'waiting to be fed'.
- Body condition score on target.

Indicators of inadequate daily dry matter intake

- Low milk yield and problems with.
- Cows appearing hungry, bellowing, waiting for feed.
- Cows rushing to fresh forage, to feed troughs, and into the dairy for grain.
- Cows eating all feed allocated in paddocks and troughs.
- Low body condition score.

Useful rules of thumb

- The heavier the animal, the higher its maintenance requirements, and the higher the intake required for production.
- An efficient milking cow needs a daily dry matter in take equivalent to at least 3% of its body weight. E.g. A 600 kg cow needs at least 600 kg × 3% = 18 kg DM/day.
- Higher producing cows will eat more than 4% of their body weight as dry matter, e.g. a high-producing (> 30 l/day) 600 kg cow could eat 600 kg x 4% = 24 kg DM/day.

Homegrown forage is the cheapest source of feed for milk production. Aim for maximum daily intake of good quality forage, supplemented and balanced with other feed sources.

Minimize daily variation in forage fed. Rumen microbes can take up to 4-6 weeks to adapt, so change gradually.

A balanced diet

Cattle must eat different types of feed to supply the various nutrients they need to survive, remain healthy and be productive – that is to grow, produce milk and reproduce efficiently. In fact all animals, including people and cattle, need balanced diets. That is diets that supply both the right variety and amount of the different type of nutrients the body needs.

Diets of cattle are usually called rations. The challenge for dairy farmers is to put together a ration for their cattle, using feeds that are readily available, that supplies all the animals' nutritional requirements, does not cause any health problems, enables the cow to produce as much milk as it is capable of - and to do all this in the most economical and cost-effective way possible.

Highest quality supplementary forages

- Silver leaf and Greenleaf Desmodium
- Lucerne
- Calliandra
- Leucaena
- Sesbania
- Mulberry
- Sweet potato vines (before and after harvesting potatoes)

Good quality bulk forages

- Young Napier grass (less than 1 m tall; dark green stems and leaves)
- Young Rhodes/Kikuyu/Setaria grass (fresh, green leaves and stems; up to flowering stage)
- Young fodder sorghum (fresh, green leaves and stems; before flowering stage)
- Young fodder oats (fresh, green leaves and stems; before flowering stage)
- Young roadside grass (fresh, green stems and leaves; before flowering stage)
- Hay (made at early to mid-flowering stage of grasses)
- Horticultural waste (outer leaves of cabbages and fresh green beans and peas rejected by export companies)

Poor quality bulk forages

- Overgrown Napier grass (more than 2 m tall)
- Dry maize or sorghum stover (after harvesting of the cob)
- Rice straw
- Wheat straw
- Barley straw
- Old, dry pasture/grass (dry leaves and dry, hard stems; seed dropped)
- Bean haulms/husks (after harvesting the beans)
- Banana pseudostems and leaves (fresh green leaves and stems)
- Sugar cane tops

Common feed measures and their weights

Table 2.1 Common forage measures and their weight.

Forage	Measure	Fresh matter weight (kg approx.)
Napier grass	Full sack	20
	Shoulder load – women	20
	Shoulder load – men	30
	Wheelbarrow	70
	Pick-up – big	900
	Pick-up – small	400
Hay (Rhodes grass)	Bale – small, loose	8 – 10
	Bale – standard, packed	15 – 20

Table 2.2 Common concentrate 'Kasuku' measure and the weight.

Meal	Volume measure (the standard 2 kg plastic Kasuku cooking (shortening) oil container)	Meal weight (kg)
Dairy meal	Kasuku top level compacted	1.3
	Kasuku top level loose	1.2
Maize bran	Kasuku top level compacted	1.3
	Kasuku top level loose	1.1
Maize germ	Kasuku top level compacted	1.4
	Kasuku top level loose	1.3
Wheat bran	Kasuku top level compacted	0.8
	Kasuku top level loose	0.7

Water

- The body of a dairy cow is composed of 70 to 75% water. Milk is about 87% water.
- Water is essential to regulate body temperature. As well, water is involved in digestion, nutrient transfer, metabolism and waste removal.

An abundant, continuous, and clean source of drinking water is vital for dairy cows.

Energy

- Dairy cows use energy to function (walk, graze, breathe, grow, lactate, and maintain a pregnancy).
- Energy is the key requirement of dairy cows for milk production. It determines milk yield and milk composition.

Protein

- Protein is the material that builds and repairs the body's enzymes, hormones, and is a constituent of all tissues (muscle, skin, organs, foetus).
- Protein is needed for the body's basic metabolic processes, growth and pregnancy.
- Protein is also vital for milk production.

Fibre

- For efficient digestion, the rumen contents must be coarse with an open structure and this is best met by the fibre in the diet. Fibre contains most of the indigestible part of the diet.
- Cows require a certain amount of fibre for rumen function.
- It ensures that the cow chews its cud (ruminates) enough and therefore salivates. Saliva buffers the rumen against sudden changes in acidity.

- Both the length and the structure of the fibre are important. These determine how much chewing a feed requires.
- Feeds which need extra chewing increase the flow of saliva.
- Fibre in the cow's diet also slows down the flow of material through the rumen and thus gives the microbes more time to digest the feed.
- Products of fibre digestion are important for the production of milk fat.

Vitamins and minerals

- Vitamins are organic compounds that all animals require in very small amounts. At least 15 vitamins are essential for animals.
- Vitamins are needed for many metabolic processes in the body, eg. for production of enzymes, bone formation, milk production, reproduction and disease resistance.
- Minerals are needed for:
  - teeth and bone formation.
  - enzyme, nerve, cartilage and muscle function or formation.
  - milk production.
  - blood coagulation.
  - energy transfer.
  - carbohydrate metabolism.
  - protein production.

Table 2.3 Dry matter content of some feeds.

Feed	Dry matter content (% of the fresh matter weight)
Hay	90
Maize stover (brown, dry)	85
Cut grass	30
Silage	25
Napier grass > 1.8 m	25
Sweet potato vines	25
Weeds	25
Napier grass (1.8 m)	20
Banana leaves	12
Maize stover (green at harvest)	10
Napier grass (0.6 m)	10
Banana pseudo stem	5

Feed partitioning

The dairy cow requires adequate feed in order to remain healthy and in good body condition. The nutrients the dairy cow consumes are used for the following body functions:

Maintenance: Animals require nutrients to maintain the body functioning without losing weight.

Growth: Apart from maintaining the body, a growing cow (calf, heifer, even an animal in its first and second lactation) requires additional nutrients in order to grow to its full size.

Reproduction: A pregnant cow requires additional nutrients to support the growth of the unborn calf.

Milk production: A lactating cow requires more nutrients in order to produce more milk.

When making rations for dairy cows, the above factors must be put into consideration.

The golden rules for feeding milk cows

- Milking cows have high requirements for water, which should be supplied separately as clean drinking water rather than as part of any concentrate slurry.
- Feed sufficient quality forages (20 to 40 kg fresh forage/cow/day). The daily amount will depend on the cows' live weight and milk yield and the farmers' available forage resources.
- Supplemented with concentrates which are formulated to overcome specific nutrient deficiencies.
- Consider wilting the forage, by leaving it out in the sun during the day before chopping it up, to reduce its moisture content and encourage the cows to eat more of it, hence produce more milk.
- At any one time, 60% of milking cows at rest should be ruminating. This is a good reflection of the overall good herd management which includes appropriate feeding management.
- If concerned about unbalanced diets in milking herd, closely monitor the manure characteristics, changes in feed intakes, changes in milk yield and composition (fat and protein or solids-not-fat) and the proportion of cows that are ruminating.
- Remember that potentially higher yielding cows are more susceptible to other farm constraints such as insufficient quality feed, heat stress, poor animal health and the limited management skills of the farmer.
- Farmers need to develop the skills to identify when cows are on heat. This requires consistent observations, including night time observations.
- Milking cows may cost more to feed better but they will do more than simply return this investment and will also yield substantial profits in producing more milk and more calves over their lifetime.
- There is no benefit whatsoever in providing concentrates in the form of a slurry.
- When planning milking cow feeding programmes, it is important to feed more concentrates to higher yielding cows.
- It is better to feed green forages rather than dried ones, such as rice straw.
- Selection of forages to grow for livestock fodder should be based on those most suited to the soils, climate and local farmer skills.
- Growing forages requires additional inorganic fertilizers as well as cow manure and shed effluent.
- You must feed the grass as well as feed the cows. Use inorganic fertilizers for forage production.
- The optimum time to harvest forages should be based on their nutritive value rather than their total forage yield. Over mature forages have a low nutritive value.
- Concentrate supplements should be formulated to provide sufficient energy, protein, minerals and vitamins for good consistent milk yield and fertility.
- Calcium and phosphorus supplements are particularly important for milking cows.
- Sourcing ingredients for concentrate supplements should be based on their relative costs of feed energy and protein.
- Cows should be able to rest for as long as they need to, on comfortable and dry bedding as this increases blood flow to the udder and hence milk yield.
- It is best to set realistic target milk yields based on the genetic quality of the cows and the feed (forages and concentrates) available.
- It is more efficient to feed fewer milking cows better but the ideal target milk yields should depend on the farmers resources (for feed supplies), management skills and the motivation to have high yielding cows.
- Cows tend to "moo" when they are on heat or are hungry. Don't ignore their cry.

How much to feed

- Dairy cows have an enormous potential to produce useful nutrients (raw milk and body muscle and fat), but they also have very high nutrient requirements to achieve this potential. For example, over a 12 month period the quantity of protein produced by Friesian cows in milk can vary from 0 to 1 kg/day.
- To achieve such performance levels, dairy cows must be able to consume up to 4% of its live weight as dry matter each and every day.
- The appetite of a milking cow depends on the rate of breakdown of feed in the rumen, other stomachs and the intestines, which is largely dependent on feed quality.
- Her appetite also depends on her health status, her level of comfort if she is heat stressed or being bullied by other more dominant cows and if she is provided with sufficient drinking water.
- Feed intake is usually expressed in terms of kg DM/cow/day, rather than kg fresh feed/cow/day.
- The daily DM intake can also be expressed as a % of her live weight with the maximum appetite being designated as 2.5%, 3% or even 4% of her live weight, depending on her lactation status and how many l/day of milk she is producing.

Water

- Lactating dairy cows in the tropics require 60–70 litres of water each day just for maintenance, plus an extra four–five litres for each litre of milk produced.
- Water requirements rise with air temperature. An increase of 4°C will increase water requirements by six–seven litres/day. High yielding milking cows can drink over 150 litres of water/day during the hot season.
- Other factors influencing water intakes include DM intake, diet composition, humidity, wind speed, water quality (sodium and sulphate levels), and the temperature and pH of the drinking water.

Energy

Cows need energy for maintenance, activity, pregnancy, milk production and for gaining body condition.

Energy needed for maintenance

Energy is used for:

- Maintaining the cow's metabolism which includes breathing and maintaining body temperature.
- Physical activities such as walking and eating.
- Physiological state (ie. pregnancy and lactation).
- With most cows in the tropics housed indoors, physical activity is negligible.

Table 2.4 shows the energy needed for maintenance at various live weights. These values include a 5% safety margin to take into account the energy required to harvest and chew the feeds.

Table 2.4 Energy requirements for maintenance.

Live weight (kg)	Energy requirement (units)
100	17
150	22
200	27
250	31
300	36
350	40
400	45
450	49
500	54
550	59
600	63

Energy needed for activity

- A small allowance for grazing and eating activity has been factored into the maintenance requirements in Table 2.4. In flat terrain, 1 unit of energy/km should be added to provide the energy needed to walk to and from the dairy.
- In hilly country, this increases up to 5 units of energy per kilometer.

Energy needed for pregnancy

- A pregnant cow needs extra energy for the maintenance and development of the calf inside her.
- From conception through the first 5 months of pregnancy, the additional energy required is approximately 1 unit/day for each month of pregnancy.
- Energy requirements for pregnancy only become significant in the last 4 months. Table 2.5 shows the average daily energy requirements during these last months in units of energy.

Table 2.5 Average daily energy requirements in the last 4 months of pregnancy.

Month of pregnancy	Energy requirement (units)
Sixth	8
Seventh	10
Eighth	15
Ninth	20

Energy needed for milk production

- Energy is the most important nutrient to produce milk.
- The energy needed depends on the composition of the milk (ie. fat and protein content).
- Milk with high fat content might need 7.1 units/ l.

Energy needed for body condition

- When an adult cow puts on body weight, it is mostly as fat. Some of this fat is apparent on the backbone, ribs, hip bones and pin bones and around the head of the tail.
- More fat is needed to produce one extra body condition score on a large-framed cow than on a small-framed cow.

Energy requirements from calving to peak lactation

If the forage is very moist, say with a dry matter content of only 12 to 17%, the rumen cannot hold sufficient fresh forage to meet the DM needs of the cow. Peak milk production occurs around weeks 6 to 8 of lactation. So, when a cow should be gorging herself with energy, she is physically restricted in the amount she can eat.

The level of feed intake is primarily determined by stage of lactation, but can be manipulated. Table 2.6 shows the feed intakes required for cows to meet their energy needs to produce target milk yields. By providing a high quality diet during early lactation (10 units of energy/kg DM), the physical restrictions of appetite would be reduced.

Table 2.6 Quantities of dry matter consumed by cows fed diets of different energy density and producing 3 levels of milk.

Milk yield (l/day)	Daily energy requirement (units/day)	Required intake (kg DM/d) 8 units/kg DM	10 units/kg DM
13	125	15.6	12.5
17	146	18.2	14.6
20	161	20.1	16.1

The 20 l/day cow could probably not eat 20 kg DM of feed at 8 units of energy/kg DM at any time during lactation, let alone in early lactation when intake is restricted. During early lactation, they will produce more milk from more energy-dense feeds because they have to eat less DM to receive an equivalent intake of energy. Nutritional requirements generally exceed voluntary food intake until week 12, so body fat reserves are drawn upon to make up the nutrient deficit.

Protein

The amount of protein a cow needs depends on her size, growth, milk production, and stage of pregnancy. However, milk production is the major influence on protein needs. Table 2.7 shows protein needs at different levels of milk production.

Table 2.7 Crude protein needs of a cow at different stages of lactation.

Milk production	Protein requirements
Early lactation	16 - 18%
Mid-lactation	14 - 16%
Late lactation	12 - 14%
Dry	10 - 12%

Fibre

- Cows need a certain amount of fibre in their diet to ensure that the rumen functions properly and to maintain the fat test.
- Fibre requirements are the absolute minimum values.
- Acceptable levels of fibre in the diet are in the range 30 to 35% of dry matter (DM).
- Low-fibre, high-starch diets cause the rumen to become acid. Grain poisoning (acidosis) may occur. Adding buffers such as sodium bicarbonate to the diet reduces acidity and hence reduces this effect. Buffers are usually recommended when grain feeding exceeds 4 to 5 kg grain/cow/day. Buffers are not a substitute for fibre. Long-term feeding of low-fibre diets should be avoided.

Vitamins and minerals

- Some farmers spend a great deal of money on vitamin and mineral supplements for their cows. Production benefits only occur when the supplements correct a deficiency.
- Before purchasing the vitamin and mineral supplements, it is important to find out whether a deficiency actually exists. In some instances, supplementing animals that don't have a deficiency may lead to poisoning and even death.
- Mineral deficiencies are less likely if green forages are the major part of the diet. High-producing herds fed diets high in cereal grain or maize silage may need added minerals.

Concentrates feeding

Concentrates are expensive and they should be used economically. Two feeding methods can be recommended:

a Challenge feeding:

This is recommended for cows in early lactation. The farmer is to begin with low levels of dairy meal concentrates (4 kg per day) and increase the amount by 0.5 to 1 kg per day as long as the there is an increase in milk production until the point at which further increase does not result in an increase in milk production. Maintain this amount until the milk production starts dropping then reduce the amount of concentrate gradually.

As a rule of thumb, I kg increase in concentrate fed should result in an increase in production of milk of 1.5 to 2 l. Feeding concentrates is economical only as long as the price of I.5 litres of milk is higher than the price of 1 kg concentrate.

b Concentrate re-allocation:

Most farmers have been advised and known to feed their cows a flat rate of 2 kg concentrate per day throughout the lactation period. This amounts to about 10 (70 kg) bags of the concentrate for the whole lactation.

Reallocation means feeding all of the ten bags during early lactation, amounting to about 8 kg concentrates per day for the first 12 weeks of lactation and providing good quality forage only for the rest of the lactation. If the cow is not already accustomed to concentrates, after calving start off by giving 2 kg and increase gradually over the first week to 8 kg.

Reallocation is advantageous in that by targeting the feeding during early lactation when the requirements are high, the cow is able to produce over 20% more milk during the whole lactation. The cow remains in good body condition and is able to come on heat and conceive faster.

Supplements for milking cows

The diet of milking cows must consist of a combination of forages and concentrates. These other feeds are called supplements to the major forage source.

Choice of supplement

A number of supplement types are fed to dairy cattle. The decision on which supplement is determined by a combination of factors, such as:

- What is the limiting nutrient: energy, protein, fibre, or a combination of all three?
- What supplements are available?
- What is their nutritive composition?
- What are the relative costs?
- What are the practical implications, eg. facilities for storage and feeding, labour requirements, reliability of supply?
- What are the nutritional implications? how will the supplement affect the ration balance? Could problems such as acidosis arise?

In forage-based dairy systems, energy is normally the first limiting nutrient. Therefore, supplements should be compared as basis of their cost per unit energy. The lower the cost of energy supplied, the cheaper the supplement. Supplements can also be compared on the basis of cost per kg protein supplied.

Feed types

High energy feeds

- Cassava chips.
- Rice bran.
- Brewers grain.
- Commercial concentrates.

High protein feeds

- Coconut meal.
- Palm kernel cake.
- Soybean curd.
- Urea.

Table 2.8 Classification of supplements and basal forages according to their energy and protein contents.

Energy/protein classification	Poor energy (< 8 units/kg DM of energy)	Moderate energy (8-10 units/kg DM of energy)	Good energy (> 10 units/kg DM of energy)
Poor protein (<10%)	Rice straw Maize stover Sugar cane tops Cassava waste	Rice bran (poor) Most grasses Sweet corn cobs Banana stem Urea rice straw	Cassava chips Paddy rice Molasses Sweet potatoes Pineapple waste Maize silage
Moderate protein (10-16%)	–	Brown rice Well managed grasses Soybean Immature grasses	Maize grain Sorghum grain Rice bran (good) Wheat pollard Palm kernel cake
Good protein (<16%)	Urea	Whole cottonseed Shrimp waste Cassava hay Most legumes Legume hays	Brewers grain Coconut meal Soybean curd Commercial concentrate Protein meals Legume leaves

Energy supplements

- Feeds with large quantities of starches and sugars (eg. cereal grains and some by-product feeds) are good energy supplements. Maize, sorghum and rice are cereal grains, while cassava and sweet potatoes are root crops.
- Many farmers feed commercially formulated concentrates and frequently high-energy byproducts such as rice bran, cassava waste and brewers grain.
- Cassava roots and molasses are very low in protein (2–4%), while much of the energy in cassava can be extracted during processing.
- Due to the contamination with rice hulls, the nutritive value of rice bran varies considerably with grade.

Protein supplements

- Many of these are derived from byproducts of leguminous grains, such as peanuts, soybean and sunflowers, while others are whole grains, such as mung beans and cottonseed.
- Urea is a common source of nitrogen, but being a form of non-protein nitrogen, it is not a true protein. It has no energy value and is all degradable in the rumen. It is sometimes used as a substitute for true protein sources in feed mixtures and pellets, but is only effective when fed in combination with an energy source such as cereal grains or maize silage.
- It is recommended that urea only be fed to animals that have a fully functioning rumen and at a maximum rate of 1% of total DM intake.
- The highest quality protein supplements originate from animals, such as fish, shrimp of blood. This is because much of their protein escapes rumen degradation and is more efficiently digested in the intestines. These supplements, originating from animals, have amino acid profiles more closely related to those in milking cows, hence are more efficiently utilized following digestion.

Five distinct feeding phases

Phase 1: Early lactation: 0–70 days (peak milk production):

- At this stage, the dairy cow has low appetite and feeding intake lags behind milk production, hence the cow loses weight (negative energy balance).
- Excessive weight loss should be avoided through formulation of appropriate rations.
- The roughage: concentrate ratio of the diet should be 40:60, at 19% Protein content, and fed preferably three equal proportions of 13 kg each as in Table 2.9a below.

Table 2.9a An example of a total mixed ration (TMR) formulation based a standard cow whose live weight (LW) = 500kg, milk yield (MY) = 25l/day, butterfat =3.6% at 1st calving.

Ingredients	Amount (kg)
Napier fresh (18% DM)	20
Rhodes hay	5
Cotton seed meal	2
Maize germ	2.5
Pollard	2.5
Molasses	1
Urea	0.15
Mineral lick	0.1
High-yield dairy meal	5
Total fresh weight	38.25
Total DM	18.65

- Always provide the cow with as much of good quality forage as possible e.g. young, dark green Napier. With good quality forage alone, it is possible to produce 7–10 litres of milk per day.
- Where protein rich forages (legumes) are available e.g. Lucerne, Desmodium, Calliandra and Lucaena shrubs, mix with the grass at a ratio of 1 part legume to 3 parts grass.
- Three kg of the legume crop can replace one kg commercial dairy meal.

Phase 2: Peak DMI: 70–140 days (declining milk production):

- This stage is critical in the determination of total lactation yield. Feed intake is optimal; with sufficient nutrient supply, the cow should be able to maintain weight gain, as well as peak milk production.
- The roughage proportion of the diet should be raised to 50:50, as in table 2.9b below.

Table 2.9b An example of a TMR formulation based a standard cow whose live weight (LW) =500kg, milk yield (MY) = 20 l/day, butterfat =3.6% at 1st calving.

Ingredients	Amount (kg)
Napier fresh (18% DM)	30
Rhodes hay	5
Cotton seed meal	1.5
Maize germ	2.5
Pollard	2.5
Molasses	1
Urea	0.15
Mineral lick	0.1
High-yield dairy meal	5
Total fresh weight	46.75
Total DM	20.5

- Potential problems during this period include a rapid drop, or decline, in milk production, low fat and protein test, silent heat (no observed heat), and ketosis.
- A cow in mid and late lactation should produce about five litres of milk on roughage only and concentrate should then be given according to the milk yield.
- For every 1 kg of concentrate, there should be an increase of 1–1.5 litres of milk above the 5 kg from basal feed.

Phase 3: Mid and late lactation: 140–305 days postpartum (declining milk production):

- Protein level in the ration should be maintained at 13%, comprising minimum concentrate and high quality roughage.
- The cow should have a body condition score (BCS) of above 2.8, preferable 3 (BCS is a measure of body fat deposits on a scale of 1–5 where 1 is very thin, and 5 is very obese).

Table 2.9 (c) - An example of a TMR formulation based a standard cow whose live weight (LW) =500kg, milk yield (MY) = 18 l/day, butterfat =3.6% at 1st calving.

Ingredients	Amount (kg)
Napier fresh (18%DM)	30
Rhodes hay	6
Cotton seed meal	0.5
Maize germ	1.5
Pollard	1.5
Molasses	1
Urea	0.1
Mineral lick	0.05
High-yield dairy meal	3
Total fresh weight	43.55
Total DM	17.0

Feeding the dry cow

- Two months (45 and 60 days) before the expected date of calving, the cow should be dried off. The feeding objective in this period is to ensure the cow is in good condition at the time of calving and the birth of a healthy calf.
- The feeding regime also aims at ensuring the cow produces as much milk as it is capable of during the coming lactation and prevent health problems associated with calving (e.g. milk fever) or in early lactation (e.g. ketosis).
- During the dry period, the cow requires nutrients to maintain its body, support the unborn calf and repair milk-producing cells of the udder in preparation for the coming lactation.
- During the dry period, the cow should not gain excessive amount of weight and the amount of concentrate given should be according to the condition of the animal and the quality of forage it is feeding on.
- Note that during the last two weeks of pregnancy, the cow's appetite goes down hence the amount of concentrate should be gradually increased.
- To satisfy these requirements, feeding regimes for the dry cow have also been divided into two stages as follows.

Phase 4: Onset of 60-day dry period (first 39 days):

- A good, sound dry cow program can increase milk yield during the following lactation and minimize metabolic problems at or immediately following calving.
- Forage intake should be the major source of the nutrients.
- However, inclusion of concentrates is necessary when BCS is less than 3.
- Calcium and phosphorus intake at this stage should be supplied in proportions of 60–80 and 30–40 g respectively.
- Always avoid over conditioning the cow.

Key management factors include:

- Observe body condition of dry cows and adjust energy feeding as necessary.
- Meet nutrient requirements and avoid excessive feeding.
- Change to a transition ration starting 3 weeks before calving.

Phase 5: The dry period (the last 21 days) transitional phase:

- Forage intake is limited because of the large volume occupied by the calf. The cows' appetite goes down. The amount of concentrate provided should be increased gradually so that by the time of calving, the cow will be getting at least 4 kg per day.
- The increase in concentrate feeding just before calving is referred to steaming up.
- This dry-cow feeding program is critical to adjusting cows, and due in-calf heifers, to the lactation ration to prevent metabolic disorders.
- Introduction of concentrate is necessary to begin changing the rumen from an all-forage digestion to a mixed forage and concentrate environment.

Some suggested management strategies during this period include:

- Provide 3–5 kg of concentrate to adapt rumen environment to fermentable carbohydrates and stimulate normal rumen function.
- Increase protein in the ration to between 14 and 15% on DM basis.

Table 2.10. An example of a steaming-up schedule.

Stage (week before calving)	Amount of dairy concentrate in diet (kg per day)
6th week	0.5
5th week	1.0
4th week	1.5
3rd week before calving	2.0
2nd week before calving	2.5
One week before calving	3.0–4.0

Chapter Three

Pasture and forage agronomy

a Pasture and crop choices

b Forage and crop cultivation

c Fertility and fertilizer

d Complex systems

e Preservation: Silage making–sweet potato vines

f Urea mineral molasses blocks

a. Pasture and forage agronomy

The cost of feeding dairy animals

In the previous chapters, we discussed how dairy cows need to consume large amounts of nutritious feed in order to produce high yields of high-quality milk.

Unfortunately, providing nutritious feed for dairy cows can be very expensive. Livestock feed is the second-highest cost for most dairy farmers, after the cost of purchasing cattle.

High feed costs make it difficult for dairy farmers to earn a profit from selling milk. To earn a livelihood, farmers must sell enough milk at a high enough price to pay for their cattle, feed and other expenses and still have extra money to keep for themselves. The more money a farmer spends on feed, the more money they need to receive from milk sales in order to earn the same income.

To increase their income, farmers must do one or more of the following:

- sell more milk,
- obtain a higher price per litre of milk (usually by producing higher-quality milk), or,
- reduce their costs for cattle, feed and other expenses.

Different farmers approach this challenge in different ways.

"Maximum production" approach
Some farmers focus on producing as much high-quality milk as possible, and buy large amounts of feed and concentrates at market to help their cows receive as much nutrition as possible. This strategy can be effective if the price of milk is high enough to pay for the extra costs. However, if the price of milk is too low, the farmer might not be able to earn enough money to pay for their expenses.

"Least cost" approach
Other farmers take a "least-cost" approach and let their cows feed on naturally occurring pasture, weeds, cereal crop residues or anything else that is available for free. While this approach costs less than buying feed at the market, naturally occurring pasture is not always plentiful and usually not very nutritious. Still, if a farmer can keep their costs low enough, they will not need to sell much milk to pay their expenses and earn a profit.

"Finding a profitable balance" approach
Most farmers try to find a balance between increasing milk production and reducing costs, and might change their approach from year to year. Even so, when a farmer is forced to choose between higher yields and lower costs, most will favour one approach over the other.

Pasture and crop choices

One cost-effective approach for feeding dairy cattle is cultivating forage crops on your farm. Farmers who cultivate their own forages can supply dairy cattle with nutritious feed for much less than it would cost to buy the same quality feed at market. For many farmers, cultivating forages is the best way to reduce costs, improve yields and increase profits.

Forages fall into two categories:

- Bulk forages include grass, hay and straw. Bulk feeds provide most of the energy that an animal needs and usually make up 30–70% of an animal's diet.

  While bulk forages are a good source of energy, most bulk forages contain only low or medium levels of protein. Bulk forages should be combined with other types of feed and supplements to make sure that animals get enough nutrition to stay healthy.
- Supplementary forages contain greater amounts of protein and other nutrients per kilogram compared to bulk forages. Farmers usually give small amounts of supplementary forages to animals that require extra nutrition, such as lactating and pregnant cows.

To make sure that dairy cattle receive sufficient nutrition, farmers need to cultivate a combination of bulk and supplementary forages.

Recommended forages

Table 3.1 lists several types of bulk and supplementary forages that are known to help dairy cattle produce large amounts of high-quality milk. In the sections that follow we will review the advantages and disadvantages of each type of forage, to help you determine which forages are most suitable to cultivate on your farm.

Table 3.1 Recommended forages.

Bulk forages	Supplementary forages
Brachiaria	Calliandra
Bush rye	Desmodium
Cenchrus ciliaris	Lablab purpureus
Love grass	Lucaena
Napier grass	Lucerne
Oats	Sweet potato (dual-purpose)
Rhodes grass	
Rye grass	

Choosing forages to cultivate

When selecting forages to cultivate, there are many factors to consider, including:

- Climate.
  - Altitude.
  - Rainfall.
- Type of soil.
- Diseases and pests.
- Drought resistance.

Climate

Different fodder crops grow better in different climates. To receive the full benefit of cultivating their own forage, farmers need to select crops that are suitable for their local rainfall levels, temperatures and elevation.

Table 3.2 The following table lists the best climate zones for cultivating each of the recommended forages.

Climate zone	Grasses	Legumes
Semi-arid Semi-arid land typically has an elevation of 1000–1800 m and receives less than 65 cm of rainfall each year.	Bush rye Cenchrus ciliaris Love grass	Lablab purpureus
Warm, wet, medium altitude This includes areas with an elevation of 1200–1850 m that receive 1000–2500 mm of rainfall each year.	Oats Rhodes grass	Calliandra Desmodium Leucaena
Cool, wet, medium altitude This would include areas with an elevation of 1850–2400 m that receive 1000–2500 mm of rainfall each year.	Napier grass Oats Rhodes grass Brachiaria Sweet potato (dual-purpose)	Desmodium Lucerne
Cold, wet, high altitude This would include areas with an elevation of 2400–3000 m that receive 1000–2500 mm of rainfall each year.	Oats Rye grass	Lucerne

Soil

Most forage crops grow better in certain types of soil than others. When deciding which crops to grow, farmers should consider the following qualities of the soil on the farm:

- Fertility: Certain crops require more nutrients in the soil than others. Soil fertility can be improved through the application of mineral fertilizer, and compost or manure.
- Acidity: Soil can be acidic, neutral or alkaline. Most crops grow well in neutral soils, but many crops do poorly in highly acidic or alkaline soils. This can also be managed in some cases through application of manure.
- Salinity: Salt can enter soil through rain, ocean winds or other sources. Some species are better able to tolerate salinity than others.
- Texture: Different crops favour different mixtures of sand, silt and/or loam.
- Depth: Some crops require deeper soils to support their root systems than others.
- Drainage: Some crops require that an area be well-drained, and will not thrive if soils becomes water-logged.

Table 3.3 Describes how well different forages grow in different types of soil.

Forage	Soil recommendations
Brachiaria	Brachiaria grows in poor, rocky, and acidic soils.
Bush rye	Prefers loose sandy loams, but will grow on silty and rocky soils.
Calliandra	Grows in a wide range of soils, including acid soils, but need moderate fertility. It does not tolerate water logging.
Cenchrus ciliaris	Grows best in lighter textured soils with high phosphorus, but also thrives on clay loams. Prefers neutral soil but tolerates slight acidity. Does not grow well in soil with significant aluminium content.
Desmodium	Adapted to a wide range of soils from sands to clay loams and tolerates slight acidity but not salinity. Acidic soils can be improved by applying manure at the rate of 8 tonnes per hectare prior to sowing or planting.
Lablab purpureus	Grows in any lowland soil texture with good drainage and low salinity.
Love grass	Grows in sandy and stony soils in disturbed places or drainage areas. Also grows in loam and sometimes clay soil. It has a high tolerance to salinity and alkalinity.
Lucaena	Grows best on deep, well drained clay soils and does not do well in acid soils.
Lucerne	Adapted to a wide range of soil conditions but prefers deep, well drained, highly fertile loamy soils. It does not tolerate water logged or acid soils and occasional liming of the soil is required.
Napier grass	Can grow in almost any soil but does best in deep, fertile, well drained soils.
Oats	Oats are well adapted to poor soils. They grow in most any soil with good drainage.
Rhodes grass	Rhodes grass grows in a wide range of soil conditions but performs best in loamy, fertile soils. It does not do well in alkaline or very acid soils.
Rye grass	Rye grass grows in rich, well-drained soils of any texture, but prefers loams and clay. Dry and wet soils are not suitable.
Sweet potato (dual-purpose)	Grows best in lightly acidic, deep, fertile loams that have been well drained.

Diseases and pests

Certain forages are vulnerable to diseases and pests. Whether or not a particular disease or pest is a problem might vary from one area to another. For some diseases and pests, there are things that farmers can do to help reduce the risk to their crops.

Table 3.4 Pests and diseases of selected fodder species.

Forage	Diseases and pests	Management options
Brachiaria	Naturally resistant to most pests and diseases except for spittlebugs.	
Bush rye	No pests or diseases of importance.	
Calliandra	Calliandra trees are vulnerable to scales (white powdery insects that attack mature trees on the stems), black ants and termites. Crickets and hoppers will mainly attack young seedlings in the nursery and immediately after transplanting. Armillaria mellea is a fungus that kills plants by attacking the roots.	Scales can be controlled by sprinkling washing detergent (e.g. "Omo") solution. Black ant and termite nests must be dug out and destroyed before they damage the tree. A tobacco and garlic mixture can be used to repel insects (chemical insecticides are not appropriate for trees used to feed livestock). To prevent Armillaria mellea, avoid planting Calliandra in areas which have been recently cleared of trees. Quickly uproot and burn any affected plants and do not replant in affected areas in some years
Cenchrus ciliaris	No diseases or pests of importance	
Desmodium	Common pests are aphids and the Amnemus weevil. If aphids are not controlled, they may transmit a viral disease known as little-leaf. A fungal disease, anthracnose, can affect Desmodium especially in poorly drained soil.	Aphids and weevils can be controlled by use of insecticides (be careful to strictly observe use and safety instructions on the pack). Anthracnose can be avoided by properly draining soil.
Lablab purpureus	The psyllid insect (Heteropsylla cubenseis) is the most important pest and it can wipe out the entire crop, especially of the species L. leucocephala. Damping-off is an important fungal disease affecting seedlings in the nursery.	Psyllids can be controlled by planting resistant species such as L. diversifolia or by introducing beetles and parasitic wasps. Damping-off can be controlled by avoiding excess watering and using free-draining soil.
Love grass	No diseases or pests of importance.	
Lucerne	The psyllid insect (Heteropsylla cubenseis) is the most important pest and it can wipe out the entire crop, especially of the species L. leucocephala. Damping-off is an important fungal disease affecting seedlings in the nursery.	Psyllids can be controlled by planting resistant species such as L. diversifolia or by introducing beetles and parasitic wasps. Damping-off can be controlled by avoiding excess watering and using free-draining soil.
Lucerne	Susceptible to numerous pests and diseases which can cause damage at any stage of growth. Some important pests include Lucerne weevil, caterpillars, cutworms/army worms, aphids and leafhoppers. Some important diseases are bacterial leaf spot, common leaf spot, downy mildew, stem blight andmany others.	Pests can be controlled by natural predators or chemical insecticides. Both disease and pests can be avoided by maintaining a healthy stand, crop rotation and planting resistant varieties.
Napier grass	Napier is relatively free of pests and diseases but it is susceptible to Napier headsmut in some regions.	Control by removing and avoiding infected material and planting resistant varieties, such as Kakamega 1.
Oats	Oats are prone to Yellow Dwarf Virus or Redleaf, Leaf or Crown Rust, Septoria Leaf Spot, Stem Rust, Halo Blight, Loose Smut and Covered Smut.	Seed may require to be dressed depending on local disease patterns.
Rhodes grass	No diseases of importance but common pests such as army worms may attack the pastures.	
Rye grass	Rye grass is vulnerable to insects, fungi, rusts and molds.	
Sweet potato (dual-purpose)	Has numerous pests including stemborers, weevils, worms and butterflies. Vulnerable to various forms of stem and root rot.	Avoid planting infested material, quickly remove infested plants. If you encounter problems with pests and disease, plant early and harvest quickly to reduce exposure. Frequently earth up around the plant to avoid pests that feed on the root. Most pests that feed on the leaves do not require control, though careful application of pesticides and hand-picking can be used when necessary.

Drought resistance

Periods of drought can be a problem for dairy farmers.

While no crop can grow without water, some crops are better able to survive in periods of drought than others. Farmers in areas where drought is common should consider planting forages that are known for their drought resistance or at least avoid forages that are especially vulnerable to drought.

Table 3.5 Drought resistance forage.

Forages that are resistant to drought	Forages that are vulnerable to drought
Brachiaria	Calliandra
Lablab purpureus	Desmodium
Love grass	Rye grass
Lucaena	
Napier grass	
Rhodes grass	

Comparison of forage crops

The following pages contain additional information on the recommended types of bulk and supplementary forages, including the major advantages and disadvantages and special characteristics of each type of forage.

Bulk forages

Table 3.6 Brachiaria ssp.

Scientific name	Ulochloa spp
Common varieties	Piata, Toledo, Mulato II, Cayman, Cobra
What is it?	A perennial grass that grows up to 120 cm high, with stout culms and broad leaves. Brachiaria is excellent for heavy grazing, haymaking and silage. and grows in a wide variety of soils. It resists acidity and low temperatures.
Advantages	Grows in a wide variety of soils Tolerates acidity Resists low temperatures, frosts and shade Highly palatable Grows well without fertilizer
Disadvantages	Toxic to some sheep Does not tolerate flooding

Table 3.7 Bush rye.

Scientific name	Enteropogon macrostachyus
Also known as	Mopane grass
Common varieties	
What is it?	A tufted annual or perennial grass that grows about 90 cm high. Bush rye has scattered leads with tufts of fine white hairs. It resists drought and can grow in poor, rocky soils.
Advantages	Highly palatable Drought resistant Grows in rocky soils Good reseeding Prevents soil erosion
Disadvantages	Can be damaged by overgrazing

Table 3.8 Love grass.

Scientific name	Eragrostis superba
Common varieties	
What is it?	A perennial, densely tufted grass that grows up to 1 m tall. Love grass is an excellent forage to cultivate in areas prone to drought. It is good for grazing and haymaking.
Advantages	Fair palatability Resists drought Recovers easily from intense grazing Good for haymaking Prevents soil erosion
Disadvantages	Nutritional value and palatability decline as it reaches maturity

Table 3.9 Napier grass.

Scientific name	Pennisetum purpureum
Also known as	Elephant grass
Common varieties	French Cameroon, Bana grass, Kakamega 1
What is it?	A fast-growing, deeply rooted, perennial grass that can grow up to 4 m tall. Napier grass spreads by underground stems to form thick ground cover. Napier grass is a very important fodder crop for dairy production in Kenya and elsewhere.
Advantages	High yield Good palatability Good nutrient content when young (dark green, less than 1 m tall) Easy to establish and persistent Resists drought Very good for silage making Prevents soil erosion Can serve as a wind-break Can be intercropped with forage legumes such as Desmodium
Disadvantages	Not suitable for grazing Vulnerable to diseases, especially in certain geographic areas (some varieties are more prone to disease than others) Takes a lot of nutrients from the soil Requires a lot of manure/fertilizer to get high yields Vulnerable to frost at high altitude (over 2 m)

Table 3.10 Oats.

Scientific name	Avena sativa
Common varieties	Conway, Glamis
What is it?	Oat forage is mainly used for livestock feeding. It may be grazed, cut-and-carried, made into hay, silage or balage. Oats are widely grown in temperate areas and are recommended as a fodder crop for high-altitude regions. Oats grow well at an elevation of 1600 m and above, but do best above 2000 and flourish at 2800 m in areas that receive 1000–2500 mm of rainfall per year.
Advantages	Can sometimes provide fodder as early as 1 month after sowing Protects soil from erosion Can usually recycle seeds Traps nitrogen
Disadvantages	Loses nutritional value when preserved

Table 3.11 Rhodes grass.

Scientific name	Chloris gayna or Eustachys paspaloides
Common varieties	Giant, Boma, Mbarara, Masaba Rhodes.
What is it?	A perennial grass with a strong root system, Rhodes grass can grow under a wide range of conditions. It is especially good for resisting drought. Rhodes grass spreads quickly forming good ground cover and grows up to 1.5 m tall. It is useful for cut-and-carry, open grazing and hay making.
Advantages	Grows well in areas with low rainfall Resistant to drought Good for grazing Very palatable Good for hay making
Disadvantages	Takes a lot of nutrients from the soil Vulnerable to frost

Table 3.12 Rye grass.

Scientific name	Lolium perrene
Common varieties	AberNiche, AberWolf, AberBite
What is it?	A perennial grass found mainly in high-altitude, rainy climates. Rye grass grows in a variety of soil textures regenerates very quickly in suitable conditions, but is vulnerable to both flooding and drought as well as high or low temperatures.
Advantages	Grows in a wide variety of soil textures
Disadvantages	Does not tolerate dry or wet soil Sensitive to strong heat and shade

Supplementary forages

Table 3.13 Calliandra.

Scientific name	Calliandra calothyrsus
What is it?	A small leguminous tree growing up to 12 m tall with a dense canopy and pink flowers. Calliandra is evergreen in humid areas, but loses its leaves during prolonged dry periods. It may die back in severe droughts but will recover with the rains. It responds well to coppicing (harvesting the branches from near to the ground). The leaves and young stems are used as protein supplement in cut-and-carry systems. Calliandra can be used for fuelwood, erosion control, smothering weeds and as green manure in rotation with arable crops.
Advantages	Grows well on acid soils where Leucaena does not thrive Resists psyllid insects that damage Leucaena
Disadvantages	Lower forage production and nutrition than Leucaena Low digestibility Limited seed production Suppresses yields of food crops if not cut back

Table 3.14 Desmodium.

Scientific name	Desmodium intortum or Desmodium uncinatum
Common varieties	Green leaf, Silver leaf
What is it?	A trailing or climbing perennial legume with small leaves and deep roots. In favourable conditions, Desmodium forms very dense ground cover. There are numerous varieties but the two most common are the green leafed and the silver leafed ones. Green leaf Desmodium is leafier with reddish brown to purplish spots on the upper surface of the leaves and reddish brown stems. Silver leaf Desmodium has stems and leaves covered in dense hairs which make them stick to hands and clothing. It has green and white leaves which are light green underneath. Desmodium is popular in cut-and-carry systems. They can be cut and fed in green form or cut and conserved as hay, whole or chopped.
Advantages	High quality, protein rich forage Can be grown between or under other crops Has the ability to increase yields of other crops and reduce the need for nitrogen fertilizer. Controls soil erosion Controls striga Reduces damage to maize from stemborers
Disadvantages	Needs rhizobium inoculant Vulnerable to pests and diseases in very high rainfall areas (more than 1500 mm per year) Vulnerable to drought (Greenleaf) Does not grow well in alkaline soil

Table 3.15 Lablab purpureus.

Scientific name	Lablab purpureus
Common varieties	Lab Lab
What is it?	A short-lived perennial or annual legume. Lablab purpureus is cultivated as food, green manure, cover crop and animal fodder.
Advantages	Provides excellent late-season grazing Tolerant to seasonal drought Compatible with forage sorghum or maize when intercropped Gives high yield of materials for conservation Resistant to diseases such as phytophthora rust and Stem rot Resistant to attack by insects like the bean fly if seeds are treated
Disadvantages	Short life Low palatability of stems Requires warm weather Susceptable to frost

Table 3.16 Leucaena.

Scientific name	Leucaena leucocephala
What is it?	Leucaena are perennial, large shrub/small tree legumes. They are deep-rooted and grow up to 20 m tall. The leaves have many thin leaflets, white flowers and produce a lot of seeds in pods. The leaves are a very good source of protein and can be used in both cut-and-carry and for grazing. The leaves will re-grow after cutting. Leucaena can be used as shade in plantation crops and living support for climbing crops (such as passion fruit). It can also be used for soil conservation and to maintain soil fertility. The mature shrub can be cut for poles for fencing and wood fuel and as bee forage.
Advantages	Resists drought Very nutritious Highly digestible and palatable
Disadvantages	Can be poisonous in large amounts due to high mimosine content Toxic to pigs and poultry Can become a weed due to its very high seed production

Table 3.17 Lucerne.

Scientific name	Medicago sativa
Also known as	Alfalfa
Common varieties	cuf 101, Hunter river, Hairy Peruvian, sa standard, KKs9595, Wl625HQ, Wl414, Wl625HQ, KKs3864, Wl625HQ
What is it?	Lucerne is a deep rooted, perennial herbaceous legume that produces a lot of stems and leaves. On maturity, Lucerne produces small purple flowers. It is established from seed. It is used as a supplementary forage for dairy cattle as well as feed for horses, beef cattle, sheep and milking goats. It is high in nutrients and very palatable. Lucerne does very well compared to other forage legumes in high-rainfall areas of East Africa. It can sustain high milk production levels when fed to dairy cattle. Hunter river and cuf 101 are suited to lower altitudes. Lucerne is used primarily as hay, but it can also be used in cut-and-carry systems and even as year round pasture. It is usually grown alone but can also be mixed with grasses or other legumes.
Advantages	Highly palatable High nutrient content High yield under irrigation
Disadvantages	Needs a lot of water and usually requires irrigation Does not tolerate water logged or acid soils Risk of bloat if animals eat too much

Table 3.18 Sweet potato (dual-purpose).

Scientific name	Ipomoea batatas
Common varieties	Local: Kiganda, Muibai, Sandak, Mugande Improved: Kemb 23, Kemb 36, Musinyamu
What is it?	Sweet potatoes plants can be used as livestock feed and also for human consumption. While humans can eat the roots, sweet potato vines provide can livestock with high nutrient content and are normally fed to cattle as a supplement. They increase milk yield when fed to lactating cows and increase the growth rate of calves. Sweet potatoes are also good for recently calved and sick animals.
Advantages	Highly nutritious Some varieties may be grown for food and fodder Surplus fodder can be sold for cash
Disadvantages	High moisture content

b. Forage and crop cultivation

Cultivating fodder crops

Cultivating forages on your farm can provide inexpensive, high-quality feed for your animals. In the previous lesson, we reviewed different types of forages and the various things to consider when deciding which type of forage is best to grow on your farm. In this lesson, we will describe the proper cultivation techniques for each type of forage.

Bulk forages

Brachiaria (Signal grass)

Climate and Soil Conditions: Brachiaria grows in areas with an elevation of 1850–2400 m that receive 1000–2500 mm of rainfall each year. Brachiaria grows in a wide range of soils and can tolerate acidic conditions. It grows well into the winter, staying green when other tropical grasses are brown and dry.

Site Selection: Brachiaria may be grown in shaded and drier areas than other grasses such as underneath trees. It may also be planted for erosion control.

Ground Preparation: Brachiaria will establish in rough seedbeds, but a well-prepared seedbed is preferable. Brachiaria may grow over rocky and poor soils as well. Lightly till the seedbed.

Sowing/Planting: Brachiaria spreads naturally from seed. It may also be laid in sods, or planted with root pieces and stems. Sow seeds no deeper than 1 cm and roll after sowing. Plant seeds during the wet season at 2-5 kg/ha. Only dry seeds should be used. Sulphuric acid may be used to aid in seed germination.

Fertilizer: Brachiaria performs well without fertilizer if lightly grazed. Nitrogen fertilizer can help Brachiaria thrive even if grazed heavily. If planted with legumes, phosphorus must be added so that the grass does not overtake the plot.

Weeding: Brachiaria is naturally weed-resistant. If weeds are a problem, apply atrazine at 2.5 kg of 80% product per hectare when first establishing the grass.

Management

Harvesting and Preservation: Brachiaria is not commonly used for harvested forage, but can make good silage and hay. If kept in a tube silo, Brachiaria benefits from the use of silage additives to aid in fermentation

Grazing: Brachiaria spreads rapidly under frequent grazing. Graze in 28–42-day rotations for best results.

Pests and diseases: Brachiaria is susceptible to spittlebugs, but is otherwise pest and disease-resistant.

Cenchrus ciliaris (Buffel grass)

Ground Preparation: Soil disturbance is generally essential for initial establishment. A rough seedbed can be prepared by ploughing.

Sowing/planting: Cenchrus ciliaris is surface-sown and lightly harrowed or rolled where possible. It is best sown just ahead of the expected rainy season at 0.5–4 kg/ha, according to seed supplies, costs, and expected rate of full ground cover.

Napier grass

Climate and Soil Conditions: Napier grass can be grown at altitudes from sea level to 2000 m. At higher altitudes, it regenerates slowly and is vulnerable to frost. It does best in areas with high rainfall (over 1500 mm) but can survive droughts due to its deep root system. Napier grass can grow in almost any soil but does best in deep, fertile, well-drained soils.

Site Selection: Napier grass grows best as a pure stand or as an alley crop, intercropped with a forage legume. In a cut-and-carry system, the plot should be located as close to the zero-grazing unit as possible, to save labour. Napier grass may also be planted in strips to prevent soil erosion along contours, river banks and steep slopes.

Ground Preparation: Prepare your planting site by ploughing or digging. Make sure the site is weed-free at the time of planting. If farmyard manure is available, it can be worked into the soil at this time.

Sowing/Planting: The best time to plant Napier grass is at the beginning of the long rainy season. Wait for two heavy downpours before planting.

Either canes or splits can be used for planting.

- Canes require less labour and planting material. If using canes, select mature Napier grass and cut a length with three to four nodes using buds from the middle part of the cane. Plant canes at an angle of at least 45^0.
- For splits, cut off the Napier plant at 10–15 cm above the soil. Uproot and divide the plant into small parts. Each part should have some roots covered with soil.

Allow a half meter between plants and a half meter between rows in high-rainfall areas, and a half meter between plants and 1 meter between rows in low rainfall areas.

The Tumbukiza Method: There is an alternative method for planting Napier grass known as the "tumbukiza" method. When using this method, several splits or canes are planted in big round or rectangular pits.

- For round pits, dig pits 60 cm in diameter, 60 cm deep and 60 cm apart.
- For rectangular pits, dig 60 cm deep by 60–90 cm wide.

The length of the pits can vary depending on available land. The pits should be 90 cm apart. Separate top soil from sub-soil. Mix about 20 kg of top-soil with about 40 kg of manure and put the mixture into each round pit or 90 cm of a rectangular pit. Plant 5–10 cane cuttings or splits in every round pit or for every 90 cm of length of the rectangular pit. Cover and leave about 15 cm unfilled space at the top of each pit.

Fertilizer: Apply 1 teaspoon of compound fertilizer (NPK: 20-20-0) per hole at planting time.

After establishment, we recommend the following:

- Return as much of the cows' manure as possible back to the Napier grass.
- If you practice zero grazing, collect slurry and apply it in a furrow between the Napier grass rows after each cutting.
- If applying dry manure, work it into the soil.
- During heavy rains, apply 4 teaspoons of NPK (20-10-10 or 20-20-0) fertilizer per plant.
- After cutting, top dress with 1 teaspoon of CAN per plant.

Weeding: Keep the plot weed-free, especially after initial planting. Once established, Napier grass is able to suppress most weeds other than very stubborn ones like Couch grass. Weed after every cutting and avoid heaping soil around the plants.

Management

Harvesting: Harvest Napier grass about 3–4 months after planting. After that, the exact cutting interval will vary depending on rainfall, but generally, you should harvest when the grass is about one meter high and definitely do not allow it to grow beyond 1.5 m.

Cut the plant to about 5 cm from the ground during the rainy season and 10–15 cm during the dry season. With good climate, soil fertility, and management, yields can be over 25 t of dry matter per hectare per year. Yields of about half this amount can be achieved with little or no fertilizer.

Grazing: Do not let your animals graze on Napier grass directly. Instead, chop the material into pieces about 5 cm long after harvesting and feed to animals in a stall.

Preservation: Excess Napier grass can be made into good quality silage using most any type of silo (trench, pit, tower, tube). If it is not possible to make silage, leave a portion of the plot standing and continue to harvest the rest at the optimum height.

When necessary, use the tops of overgrown Napier grass to feed cattle. The old canes can also be used as mulch or they can be made into compost.

Pests and diseases: In most areas Napier grass has very few problems with pests and diseases. However, there are some regions where it is susceptible to Napier Stunt Disease (NSD) and headsmut.

Headsmut: Symptoms of headsmut include thinner, shorter stems, fewer leaves and misshapen leaves. Farmers can protect Napier grass crops against headsmut by removing infected material and planting resistant varieties such as Kakamega 1.

Napier Stunt Disease: Napier Stunt Disease is spread by leafhoppers after feeding on an infected plants. Symptoms include stunting and yellowing as the grass re-grows after being cut or grazed. Often the whole stool will die. While there has been some success with resistant varieties such as South Africa and Ouma 2, farmers and scientists are still working to find an effective management solution for NSD.

Oats

Climate and Soil Conditions: Oats grow well at an elevation of 1600 m and above, but do best above 2000 and flourish at 2800 m in areas that receive 1000–2500 mm of rainfall per year. Common varieties of oats grow well in most climates and can be grown in most soils with good drainage. Certain varieties of oats are adapted to warmer conditions. Other varieties of oats such as the bristle-pointed oat are well adapted to poor soils and low summer temperatures and grow well in mountainous places.

Site Selection: Oats may be grown pure or in mixture with vetch or peas.

Ground Preparation: Oats grow best in a clean, well-prepared seedbed.

Planting: Seed is drilled to 4 cm deep. If drilling machinery is unavailable it may be broadcast, but establishment will be poorer. Sow at 60 kg of seed per hectare. Oats are often mixed with vetches, and sometimes peas. In these cases, reduce the seed rate by half.

Time of sowing varies according to climate. In areas with very cold winters, they should be sown in spring. In temperate climates, oats can be sown in both autumn and spring. In high altitudes, they should be sown at the onset of the rainy season.

Fertilizer: A top-dressing of nitrogen fertilizer should be applied. Apply 2–3 bags TSP fertilizer per hectare at planting. After harvesting, topdress with 3 bags of CAN/ha to enhance growth and fodder yield.

Weeding: Weeds should be controlled if serious. Hand weed or spray with herbicide 2,4-D amine 72% at the rate of 2.5 liters per hectare. Do not spray if the oats are planted in a vetch.

Management

Harvesting: Oats can be harvested by mowing or by scythe or sickle. Cut at milk stage (4 weeks) leaving a stubble height of 5 cm from ground level.

Grazing: Oats are usually mown but can be grazed. At high altitudes with well-distributed rainfall, oats provide many months of grazing if carefully managed. If oats are lightly grazed, a second grazing will be possible. For the final grazing, allow animals to remove the whole crop.

Preservation: Oats are an excellent crop for both hay and silage.

Pests and diseases: Diseases to which oats are prone include: Yellow Dwarf Virus or Redleaf, Leaf or Crown Rust, Septoria Leaf Spot, Stem Rust, Halo Blight, Loose Smut, Covered Smut.

Rhodes grass

Climate and Soil Conditions: Rhodes grass grows well at altitudes up to 2000 m above sea level, in areas that receive more than 450 mm of rain per year. It can also survive in drought conditions.

Rhodes grass grows in a wide range of soil conditions but grows best in loamy, fertile soils. It does not grow well in alkaline or very acid soils.

Site Selection: It is usually best to grow Rhodes grass in grazed plots, which can be temporarily used for hay making.

Ground Preparation: Plough and harrow the plot at least once to make a fine seedbed. Harrow again whenever weeds emerge to reduce competition.

Sowing/Planting: Rhodes grass is usually established from seed but can also be grown from root splits.

The best time to sow is during the short rainy season (or, in regions with one rainy season, between early and mid-rains). Sow Rhodes grass seeds immediately after harrowing, when the soil is loose (dry).

Make furrows 25 cm apart using a peg. Drill the seeds in the furrows, at a rate of 12 kg per hectare. Cover the seeds with light tree branches or something similar.

Fertilizer: Apply 100 kg of nitrogen fertilizer per hectare during heavy rains.

Weeding: Make sure the plot is weed-free during the initial period of establishment. Remove weeds between the rows using a hand hoe.

Management

Harvesting: Start harvesting or grazing soon after flowering. If cutting, cut close to the ground to stimulate spreading. Leave to re-grow again until next flowering. Feeding value declines dramatically after seed-set. When well-managed, Rhodes grass can yield an average of 8 tons of dry matter per hectare per year.

Grazing: Grazing is the most common method of feeding Rhodes grass although some farmers use it for cut-and-carry. It will not persist on over-grazed pasture due to its high palatability.

Pests and diseases: Rhodes grass rarely suffers from disease.

Preservation: Rhodes grass is very good for haymaking.

Rye grass

Climate and Soil Conditions: Rye grass is suited to sunny areas with an elevation of 2400–3000 m that receive 1000–2500 mm of annual rainfall. Rye grass does poorly in areas with hard frost, high temperatures, drought, or winter flooding.

Rye grass may grow on a variety of soil textures. Loams and clays are the most suitable. Sandy soil may also be suitable if close to water. The soil must be nutrient-rich, slightly acidic to neutral and normally drained. Rye grass does not grow well in very dry or very wet soils.

Site Selection: Rye grass can grow on its own or mixed with legumes, grasses or clovers.

Sowing/Planting: Broadcast at 3.5–5 kg/ha for highly fertile fields or 5–6 kg/ha for fields with low to medium fertility, Lightly harrow the soil afterward to ensure good soil contact. Overseeding will require less seed – generally 2.5 kg/ha.

Management

Grazing: Rye grass may be grazed throughout the growing season. Leaf turn-over is very fast and Rye grass grows well in frequently grazed covers. During the first year, Rye grass should not be harvested or grazed until the plants are at least 60–75 cm tall. Animals should be removed from pastures when the Rye grass stubble is from 4–5 cm in height. Established Rye grass pastures can be initially grazed when spring growth reaches 5–7.5 cm height and the grazing does not cause excessive pasture damage due to wet soil conditions. Established Rye grass may be continuously grazed, but yield and plant persistence are compromised if it is continually grazed below 4 cm in height. Greater yields are possible when Rye grass is rotationally grazed. Allowing 20–60 cm of regrowth between grazings will benefit grass yield as well as persistence.

Supplementary forages

Calliandra

Climate and Soil Conditions: Calliandra grows well in warm climates with altitudes up to 1500 m and an average rainfall of 700–4000 mm per year. It can grow in any moderately fertile, well-drained soil, including acidic soil. It does not grow well in water-logged soil.

Site Selection: Calliandra grows well as a pure stand, hedgerows or live fences. Up to 40,000 Calliandra trees can be planted per hectare. They can be grown within a Napier grass plot or planted along borders to prevent soil erosion. Calliandra can also be planted as an alley crop.

Ground Preparation: Calliandra can be established through seeding or by transplanting plants form a nursery.

- For direct sowing, plough the land and harrow to prepare a fine seedbed.
- If seeds are to be sowed in a nursery, prepare a seedbed about 1 m wide and 3 m long for 400 seedlings. Raise the seedbed by piling the soil to a height of about 10–15 cm and then level the top. Paths of 0.6 m should be left if additional nursery beds are to be prepared. Support the sides with materials like banana stems, timber, or stones.
- In areas with two rainy seasons, you should prepare the nursery during the short rains so that the seedlings will be ready for transplanting during the long rains.

Planting: The best time to sow Calliandra seeds or transplant seedlings is just after the onset of heavy rains. Germination can be improved by briefly immersing seeds in boiling water, then soaking the seeds for another 24 hours It is strongly recommended to inoculate seeds. However, if you choose to inoculate your seeds, mix inoculant with water, then add soaked seed then sow immediately.

Direct Sowing: If you sow seed directly onto the plot, then make furrows 3–10 m apart and drill 1–2 kg of seed per hectare. Seeds should be placed 2–3 cm deep.

Nursery Establishment

Planting: A 1 m by 3 m seedbed requires about 40 g of seed. Apply 15 kg of manure to the seedbed and mix thoroughly with the soil. Next, make furrows around 2 cm deep and 10 cm apart. Place seeds in the furrows 5 cm apart and cover. Thoroughly water the seedbed immediately after sowing, then cover it with dry grass (unless termites are a problem).

When seedlings produce two leaves, they should be replanted into plastic tubes to improve their survival rate.

Management: Construct a shade structure 1 m above the seedbed, then cover it lightly with grass. Gradually reduce the shading as the seedlings grow.

It is important to avoid over-watering the seedlings. During the first two months you should water seedlings twice a day, in the morning and late evening. After that, reduce watering to once a day, preferably in the late evening. Keep the nursery completely free from weeds. You can sprinkle ash around the seedlings to protect them from pests.

Transplanting: In the final two weeks before transplanting, reduce the watering frequency to 2–3 times per week. Remove the shading completely to help seedlings harden, so they can better withstand field conditions. Dig holes a half meter apart in the plot, then carefully remove seedlings from the seedbed or plastic tubes and plant in the holes. Bare roots should be kept in water during transplanting, to prevent the seedling from drying up. When transplanting seedlings, apply 2 kg manure per hole and mix well with the soil.

Fertilizer: After germination apply about 2 g (one soda bottle top) of phosphate fertilizer at the base of each seedling to speed-up growth. To sustain production, apply manure or approximately 100 kg of fertilizer per hectare.

Weeding: Keep seedlings weed-free especially during the first few months after the transplant. Once fully established, the crop should be able to suppress most weeds. Though you will still need to pull the most stubborn weeds after each harvest.

Management

Grazing: It is not recommended to allow animals to graze on Calliandra.

Pests and diseases: Calliandra is vulnerable to many diseases and pests. Most of them can be controlled fairly.

Figure 3.1 A well-prepared Calliandra nursery with reinforced sides to prevent erosion and a shade made of grass.

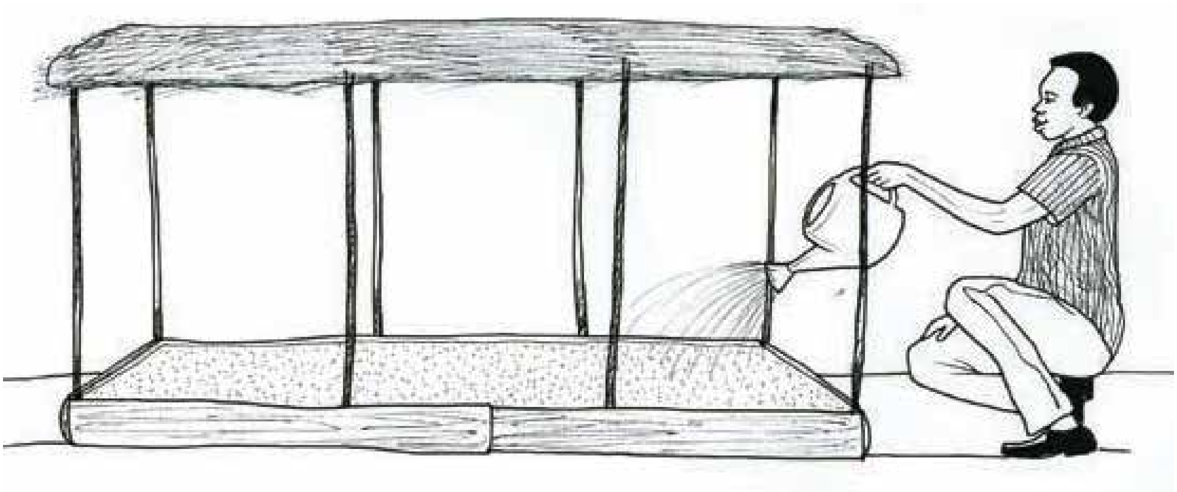


Table 3.19 Tests and diseases of Calliandra ssp

Pest/disease	Description/symptoms	How to control
Scales	White powdery insects that attack mature trees on the stems.	Sprinkle affected parts of the tree with washing detergent solution (e.g. "Omo").
Black ants	Kill trees by attacking the bark.	Dig out and destroy the ant nests. Smear wet dung, old engine oil or sprinkle ash at the base of the stem.
Termites	Seriously damage the tree by feeding on the stem.	Dig out and destroy the termite nests. Smear wet dung, old engine oil or sprinkle ash at the base of the stem.
Crickets and hoppers	Mainly attack young seedlings in the nursery and immediately after transplanting.	Use a mixture of tobacco and garlic to repel crickets and hoppers.
Armillaria mellea	A fungus that attacks the roots causing the plant to die. Common in forested areas that have been recently cleared of trees.	Do not plant Calliandra in areas which have been recently cleared of trees. Uproot affected pants and burn them. Leave affected areas fallow for several years before replanting.

Preservation: The best way to conserve excess Calliandra is leaving it uncut on the tree and harvesting it when needed. Alternatively It can be cut, air-dried and stored as leaf meal after all the leaves have fallen from the stems.

Desmodium

Climate and Soil Conditions: Desmodium does well in warm, wet climates that receive at least 875 mm of rain per year, at altitudes of 800–2500 m. It is adapted to a wide range of soils from sands to clay loams and tolerates slight acidity but not salinity.

Site Selection: Desmodium can be grown as a pure stand or mixed together with Napier grass in a cut-and-carry plot. It can also be grown as a cover crop under maize, bananas or coffee.

Ground Preparation: Desmodium seed is expensive and the seedlings are vulnerable to weeds. Ideally, you should sow Desmodium in a weed-free, well-prepared nursery seedbed with fine textured soil, raised 15cm above the ground.

Apply 500 g of phosphate fertilizer (TSP 45% P or DAP 46% P, 18% N) to a 3 m by 3 m plot before sowing and mix thoroughly with the soil. Alternatively, you can add 15kg of dried farmyard manure. If the soil on your farm is acidic, it can be improved by applying 8 tonnes of manure per hectare prior to sowing or planting.

Sowing/Planting: The best time to plant Desmodium is at the start of the rainy season. For areas with two rainy seasons, sow seeds during the short rains but plant cuttings during the long rains. A 3 m by 3 m seedbed will require about 100 g of seed.

Rhizobia inoculant

Desmodium needs a beneficial type of bacteria called Rhizobia in order to grow. These bacteria live in the roots of Desmodium and other legumes and fix nitrogen from the air, providing food for the Desmodium plants. You can add Rhizobia to Desmodium seed by purchasing an inoculant or, if an inoculant is not available, mixing the seed with a handful of soil from another well-established Desmodium plot. Add the inoculant per the instructions on the pack, then sow the seed immediately.

Sowing: Seeds can be sown by drilling or broadcasting.

- Drilling Make shallow furrows about 5 cm deep, spaced 30 cm apart. Cover the seed with 1 cm of soil and press softly.
- Broadcasting Spread the seed evenly over the seedbed.

The nursery bed should be watered carefully and often. Shade may be provided but it should be removed soon after germination.

Cuttings: Desmodium can also be established from cutting. Compared to seed, cuttings are bulky but can be obtained at little or no cost from a neighbour. They are also more resistant to weeds during the early weeks than plants grown from seeds. You can get cuttings from an established nursery or from Desmodium in the field. Cut pieces of vine 60 cm long, making sure that soil is still attached to the roots. Make furrows 30 cm apart and 10 cm deep and plant the vines 30 cm apart.

Intercropping with Napier grass: When grown together with Napier grass, Desmodium adds nitrogen to the soil, benefiting the Napier and reducing the amount of nitrogen fertilizer required for topdressing. Plant the Napier grass at a spacing of 1 m between plants and, wider than usual, with 2 m between rows. Make holes for planting Desmodium between the newly planted rows of Napier grass, spaced 30 cm apart. When growing Desmodium with Napier grass, add one handful of farmyard manure per hole at planting and mix thoroughly with the soil.

Once Desmodium has fully established, it forms a complete ground cover which smothers weeds, reducing the labour required to weed the Napier plot.

Figure 3.2 Intercropping Desmodium with Napier grass.

Weeding: Keep the plot weed-free, especially during the early stages of establishment. After it is established, Desmodium is able to suppress the growth of weeds.

Management

Harvesting: The best way to harvest Desmodium depends on whether it is being grown as a pure stand or together with Napier grass.

- Pure stand Wait at least four months before harvesting. Cut at 12-week intervals to no less than 10 cm above soil level.
- Mixed with Napier Always cut the Desmodium and Napier grass together if possible. First harvest should be at least four months after establishment or when the Napier grass is about 1 m high. Afterwards, cut at intervals of 4–10 weeks. Leave 10–15 cm stumps for both crops.

Harvest only as much as is needed for feeding and spread it in the sun for a few hours to wilt. Chop the Desmodium and mix it thoroughly with other forages, such as Napier grass, before feeding it to animals.

Grazing: Will not withstand heavy grazing

Pests and diseases: Desmodium is mainly vulnerable to aphids, weevils and a fungal disease known as anthracnose. Aphids and weevils can be controlled by use of insecticides. Carefully follow the safety instructions on the insecticide pack. If aphids are not controlled, they may transmit a viral disease known as “little leaf”. Anthracnose mainly occurs in poorly drained soil, and can be prevented by making sure that soil is thoroughly drained.

Preservation: Excess Desmodium may be cut, dried and baled into hay. Desmodium hay can be mixed with grass as a protein supplement.

Lablab purpureus

Climate and Soil Conditions: Lablab grows in warm weather from sea level up to 2000 m, but grows best at lower elevations. It thrives in areas with annual rainfall between 750 mm and 2500 mm but can survive with as little as 400 mm. Once established, it is highly drought resistant. Lablab can grow in a variety of soil textures. It grows in deep sands to heavy clays with good drainage. It will grow in neutral to acidic soil, but high salinity will reduce yields.

Site Selection: Plant lablab on land that has not been previously cultivated. It can be sown alone or in widely spaced maize or sorghum rows. Be sure to select a space with easy access due to lablab’s early and short growing season.

Ground Preparation: Lablab has a large seed and therefore does not require a fine seedbed like other legumes and grasses, but performs best when drilled into a well-prepared seedbed. Space at 45 cm between rows and 30 cm from plant to plant, placing 2 seeds per hole. Lablab can also be established by broadcasting into roughly ploughed or cultivated land if the seed is covered. In both cases, use 60 kg of seed per hectare.

Fertilizer: Lablab does not require fertilizer in already fertile soils. If needed, use 1–2 bags TSP per hectare or 5–10 t/ha of well-decomposed farmyard manure. In poor sandy soils, use 250–500 kg./ha molybdenized superphosphate and some potash if needed.

Weeding: If planted in rows, cultivate the space between rows to remove weeds early in the growing season. Hand weed if needed.

Management

Harvesting: For best results, harvest lablab at the early flowering stage, about 6 weeks (1 ½ months) after planting, leaving a stubble height of 15 cm from ground level.

Grazing: Lablab will not stand heavy grazing of stems, but can provide two or three grazings per season if animals are only allowed to eat the leaves. The plant should not be grazed below 25 cm and recovery will take four to five months before a second grazing is possible. Do not allow hungry animals to eat a diet of only lablab or bloat may occur, especially with young regrowth. If possible, include lablab as part of a mixed grass and legume diet.

Pests and diseases: For insect and disease control, treat seed with dieldrin or endrin prior to sowing to protect from bean fly. A stem rot caused by Sclerotinia sclerotiorum may attack the plant under wet conditions.

Preservation

Haymaking: Lablab laves makes excellent, but the stem is difficult to dry and must be conditioned mechanically to cure. Lablab can be bailed if it is mown, crushed (conditioned), windrowed and, when dry enough.

Silage: Lablab may be preserved alone in trench silos. Otherwise, it may make excellent silage in a mixture with sorghum. Lablab may also be mixed with maize if grown together.

Leucaena

Climate and Soil Conditions: Leucaena grows from sea level up to 1900 m but performs best under 1000 m.
It grows well in areas with rainfall above 600 mm per year. Leucaena grows best in deep, well-drained soils. It does not do well in acid soils.

Site Selection: Leucaena may be planted as single plants, single hedgerows or multiple hedgerows.
It can be grown in cut-and-carry plots or grazed plots. It can also be planted along boundaries or contours to control soil erosion.

Ground Preparation: Plough and harrow the plot thoroughly to make a fine seedbed.

Sowing/Planting: Seed Prepearation.

Prepare the seeds using one of the following methods:

- Soak seeds in in warm water for 48 hours, or
- Soak in boiling water for 4 seconds.

Sowing: Before sowing Leucaena seeds, you need to prepare a sticking agent:

- Mix 2 parts sugar with 1 part of warm water.
- Add a Rhizobia inoculant, following the instructions on the pack.

- Pour the seeds into the mixture and mix until every seed has a fine, sticky coating.
- Spread the seed to dry in cool shade for 15–30 minutes
- Plant immediately

Leucaena seeds can be sown either directly into the field or in a nursery.

Direct Sowing: For direct sowing in the final growing site, make furrows 3–10 m apart. Plant the seeds 2–3 cm deep. Seed should be sown at a rate of 1–2 kg per hectare.

Nursery Establishment: Plant Leucaena seeds in plastic tubes filled with 3 parts free-draining soil, 2 parts sand and 1 part manure. Sow two seeds per tube.

Water the tubes regularly and control weeds by hand-pulling. One week after the seedlings emerge, thin to one seedling per tube.

Transplant seedlings when they are eight weeks old. For a pure stand, prepare holes spaced 1 m by 1 m and at least 30 cm deep. For alley-cropping or grazing, allow 75 cm of space between plants and 3–10 m between rows. Remove plastic tubes and place the seedling in the holes, then cover with moist soil and firm around the seedling.

Fertilizer: At the time of transplanting, apply one tablespoon of triple super phosphate fertilizer per hole (120 kg per hectare) and mix with soil.

Weeding: Leucaena seedlings are very susceptible to weeds. Make sure the plot is weed-free, especially when the seedlings are small.

Pests and diseases: Leucaena is vulnerable to the psyllid insect and a fungal disease known as “damping-off”. The psyllid insect can wipe out an entire crop of Leucaena, especially the L. leucocephala variety. If psyllid insects are a problem in your area, then plant resistant varieties such as L. diversifolia. Damping-off is a fungal disease that affects Leucaena seedlings in the nursery. It can be controlled by avoiding excess watering and using free-draining soil.

Management

Harvesting: Start harvesting Leucaena at the beginning of the second wet season by cutting it back to 50 cm above ground level.

You can cut twice during the wet season when re-growth is 50-60 cm, or once at the end.

Grazing: Light grazing is allowed after plants reach 1.5 m in height. Avoid heavy grazing until the plants are fully mature, from 1–3 years old. Grazing intervals can be 6–8 weeks or up to 12 weeks in less favourable conditions.

Preservation

Excess Leucaena leaves can be dried and fed to animals as dry leaf meal.

Lucerne

Climate and Soil Conditions: Lucerne will grow in a wide range of climates but does best in warm climates with lots of sunshine and adequate water. It grows best in deep, well-drained, highly fertile, loamy soils. Lucerne does not tolerate water logged or acid soils.

Site Selection: Lucerne is best grown as a pure stand.

Ground Preparation: Prepare a very fine, level and firm seedbed. Occasional liming of the soil will be required. If possible, apply 100 kg of single super phosphate fertilizer per hectare before planting.

Planting/Sowing: Sow seeds at the start of the rains, either in furrows or by broadcasting.

- When sowing in furrows, prepare shallow furrows 30 cm apart then drill.

- When broadcasting, spread 5–7.5 kg of seed per hectare. Cover the seeds to a depth of approximately 0.6 cm.

The first time you grow Lucerne, you will need to inoculate the seeds with Rhizobia. Be sure to follow all of the instructions on the inoculant pack.

Fertilizer: To maintain a vigorous, productive stand, re-apply single super phosphate fertilizer each year.

Weeding: Keep the plot weed-free until full ground cover is achieved.

Pests and diseases: Lucerne is susceptible to numerous pests and diseases which can cause damage at any stage of growth. Major pests include lucerne weevil, caterpillars, cutworms/army worms, aphids and leafhoppers. Pests can be controlled by natural predators or chemical insecticides.

Diseases affecting Lucerne include bacterial leaf spot, common leaf spot, downy mildew, stem blight and many others. They can be controlled by use of chemicals, maintaining a healthy stand, crop rotation and cultivating resistant varieties.

Management

Harvesting: In general, annual yields of lucerne decline with the age of stand, the decline being faster if the crop is poorly managed, affected by extreme weather or attacked by pests and diseases. Harvest for the first time when the crop begins to flower. Cut at 5 cm above the ground every 5–7 weeks.When feeding as cut-and-carry fodder, leave the cut forage to wilt before giving to the animals to prevent bloat. You can also mix the lucerne with grass or commercial “stop bloat” supplements.

Grazing: Use a rotational grazing system, allowing 30–35 days for re-growth. Allow animals to graze only when the soil is dry to avoid root damage from trampling. Do not turn hungry animals onto lush lucerne pastures, as they will overeat and potentially suffer bloat.

Preservation

Excess lucerne is best conserved as hay or silage. For haymaking, cut the crop in the early bud stage. For silage, the crop must be wilted and mixed with an additive such as molasses or other feeds such as sorghum.

Sweet potato

Climate and Soil Conditions: Sweet potato vines grow best in lightly acidic, deep, fertile loams that have been well drained. Sweet potato vines grows at altitudes up to 2000 m in temperate conditions. Select an area with well-drained and fertile soil. Avoid areas where sweet potatoes were grown the previous year.

Ground Preparation: Begin land preparation early enough so that the land is ready at the onset of rains. Plough twice (at 30 cm depth) at two week intervals to allow decomposition of weeds/grasses. After the second ploughing, form ridges and/or mounds for planting. Ridges and mounds should be 60 to100 cm wide and 60 cm high.

Sowing/Planting: Plant 30 cm cuttings of sweet potato vine in rows, with approximately 90 cm of space between rows and 30 cm between vines within rows. If planting on mounds, plant three vines per mound. The best cuttings are tip vines from 2–3 month old fields. Avoid the base of the vines as they might harbor sweet potato weevils and establish slowly. Middle portions can be used, but only when tips are in short supply.

Weeding: Sweet potato competes better with weeds than other root and tuber crops. Weed twice at 3 weeks and 6-8 weeks with a careful second weeding to ensure hilling up of the vines not to expose the bases to sweet potato weevil infestation.

Management

Harvesting: Depending on the feed needs, sweet potato vines can be harvested twice. The first harvest is done when the vines cover the ground, about 75–90 days after planting. Cut any vines longer than 30 cm with a sharp knife, 10 cm form the ground. Leave shorter intact to allow for new vine growth.

The second harvest is done 150 days after planting. Cut all vines to ground level. The vines can be fed to animals or converted into silage, while the roots can be used for human consumption (or sold for income). Vines harvested at 150 days normally have higher crude protein than vines harvested earlier.

Grazing: Not suitable for grazing.

c. Fertility and fertilizer

Soil fertilization

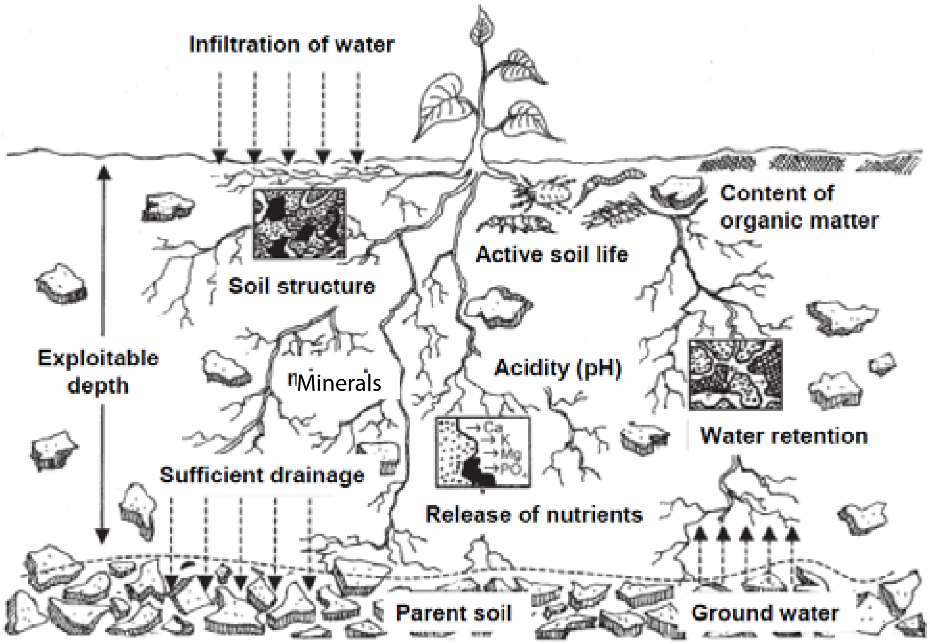
In the past, African farmers traditionally cleared land, grew crops for a few seasons and then moved on to another piece of land. In this way, the abandoned soil was allowed to regain its fertility. Currently, the lack of available land is forcing farmers to continually plant crops on the same land, which reduces soil fertility and crop yields. This section provides options where farming practices can be adapted to local conditions to improve productivity through soil fertility management. Strategies that examine the use of mineral (synthetic) fertilizers and organic matter to replenish lost soil nutrients will also be discussed.

In order to better understand the basic principles of soil fertility, it is important to know soil types and soil composition and the role of different soil components. This will be covered in the first chapter of this section. This section will also provide information on how to identify fertile soils, the nutrients which plants need and how plants will manifest lack of nutrients. Finally, details on the fertilizers available and selection of suitable fertilizers for plants will be covered.

Composition of the soil: The basic components of soil are minerals, organic matter, water and air. Ideal soil (ideal for the growth of most plants) consists of approximately 45% minerals, 25% water, 25% air, and 5% organic matter. Usually, the percentages of these four components vary greatly depending on climate, water supply, farming practices, and soil type. Soil air and water are found in the spaces between the solid soil particles. The ratio of air-filled pore space to water-filled pore space often changes seasonally, weekly, and even daily, depending on water additions through precipitation, and irrigation.

The mineral portion of soil usually consists of fine materials (sand, silt, and clay), however soils may also contain larger particles, such as pebbles, cobbles, and boulders. Sand consists of particles less than 2 mm that are visible to the naked eye and feel gritty. Silt is smaller than sand, and is smooth to the touch, similar to wheat flour. When moistened, it is soapy slick. Clay particles are even smaller than silt and feel slick and sticky when wet but smooth when dry. Soils with a lot of sand are generally loose and drain water quickly and so they rarely become waterlogged. However, because they do not hold water, they become very dry if no rain (or irrigation) has fallen for some time. Regular applications of organic matter can improve the water and nutrient retention and reduce evaporation therefore making them better suited to withstanding drought periods. Soils with higher silt concentration can hold more nutrients and moisture however they are eroded and need to be protected. Again, similar to sandy soils, additions of organic matter improve the soil allowing it to absorb more rain water, maintain structure and resist erosion. Soils high in clay can hold a lot of moisture and nutrients, but may resist water infiltration. Some clays though bind strongly to certain nutrients making the nutrients unavailable for crops. Poor infiltration in clay soils can cause puddles to form on clay soils, which increases the risk of compaction and damage to the soil. As a result, farmers should avoid working on these soils when the soils are very wet. A relatively even mixture of sand, silt and clay produces what is called a loamy soil and is considered to be good for farming.

Figure 3.3 The soil constituents.



Source: FIBL / IFOAM

Soil water/air: Plant roots require a moderate amount of soil water. Insufficient water causes the soils and plants to dry out and potentially die, while too much water in the soil means that the plant roots are unable to "breath". Most plants will die under such conditions, with only a few exceptions such as rice and yams.

Soil organic matter: The organic matter in soil can be divided into three components: living microorganisms, fresh and partially decomposed residues and humus (well-decomposed organic matter). Organic matter typically constitutes between 1–6 % of the topsoil for most upland soils and soils with more than 20% organic matter are considered organic soils.

Soil organisms: The soils are full of many different organisms with only some visible to the naked eye like earthworms and termites, and like people these organisms require food, water and air. These soil organisms are vital for breaking down organic matter (i.e. crop residues, manure etc.), which is how many of the nutrients become available to the growing plants. The organisms are also important in developing the structure of the soil, thus improving water retention for improved crop growth.

Soil fertility

What is soil fertility? Fertility of a soil is defined by its ability to provide all essential nutrients in the proper balance for plant growth. The availability of the nutrients depends on the total amount of nutrients in the soil, the amount of organic matter, the pH and the ability of the soil to retain water. A fertile soil is easy to work, absorbs rain water well, and is robust against erosion.

Properties of a fertile soil:

- has an appropriate balance of nutrients necessary for basic plant nutrition.
- contains an appropriate amount of soil organic matter.
- has a suitable pH for crop production (between 6.0 and 6.8).
- is biologically active.
- has good water retention qualities.

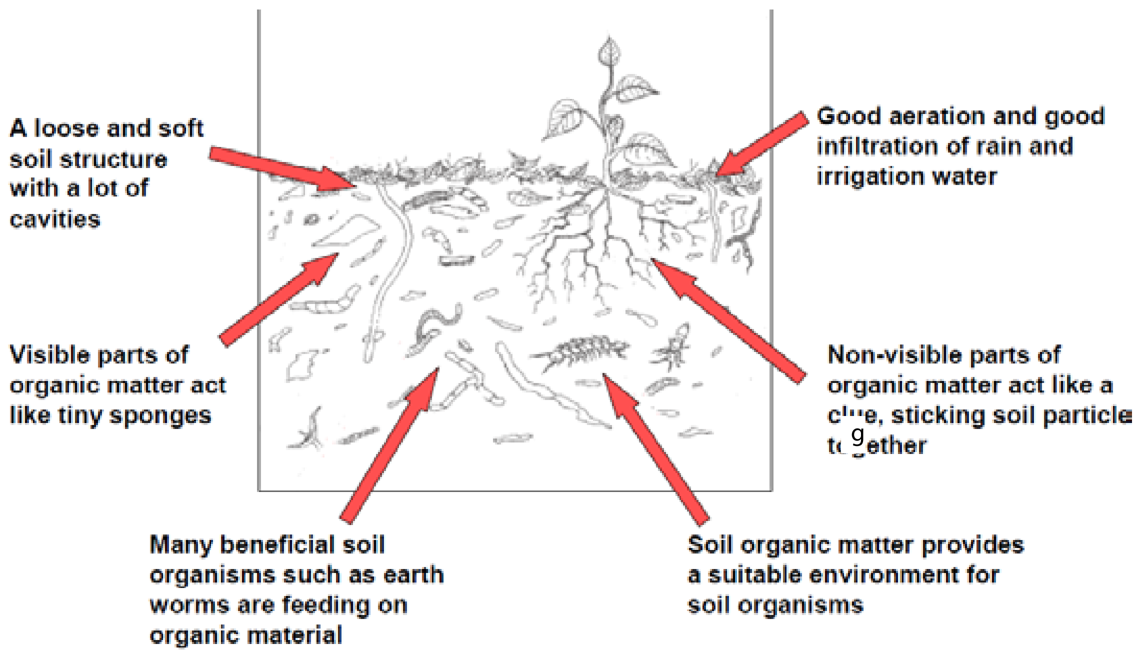
Soil nutrients: There are 16 essential nutrients that plants need to grow properly, of which only hydrogen, carbon and oxygen can be obtained from the air and water while the rest come from the soil. Some nutrients are required in large amounts and are called macro (major) nutrients. These include nitrogen (N), phosphorus (P) potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S). Others are required in small amount and are called micro (minor) nutrients. These include boron (B), copper (Cu), iron (Fe), chloride (Cl), manganese (Mn), molybdenum (Mo), and zinc (Zn). Recycling organic matter such as crop residues and tree leaves is an excellent way of providing many macro and micronutrients to growing plants. Knowledge of soil pH, texture, and history can be very useful for predicting what nutrients may become deficient. On the other side, too much of a nutrient can be toxic to plants.

Table 3.20 Importance of the primary macro-nutrients.

Nitrogen (N)	Phosphorus (P)	Potassium (K)
Increases growth and development of all living tissues	Helps in early maturing by stimulating flowering	Enhances the plant's ability to resist diseases
Improves the quality of leafy vegetables and fodder and the protein content of the food grains and makes them green	Helps in seed and fruit development	Assists carbohydrate translocation and water utilization by stomatal regulation
Helps uptake of phosphorus, potash and micronutrients	Helps for the growth and development of root of the plant	Resist from wilting and lodging of plants

Soil pH: Soil pH (how acidic or alkaline the soil is) affects nutrient availability in the soil. In Africa, about one-third of the soils are acidic while another third is either saline or alkaline and all are difficult to manage. Soils that are too acidic can be treated with lime, compost with high pH (8) or poultry manure to help neutralize acidity and, increase the nutrient availability.

Figure 3.4 Properties of good soil



Soil structure: Plant roots prefer soil with a crumbly structure, like well-made bread. Such soil is well-aerated and the plant roots are able to penetrate easily, allowing them to access more nutrients to support good growth. Soil aggregation is also an important indicator of the workability of the soil. Good soil structure also reduces soil erosion, as water infiltrates more easily into the soil and the aggregates (crumbs) are too big to be carried away by the water.

High biological activity: Even if we cannot see most soil organisms doing their work, the majority of soil organisms are very important to the quality and fertility of soils. They contribute to the transformation of crop residues and organic fertilizers to forms that the plants can use. High biological activity is an indicator of fertile soil. Most soil organisms prefer the same conditions as plant roots: humid conditions, moderate temperatures, air and organic material.

Soil fertilization

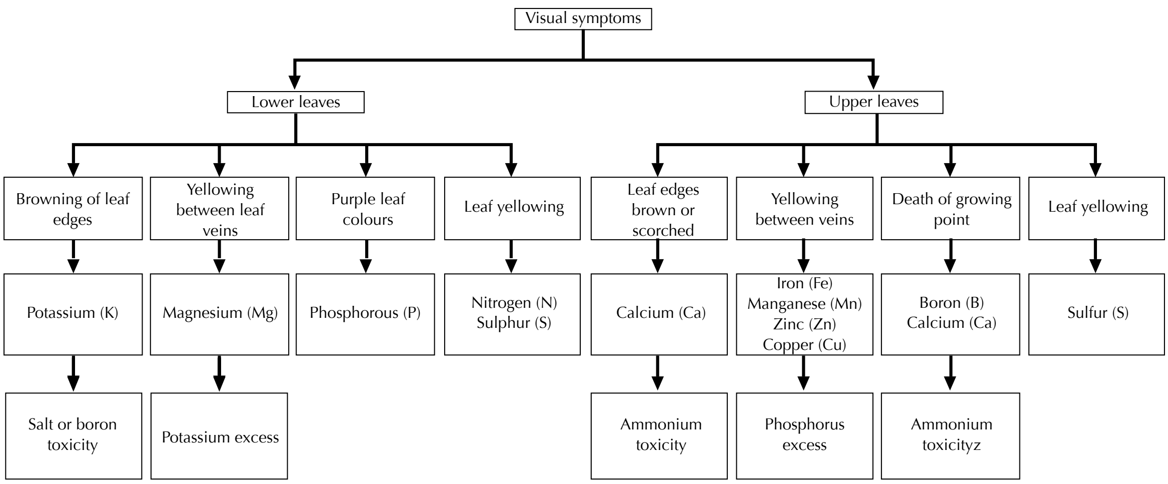
What is a fertilizer? A fertilizer is any material that is applied to plants in order to provide nutrients to improve growth, yield or nutritive value of the plant. There are two main types of fertilizers: organic and chemical (synthetic) fertilizers.

Organic fertilizers: Organic fertilizers are by-products of everyday life, such as manure and plant refuse. Organic fertilizers provide many (or all) of the macro and micro-nutrients that plants need, often in a slow-release form that stays in the soil longer. Organic fertilizers typically have a lower NPK content than synthetic fertilizers but feed plants for a longer period of time.

Chemical (synthetic) fertilizers: Chemical fertilizers are manufactured from diverse sources and are usually more concentrated than organic fertilizers. The available nutrients typically dissolve easily in water and are available for plant growth almost immediately. Chemical fertilizers are best known for being fast-acting and may come in a variety of forms (liquid, pellets, granules, spikes, etc.).

Why apply fertilizer? Fertilizers are used to improve or maintain soil fertility and thus improve crop yields. Nutrient deficiencies can cause symptoms as shown in the following table and figure:

Figure 3.5 Visual symptoms of nutrient deficiencies in plants.



Visual symptoms of nutrient deficiencies and disorders. Symptoms can be caused by other factors (e.g., drought can also cause browning of leaf edges). Purpling may also be seen in some cereal varieties that are rich in anthocyanins. Phosporus deficiency is often indicated by stunting (e.g., in maize) and small leaf size (e.g., in legume crops).

It is important to note that some symptoms can also be caused by other factors. For example browning of leaf edges can also be caused by drought; purpling may also be seen in some cereal varieties that are rich in anthocyanins. Phosphorus deficiency can also be indicated by stunting in maize for example and by small leaf size in legumes.

Table 3.21 Symptoms and suitable fertilizers for nutrient deficiencies in cotton.

Nutrient	Deficiency symptoms	Possible Reasons	Suitable Manures/Fertilizers
Nitrogen (N)	Small, pale yellow leaves stunted growth	Few organic matter in the soil; water logging or dryness; presence of straw, immature compost etc.: too much irrigation	Crop rotation with pulses, application of organic manure (e.g. DOC) before fowering
Phosphorus (P)	Stunted plants with dark green leaves, purple spots on leave edges; Premature senescence	Sandy soils; few organic matter content:reduced uptake due to water logging or overcast weather	Application of compost, manure: application of rock phosphate in compost (50-100 kg/ha)
Potassium (K)	Leaf margins and interveinal areas show yellowish white mottling, then rusty bronze colour, then necrotic spots: small immature bolls; poor fibre quality	Sandy soils; high contents of nitrogen, soda, magnesia or calcium	Application of wood ash in compost; application of muriate of potash (50 kg K/ha)
Sulfur (S)	Yellowing of young leaves while old ones remain green: spindly plants with short slender, stem	Mainly in dry-land crops and sandy soils. Problem of leaching of Sulphate	Application of gypsum (25-50 kg/ha)
Zinc (Zn)	Intervenial chlorosis (yellowing between the leave veins): cupped leaves, bronzing. Short growth	Poorly soluble in the soil, thus associationwith VAM improves uptake. Low VAM due to long fallow or dry conditions	Application of 50-10 kg Zn-Oxide or Zn-Sulphate per ha once in several years
Boron (B)	Young leaves become light green at their base, older leaves become twisted; flowers are malformed; deformed bolls	Mainly in sandy soils, easily leached; alkaline soils. Main supply from organic matter	Application of 0.5-1 kg Borax salt per ha. applied just beforesowing. Attention: high application has toxic effects!

Advantages and disadvantages of organic and synthetic fertilizers

Advantages of organic fertilizers

- Helps build the soil: provides organic matter, which is one of the building blocks for fertile soils.
- Slow nutrient release: Release rate is more similar to the rate that plants are able to use the nutrients. No danger of doses being too high, since microbes must break down the material.
- Trace minerals: typically present, providing more balanced nutrition to the plant.
- Long lasting: doesn’t leach out since the organic matter binds to the soil particles and holds the nutrients where roots can access them.
- Fewer applications required: once a healthy soil condition is reached, it is easier to maintain.
- Controlled growth: does not over-stimulate plant growth.
- Stronger plants and grass: greater resistance to disease and insect attacks.
- Beneficial to environment: Less likely to cause pollution due to run-off from irrigation or rain.
- Encourages soil life: Provides food for beneficial microorganisms.
- Inexpensive: Most farmers have either manure or plant residues readily available at no cost.

Disadvantages of organic fertilizers

- Slow to release nutrients: may not provide an immediate boost to crop growth.
- Dependent on soil microorganisms: to break down organic material. Soils depleted of these beneficial microbes further delay the results from organics.
- Application less convenient in some forms: Fresh manure can be heavy due to the large amount of water and may be difficult to apply on large areas.
- Can attract pests: if not stored and managed properly.
- Immobilization of nutrients: Application of organic fertilizers can tie up many nutrients for a short period of time (generally a week or so), making these nutrients unavailable for plant growth during this time.

Advantages of chemical fertilizers

- Readily available: as the most common form used, it is less bulky and can be easily transported.
- Formula variety: it is easy for chemical companies to vary the elements to produce blends for different seasons and for specific plants.
- Fast acting: Usually see results within 1-2 weeks if the formula used is appropriate for the season.
- Ease of application: using fertilizer spreaders. Rates and settings are usually calculated and displayed on bag.
- Multiple forms: available in pellets, granules, liquid, tablets, spikes, and slow-release, to suit every preference.

Disadvantages of chemical fertilizers

- Water soluble in most forms: Since water releases the nutrients, it is not uncommon to lose one-third of the nutrients by leaching out of the soil before the plant can access them.
- Short life span: Unless using a controlled release form.
- Doesn’t build the soil: If the soils are depleted of organic matter, these do not provide additional carbon to replenish the soil.
- May decrease soil fertility: Chemical nitrogen stimulates the growth of existing microorganisms, which then use up the existing organic matter in the soil. Repeating this cycle regularly without replenishing the organic matter (e.g. leaving crop residues on site, or application of organic fertilizers) can deplete the soil.
- Excess growth can occur with some varieties or with surplus application. This results in more mowing or pruning, places stress on roots.
- Salt burn risk: Over-concentration can cause dehydration and plant tissue is destroyed.
- Trace nutrients missing in many synthetic blends.
- Environmental problems: Excess phosphorous and nitrogen can leach into ground and surface water bodies.
- High energy consumption required to produce these products.

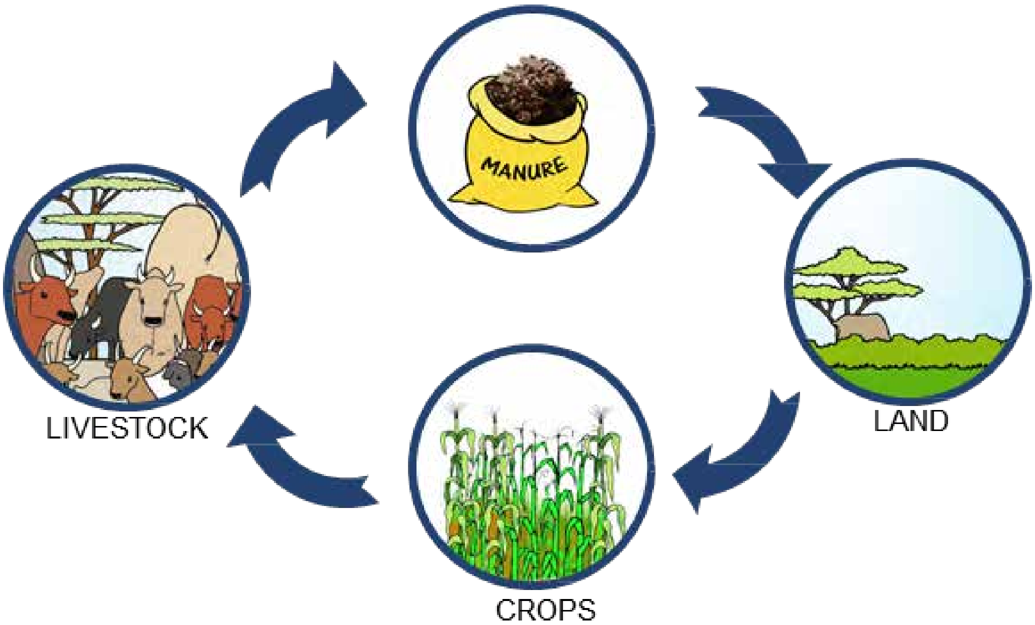
Looking at the various advantages and disadvantages of organic and synthetic fertilizers, it is advisable to apply appropriate combinations of organic and synthetic fertilizers as the best way of effecting soil fertility management to boost production and achieve sustainable yields.

Organic fertilizers

Organic fertilizers are either of animal origin (animal manure, slaughter house waste, blood meal, bone meal, fish meal, etc.) or of plant origin (green manure, crop residues, etc.).

Animal manure: Animal manure consists of excrements from animals and can be mixed with leftover feed, litter, bedding material, cleaning water, etc.. The figure below illustrates how nutrients are recycled in crop-livestock systems.

Figure 3.6 Nutrient cycles in crop-livestock systems



Sources of animal manure include cattle, goats, poultry, sheep, pigs, etc., with the manure from the different species varying in quality (see Table 3.22). The amount and quality of the manure obtained depends on the housing system, the manure collection and storage system, the amount of feed, the method of feeding (pen rearing, kraaling the animals at night, or free range), the quality of the feed and the efficiency of manure and urine collection. In general, manure from pigs and poultry has higher nutrient content than manure from goats and cattle. It is worthwhile though to apply even the "poor quality" manure to crops.

Table 3.22 Nutrient values from different types of organic fertilizer.

		Dry matter (%)	kg/ton fresh matter (= g/kg)				
Manure type: Solid manures			N total	NH_4^+-N	P_2O_5	K_2O	Mg
Solid cattle manure	Range	16 – 43	2 – 7.7	0.5 – 2.5	1.0 – 3.9	1.4 – 8.8	0.7 – 2.1
	Average	22	4.8	1.3	3.0	5.7	1.1
Solid sheep and goat manure	Range	25 – 48	6.1 – 8.6	1.3 – 2.6	2.3 – 5.2	5.7 – 16	1.1 – 3.5
	Average	30.6	7.8	2.0	4.0	9.9	2.1
Solid pig manure	Range	20 – 30	4-9	0.7-6	1.9-9.2	2.5-7.2	0.5-2.5
	Average	24	6.8	2.4	6.3	4.9	1.4
Solid broiler manure	Range	45 – 85	18 – 40	2 – 15	6.9 – 25	6.7 – 23	2.5 – 6.5
	Average	60	30	7.6	18.5	17.1	4.2
Solid layer manure	Range	22 – 55	13 – 45	5 – 25	8 – 27	6 – 15	1.2 – 6
	Average	40.6	23.6	10.9	16.6	10.7	3.1
Liquid manures							
Pig slurry (no added water)	Range	1.5 – 15.7	2.5 – 10.6	1.3 – 5.5	0.3 – 11.9	2.4 – 10.8	0.2 – 3.0
	Average	7.4	6.5	3.6	3.9	6.8	1.5
Cattle slurry (no added water)	Range	3.4 – 20	2.4 – 7.8	0.2 – 4.4	0.6 – 7.7	1.2 – 9.1	0.6 – 2.7
	Average	9.6	4.9	2.4	2.0	6.2	1.4
Pig bioslurry (no added water)	Range	1.2 – 12.9	2.5 – 10.6	1.6 – 6.9	0.3 – 11.9	2.4 – 10.8	0.2 – 3.0
	Average	6.1	6.5	4.0	3.9	6.8	1.5
Cattle bioslurry (no added water)	Range	2.8 – 16.5	2.4 – 7.8	0.3 – 5.1	0.6 – 7.7	1.2 – 9.1	0.6 – 2.7
	Average	7.9	4.9	2.8	2.0	6.2	1.4

Managing solid manure

Solid manure is manure that is devoid of urine or washout water that can be stored as a solid and stackable product. The most common types of manure storage in sub-Saharan are: a pile or heap outside the confinement (Figure 3.7) or deep bedding in the animal confinement. Examples of both good and bad manure management systems are shown in Figures 3.7, 3.8 and 3.9.

Figure 3.7 Solid cattle manure a) outside confinement (poor management) and b) in a shaded pit (good management).

Housing and collection

- Manure should always be collected for use as a fertilizer.
- The manure from the housing facility should be removed regularly and covered during storage to facilitate maturity and reduce nutrient losses.

Storage

Manure needs about 2–3 months to mature before it can be used as fertilizer. The maturation time allows the organic matter to be broken down so that the nutrients are in a form that is usable by plants. The amount of nutrients in the manure tends to decrease over time, because NH_3, N_2 or N_2O are emitted as gases or because soluble N (primarily Nitrate NO_3^-) P and K are leached by rainwater. To prevent losses, manure should be covered during storage.

Figure 3.8 Good manure management.

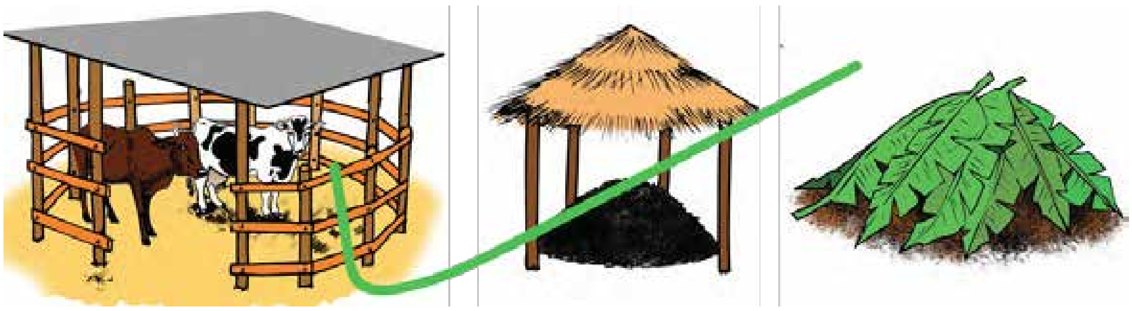
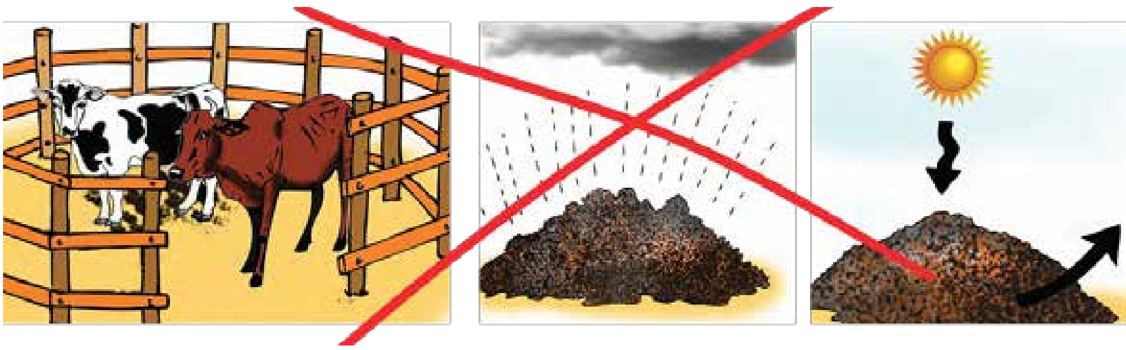


Figure 3.9 Poor manure management.



Manure application

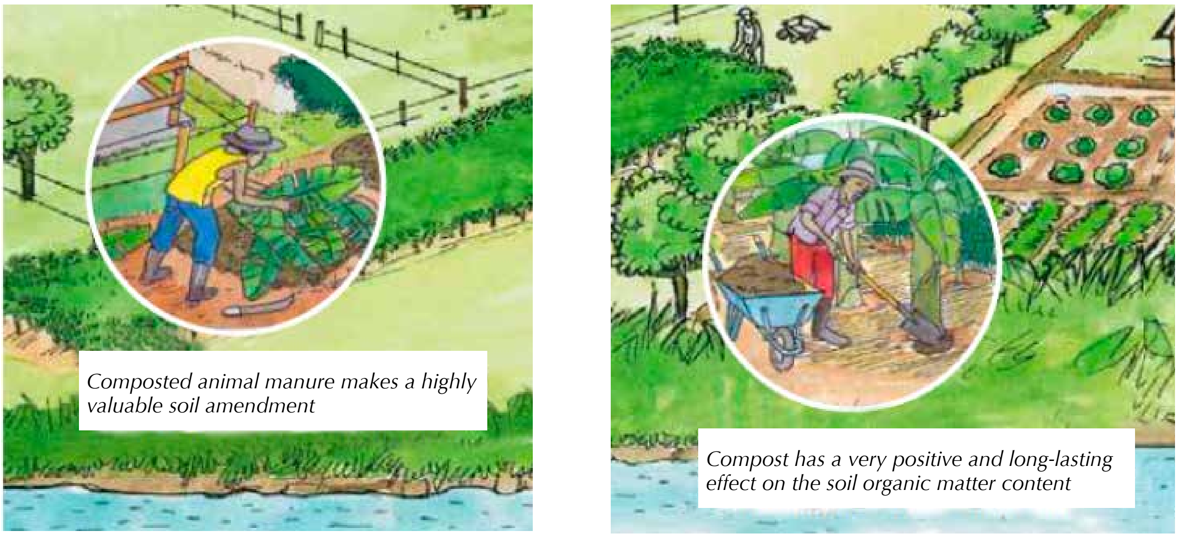
- Preferably use composted or well decomposed manure, which smells “earthy” and where the original bedding material cannot be recognized.
- When applied to the fields, manure should be quickly incorporated into the soils (e.g. ploughing), since exposure to sunshine for long periods causes loss of nutrients. Heavy rains can also wash some of the nutrients away through erosion.
- The best time to apply manure is 2–8 weeks before planting so that the nutrients will be available when the plants germinate. Manure can also be surface banded (applied to the field in a “band” beside the actively growing plants) when the plants are actively growing, however the plants should be a minimum size (e.g. for maize, the plants should be at least 30 cm high). Manure applied while plants are actively growing should be combined with a synthetic fertilizer.

Figure 3.10 *Manure application.*

Composting

What is composting? Composting is the natural process of 'rotting' or decomposition of organic matter by microorganisms under aerobic (oxygen-rich) conditions. Composting is an attractive proposition for turning on-farm organic waste materials into a farm resource.

Figure 3.11 Composting process in action.

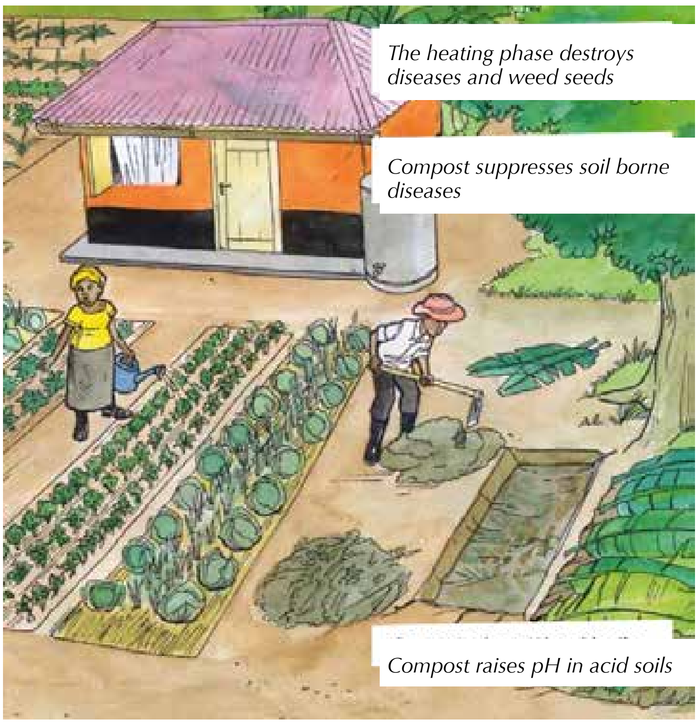


Raw organic materials such as crop residues, animal wastes and food garbage, enhance their suitability for application to the soil as a fertilizing resource, after having undergone composting.

Compost is a rich source of organic matter. Soil organic matter plays an important role in sustaining soil fertility. In addition to supplying plant nutrients, it also improves the ability of the soil to capture and retain water and nutrients. For a description of how to make compost, see page 79 ff.

Benefits of using compost

Figure 3.12 Benefits of compost.



- Easy to make and is very effective at improving the soil. Less expensive compared to other soil amendments.
- Improves the structure of the soil. This allows better aeration of the soil, improves drainage and reduces erosion.
- Improves soil fertility by adding nutrients and by making it easier for plants to take up the nutrients already in the soil. This produces better yields.
- Improves the soil's ability to hold water. This stops the soil from drying out in times of drought.
- Can reduce pests, diseases and weeds on the farm. This is because, unlike raw manure, the high temperatures that occur during composting usually kill the disease-causing organisms and the weed seeds.
- Large amounts of vegetation, such as crop remains, garden weeds, kitchen and household wastes, hedge cuttings, garbage, etc., are put to use.
- When properly made, compost nutrients become slowly available as plant food.
- Good crops can be obtained with reduced need for extra chemical inputs.
- All farmers, regardless of their financial abilities, can make and use compost.

Disadvantages of using compost

- if not properly composted, the material may spread weed seeds.
- requires more labor for collection, handling and application.
- The nutrient composition of the compost varies, depending on the materials used and the preparation methods.
- There may not be enough vegetation and water to make compost in drier areas.

However, under practical situations, the benefits of using compost far outweigh the disadvantages.

Storage of compost: Mature compost should be kept covered to protect it from rain and sun. If the compost is kept for too long before use it will lose some nutrients and may also become a breeding place for unwanted insects.

Field application of compost: When delivered to the fields, compost should be immediately incorporated into the soil. This will help to avoid loss of nutrients through evaporation or through runoff / leaching in case of heavy rainfall. Application of compost should be done shortly before the planting period.

As for other forms of fertilizer, the application rate of compost depends on the soil type, the type of crops cultivated, etc. As a rule of thumb, well-decomposed compost should be applied at the rate of about 20 t/ha (8 t/acre): Approx. two large hoes per square meter, or enough to barely cover the ground with a layer 1 cm thick. The application rate for compost from chicken should be less (one hoe full) since it is usually richer in nutrients.

Synthetic fertilizers

Goal: Know about different types of synthetic fertilizers and basic principles of application.

Fertilizer (types, management, application)

Based on the main element provided, there are three common types of synthetic fertilizer.

Nitrogen fertilizers: Nitrogen fertilizers are developed to supply nitrogen (N) to the plants, either as ammonium or nitrate. Nitrogen is mobile in plants, and moves from older to younger leaves as the plant grows. As a result, symptoms of N deficiency occur first on the lower and older leaves. Plants generally take up nitrogen as nitrate (NO_3^-) or ammonium (NH_4^+). Nitrate (NO_3^-) is mobile in the soils and can be lost easily by leaching, while moves very slowly through the soil. Most plants though, require that NH_4^+ is converted to NO_3^- before they can use it.

Although many soils in Kenya are very low in N, there is the remote possibility that if too much N is used then vegetative growth is encouraged, which can delay crop maturity (fruit and seed formation). Application of too much N fertilizer (for maize crops this is generally more than 200 kg N/ha) can also lead to high greenhouse gas (GHG) emissions and pollution of local ground water and rivers and lakes.

Nitrogen use efficiency (the proportion of fertilizer N that is taken by the crop) can be enhanced by using the right fertilizer on the right crop and soil, with the right method, at the right dose and the right time (i.e. the 5-Rs). However, you also need to ensure that the other nutrients are available in adequate amounts and balanced proportions in the soil.

Phosphate fertilizers: The major source of P is the phosphate rock deposits and is taken up by plants primarily as orthophosphates ($H_2PO_4^-$ or HPO_4^-). It is mobile in plants and symptoms P deficiency are manifested in older leaves as purple discoloration in grain crops and cereals. Managing P fertilizers is similar to the N fertilizers and so is focused on the type, amount and time of application to prevent loss through immobilization and soil erosion (5-Rs).

Phosphate fertilizers include single super phosphate (SSP) 0-(16-22)-0+16S, and triple super-phosphate (TSP) 0-46-0).

Potassium fertilizers: All potassium fertilizers are water soluble and quick acting. Common examples of K-fertilizers are muriate of potash (MOP), sulphate of potash and potassium magnesium sulphate.

Complete and incomplete fertilizers: Incomplete and complete fertilizers are classified as ammonium phosphates, and nitrophosphates and NPK fertilizers.

Ammonium phosphates: The common ones are mono-ammonium phosphates (MAP) and di-ammonium phosphates (DAP) and each of these provides N as NH_4^+ and water soluble P_2O_5. DAP is suitable in areas and crops where P requirement is relatively higher than N. It has an acidifying effect requiring periodic lime application. On the other hand MAP has a wide N: P_2O_5 ratio and may require additional nitrogen.

Nitrophosphates and NPK fertilizers: Examples are 23-23-0, 20-20-0, 20-10-10, 17-17-17, and 20-10-10. For the NPK fertilizers, the numbers correspond to the amount of nitrogen, phosphorus and potassium, respectively. Nitro-phosphates are best applied as basal dressings.

What fertilizer to apply and when to apply? When choosing what fertilizer to use and how much, one needs to consider the following factors:

- Type of crop and its nutrient requirements. Some crops require a supply of certain nutrients more than others, e.g., fruit trees will require a lot of K while leafy vegetables require more of N. A maize crop, planted at a spacing of 75 by 50 cm will require 23:23:0 applied at a rate of 10g/hole (200 kg/ha).
- Stages of growth of the crop – at planting, plants require more of phosphorus for root development.
- Soil reaction – some fertilizers like DAP or MAP should not be used in highly acidic soils as this would make some nutrients unavailable for uptake by plants. Either that, or these fertilizers should be applied with lime.

- Soil analysis results – This is the best guide on what type and amount of fertilizer to use.
- Weather condition – When it is very dry and crops are water stressed, foliar feed is the best option.

Timing of fertilizer applications

Basal application: fertilizer is applied before, or shortly after planting but before crop emergence. Compound fertilizers are generally used for basal applications. Basal application gives plants the initial boost needed to achieve the crop's yield potential. Nutrients such as phosphorus are important for rapid root development and must be available during early plant growth. Therefore basal fertilizer should be rich in phosphorus. Because the plant N demand is very low at planting, either slow release or at least ammonium based N fertilizers should be used.

Top dressing: fertilizer is applied after seed emergence and establishment of a crop. Top dressing may be applied as late as the flowering stage of an annual crop. It can provide nutrients that can easily be lost from the soil because the roots are generally already well developed. Ammonium nitrate (AN) and urea is widely used for top dressing cereals.

Split applications: This is when fertilizer applications are done in several stages to reduce nutrient losses. Typically, slow acting fertilizers are added at planting, while the more fast acting fertilizers will be added when the crop is actively growing. The applicability and number of split applications will depend on soil type. Sandy soils are generally less fertile and thus may require more fertilizer, while they are also more freely-draining, which can lead to transport of the fertilizer below plant roots and into groundwater or out into rivers and lakes. These losses reduce the effectiveness of the fertilizer. Thus, the efficiency with which nutrients are absorbed by the crop can be increased.

Table 3.23 Some inorganic fertilizers their uses and characteristics

Material	$N-P_2O_5-K_2O$ Analysis	Major uses	Traits
Anhydrous ammonia	82-0-0	Sidedressing N in corn. Used to make othe N fertilizers, like urea	Most concentrated N source, liquid under pressure, highly caustic – if exposed can "burn" plants and people.
Urea	46-0-0	Topdressed N on perennial grasses ans included in blends (e.g. 19-19-19).	volatile, hydroscopic (absorbs water from the air), can cause high pH near seed, concentrated N source, salt toxicity potential.
Ammonium nitrate	33-0-0	Used to topdress, in starter, and in blends.	hydroscopic (absorbs water from the air), salt toxicity potential, cannot purchase in bulk.
Ammonium sulfate	21-0-0 24-5	Mild N source for starter fertilizers. Also supplies sulfur used in blends	reduces soil pH, flows well through planter, less salt toxicity potential.
Diammonium phosphate (DAP)	18-46-0	Used in blends for broadcasting and banding	Can ause high pH near seed.
Monoammonium phosphate (MAP)	11-52-0	Used in blends for broadcasting and banding	Easy on seeds, but do we need the P in the field? More mild starter blends than DAP.
Muriate of potash	0-0-60	Used for topdressing K on legumes and included in blends	Salt toxicity potential.

Organic and inorganic nutrient combinations

While fertilizer use is essential to attain sustainable agricultural growth, the use of organic resources is also recommended and is often a more viable alternative for resource poor farmers. However, traditional organic materials such as compost, animal manure, green manure etc. cannot by themselves reverse soil fertility decline because:

- they are not available in sufficient quantities as there are other competing uses (fuel, forage, etc.).
- they contain low nutrient content (NPK).
- they require a lot of labour in processing and application.

Therefore combining mineral and organic fertilizers is strongly recommended. Moreover, decisions on purchasing fertilizers are made before planting, at a time of high demand for other important household expenditures (e.g., paying school fees), or when farmers have already sold their harvest from the previous season. As a result, the amounts of fertilizers that farmers can access are small, and therefore it is crucial that strategic targeted fertilizer use together with organic nutrient resources is designed to ensure fertilizer use efficiency and increased crop productivity. Practiced at farm scale these are the basic principles of integrated soil fertility management (ISFM). This is because within smallholder farms, fields can be identified that exhibit different patterns of responsiveness to applied nutrients: poorly responsive fertile fields, poorly responsive infertile fields, and responsive medium-to-infertile fields In particular, poorly responsive infertile fields require long-term rehabilitation to build up soil fertility before crops will respond to applied nutrients.

Synergies and/or additive effects have been observed in field experiments testing different combinations of manure and mineral fertilizers. A combination of organic and inorganic nutrient sources also improves the synchronization of nutrient release and subsequent uptake by the crop. For example the synchrony between N release and uptake is thought to be best achieved under a combined application of manures and inorganic fertilizers.

Application rates

Two application rates options with maize:

- One handful of manure per hole plus one bottle top (5 g) of inorganic fertilizer such as 23:23:0 or one handful of manure per 1 m length of furrow plus 5 g of inorganic fertilizer (3.75 t of manure per hectare).
- Five tons FYM or compost (100 wheelbarrows 50 kg each) together with 30 kg P2O5 (1 1/4 bags DAP of 50 kg each) and 30 kg N (1 1/2 Bags CAN of 50 kg each) is equivalent to 10 t FYM or compost (200 wheelbarrows 50 kg each) as organic manure alone and 60 kg P_2O_5 (2 1/2 bags (50 kg bag) DAP and 60 kg N 3 bags CAN, 50 kg each as inorganic fertilizer alone.

For exotic vegetables (cabbage and kale) 5 tons FYM or compost (100 wheelbarrows, 50 kg each) together with 30 kg P_2O_5 (1 1/2 bags DAP 50 kg each) and 30 kg N (1 1/2 bags CAN 50 kg each) is equivalent to 10 tons FYM or compost (200 wheelbarrows, 50 kg each) applied as organic fertilizer alone and 60 kg P_2O_5 (2 1/2 bags DAP, 50 kg each) and 60 kg N (3 bags CAN, 50 kg each) applied as inorganic fertilizer alone.

Preparing of compost

Materials needed for compost making

- Twigs (branches of trees).
- High carbon materials – includes dry vegetative matter such as maize stalk, seed husks, dry grass etc..
- Nitrogen rich material – includes green vegetative materials such as weeds, grass, hedge cuttings (e.g. tithonia "Tithonia diversifolia") or kitchen wastes such as fruit and vegetable peelings.
- Animal dung or slurry.
- Top soil – adds microorganisms that are useful in decomposition.
- Ash – provides minerals such as potash, phosphorous, calcium and magnesium. It also reduces the pH
- Sharp-pointed stick 2–3 m long (thermometer) – to detect heat and water requirements.
- Water – to soften materials and regulate heat in the heap.
- Wheelbarrow, watering can, hoe, machete.

The living decomposers in the compost pile need carbon and nitrogen in the proper proportion in order to grow and produce the final composted material. Your job is to provide them with materials that have a proper proportion of carbon and nitrogen, ideally the carbon to nitrogen ratio (C/N ratio) should be between 20:1–30:1, with a higher number representing carbon. A few materials, such as cattle manure mixed with bedding, soybean shells, and legume hay have C/N ratios close to the ideal range. Materials high in nitrogen are animal manures and vegetable waste, while those high in carbon are maize stalks, saw dust and hay. See Table 3.24 below for a list of some common compost materials and their C/N ratios. Having the proper C/N ratio will ensure the heap is active and the process of transforming the materials into humus will happen. If too much green material is included, the heap will become rotten and much of the nitrogen will be lost as gas. If too little green material is used then the decomposition process will be too slow and tough materials, weed seeds and pathogens will not be broken down.

Preparing your materials

- Bulky materials such as maize stalks should be cut up into pieces no larger than 10 cm (Figure 3.13) otherwise they would take too long to break down and larger pieces will still remain intact when the rest of the material has decomposed. Bulky material can easily be cut up using a hoe or a panga into equal size pieces.
- Fresh green materials, such as grass, weeds or vegetable trimmings can be used without preparation.

Composting Methods: There are different methods of composting and the two most common are:

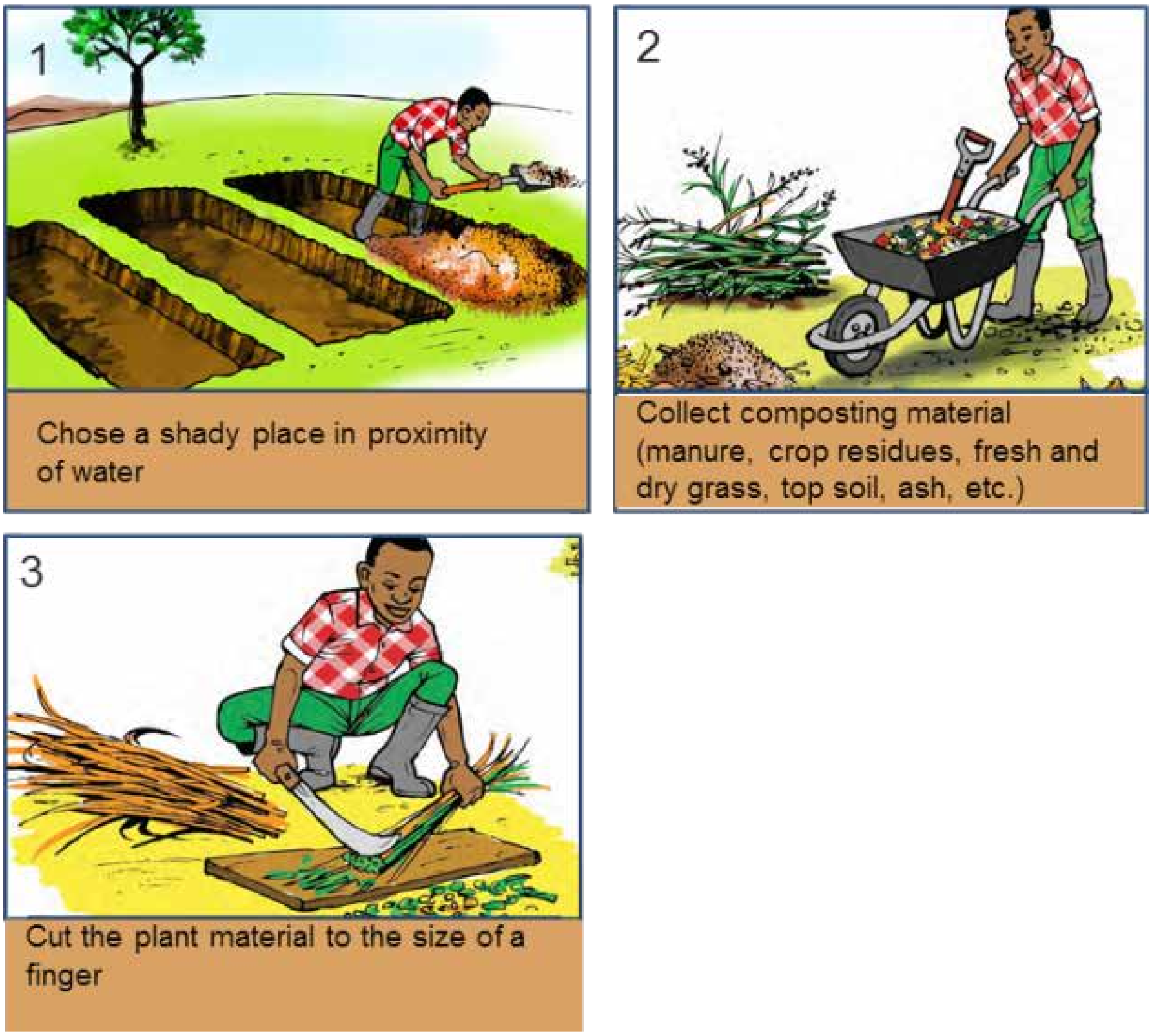
a Heap or pile composting.

b Pit method.

Table 3.24 C/N ratio of compost materials.

Cattle manure	20:1	Legume hay	25:1
Sheep/goat manure	14:1	Maize stalks	60:1
Chicken manure	10:1	Straw/hay	90:1
Vegetable waste	12:1	Saw dust	200:1
Grass/weeds	20:1	Newspaper	800:1

Figure 3.13 Preparing materials for composting.

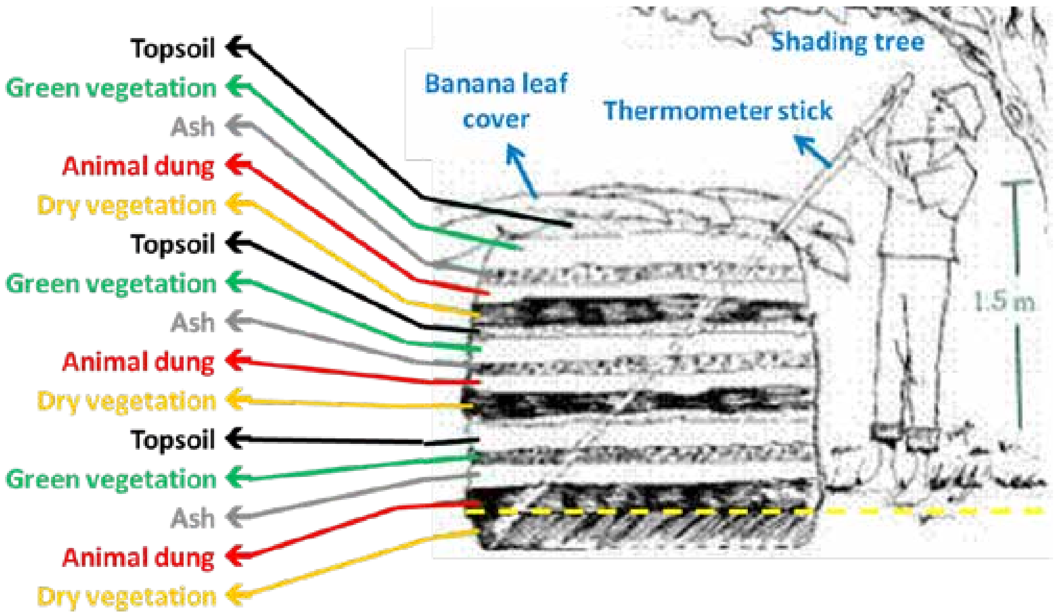


How to build the compost heap (Pile composting)

This method is suitable for areas with higher rainfall.

- Make a base 30–45 cm deep and 2 m wide with any convenient length. Loosen the ground and lay some coarse plant materials such as twigs. This will ensure good air circulation and drainage.
- Put a layer of 30 cm of dry vegetative matter. Chop them into small pieces. Small pieces decay faster.
- Add a 10 cm layer of old compost, animal manure or slurry. This will add extra bacterial and fungi to fasten decomposition.
- Add a 10 cm layer of green materials. Try to maintain a ratio of 1 part greens to 3 parts of dry matter. Kitchen wastes, such as, fruit and vegetable peelings decomposes quickly.
- Add a sprinkling of top soil from the top 10 cm of cropped land.
- Ash can then be sprinkled on to these layers.
- Water the whole pile well.
- Repeat all these layers except the first layer of twigs until the heap reaches 1–1.5 m high.
- The heap should be covered to protect it against heavy rain as this will wash away nutrients. A 10 cm layer of top soil may be applied as this may reduce nitrogen loss from the compost.
- A long sharp-pointed 'thermometer stick' (as in Figure 3.14) is then driven into the heap at an angle and used to check on heap condition from time to time and to allow air to enter the heap through the hole of the stick.

Figure 3.14 Layers of compost heap.



Managing a compost heap

- Water the heap twice a week. If the heap is too dry, the microbes become dormant and the composting process will slow down. However, if the heap is too wet there will not be enough air and the composting organisms will die.
- The pointed stick (Figure 3.14) should be used to regulate temperature. After a few days, the stick should feel slightly hot when removed. If it does not, this may be because decomposition has not started and more air or water may be needed. If the heap is very hot, decomposition is taking place but the excessive heat may kill the organisms and water should be added to cool it down. If the stick is white, it indicates a fungus is present, which is an indication of poor decomposition process and water should be added.
- The compost heap should be turned (Figure 3.15) every 2 - 3 weeks so that the outer materials are put in the middle of the heap. Turning will help aerate the heap and ensure that the materials on the outer layers decompose as well.

Figure 3.15 Transfer of compost manure from 1st to the 2nd then to the 3rd pit after every 2–3 weeks.

The heap should always be covered (for example with banana leaves) after turning. Duration of compost making varies depending on the quality of materials used but on average 6-8 weeks are sufficient to prepare provided the material is not too fibrous.

Characteristics of mature compost

- Coarse materials become finer over time until a fine, loamy material is produced.
- The different materials are no longer recognizable.
- Has only a slight 'earthy' and inoffensive smell.
- Temperature drops and the compost is cool.
- Compost is moist.

Pit method: The pit method of making compost conserves moisture, so it is useful in areas with low rainfall and a long dry season. Do not use it in wet areas, as the compost may become waterlogged.

- Dig a pit 1.2 m wide and 0.6 m deep, and as long as you need for the amount of materials you have.
- Build a pile in the pit (see Figure: 3.15).
- Add water if necessary.
- Push long poles into the pile to allow air to get into the layers beneath.
- Turn the pile every 2–3 weeks.

You can produce a regular supply of compost by digging three pits side by side. Every 2–3 weeks, turn the compost from one pit into the next one, and start a new compost pile with fresh vegetation in the empty pit.

d. Complex systems

Additional benefits of forage cultivation

Cultivating your own forages can have benefits beyond providing feed for animals. Certain combinations of forages can actually improve the yields of other plants. In this lesson we will look at one example of this, known as the "push-pull" strategy, where Napier grass and Desmodium together protect maize crops from a pair of deadly pests.

Using Napier grass and Desmodium to protect maize crops (push-pull)

Maize and other cereal crops are vulnerable to parasites such as striga weed (a.k.a. "witch weed") and stemborer moths. Stemborers lay their eggs on maize plants, after which their worm-like larvae will destroy the stem from the inside. Striga weeds attach themselves to maize roots and steal nutrients from the maize plant, stunting its growth. Together, these pests can cause yield losses of 30-100% if they are not controlled.

Figure 3.16 Stemborer Moth.

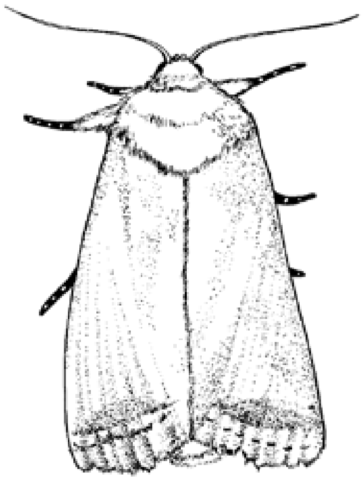


Figure 3.17 Stemborer larvae inside a maize stem.

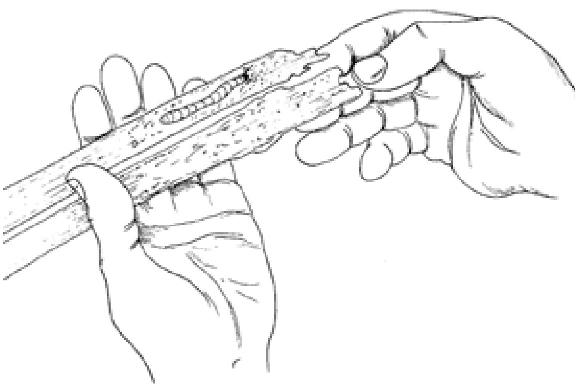
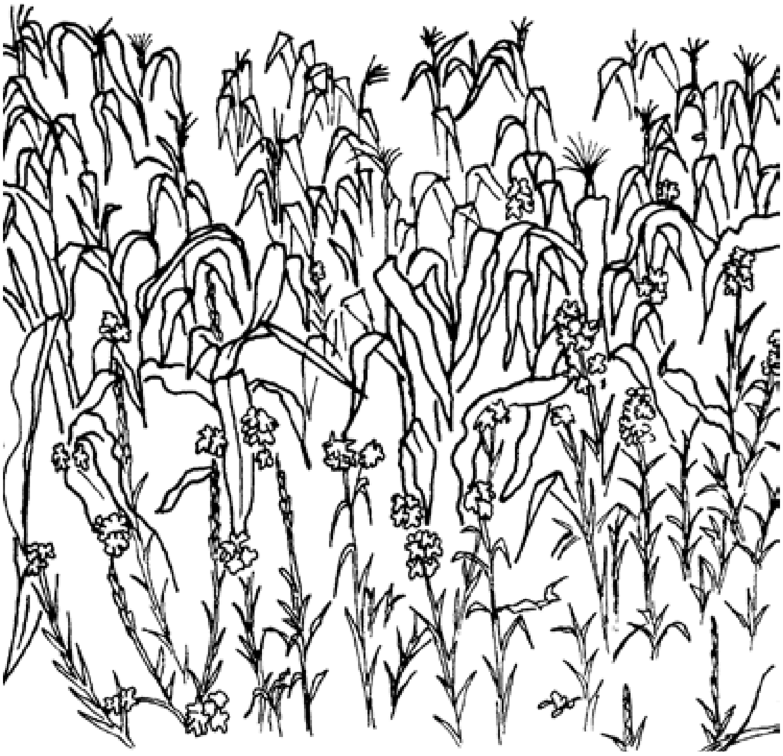


Figure 3.18 Striga weed surrounding maize crops.



The push-pull strategy

Using insecticides and herbicides to control stemborers and striga is expensive, ineffective and harmful to the environment. Fortunately, farmers can repel stemborers and striga naturally, without the use of chemicals, by planting Napier grass and Desmodium around a maize crop. This strategy is known as "push-pull", because of the unique ways that each of these forages keeps pests away from maize:

- Desmodium roots produce a chemical that prevents the growth of striga weed, meanwhile the plant gives off a smell that "pushes" stemborers away. When planted near maize, Desmodium can shield the crop from both of these threats. Desmodium also improves soil quality, helping the maize crop to grow.
- Napier grass is naturally more appealing to stemborer moths than maize, and can "pull" stemborers away from maize and towards the Napier grass. However Napier grass has natural defences, and will trap the stemborer larvae in a sticky, glue-like fluid that will kill most of them before they can damage the crop.

Done properly, the push-pull strategy can help protect your maize crop while at the same time providing nutritious Napier grass and Desmodium to feed to your dairy cattle. In areas afflicted by stemborers, this strategy can boost yields by as much as 30%. In areas affected by both stemborers and striga, it can double yields.

Planting a push-pull plot

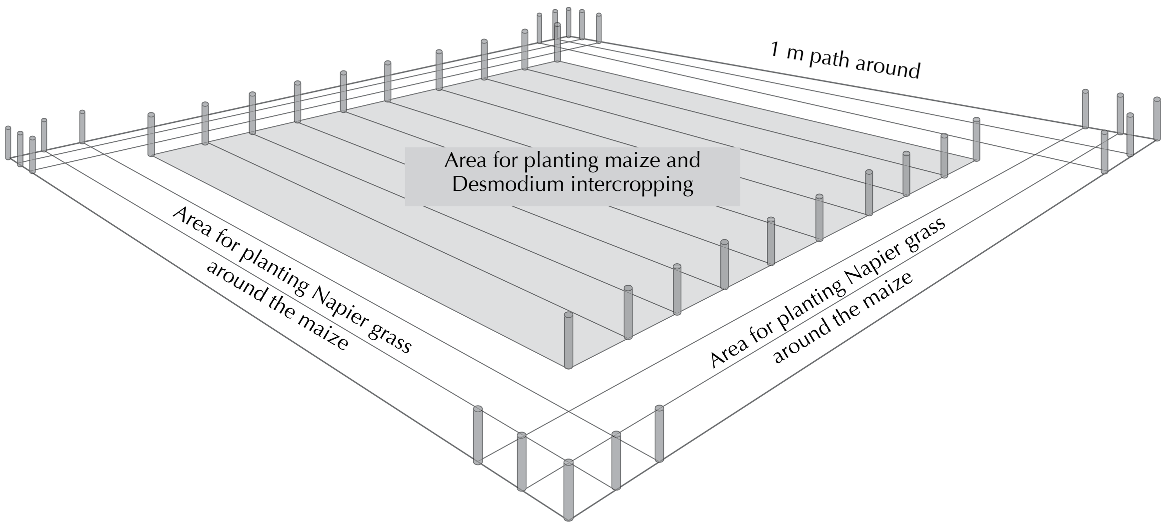
Applying the push-pull strategy requires some planning and effort, but overall the process is fairly simple. In the following sections, we will review the steps for establishing a push-pull plot in the first season, then managing it over the second and subsequent seasons.

First season

Land preparation (first season)

- Clear your land during the dry season.
- Measure out your push-pull plot to a maximum size of 50 by 50 m. If you wish to cultivate a larger area, then divide it into multiple push-pull plots of no more than 50 by 50 m in size.
  The push-pull strategy will work for smaller plots, but should not be used on plots less than 30 x 30 m in size, as the Napier grass will have a shading effect on the maize crop.
- Before the start of the rainy season, plough and harrow your land to very fine soil particles. This is important, as Desmodium has very small seed that grows best in fine soil.

Figure 3.19 Layout of push-pull plot.



Planting (first season)

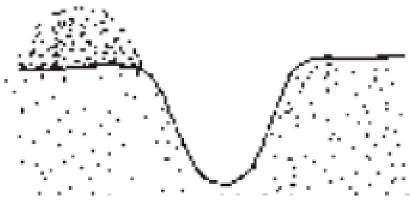
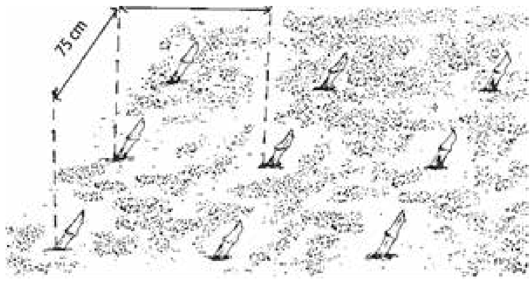
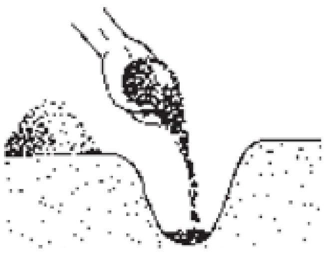
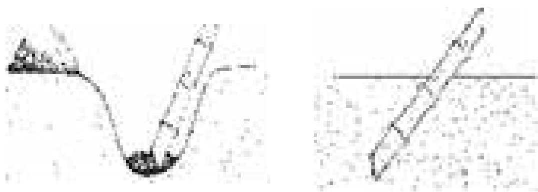
Before planting, ensure that you have all of the necessary materials:

- Maize seed
- Desmodium seed (you will need 1 kg of Desmodium seed for 0.4 ha of land).
  - In case you do not find Desmodium seed, then you can use Desmodium root splits or cuttings from any neighbouring farm. Planting of the splits or cuttings should be done when there is enough soil moisture to ensure good establishment. To make a Desmodium cutting, cut the stem of the mother plant so that it has at least two internodes.
- Napier grass root splits or canes. The Bana variety is recommended. Ensure that the plot from which you are getting the planting material is not infected with Napier grass diseases. Diseased Napier grass plants are yellowish, stunted plants with short internodes. The leaves are very narrow. The disease is carried by a micoorganism (phytoplasma) and is transmitted by an insect leafhopper called *Maiestas banda Kramer*, which is not yet known.
- Triple superphosphate or single superphosphate fertilizer or farmyard manure.

Clean Napier grass planting materials can be obtained from Kenya Agricultural and Livestock Research Organization, ICIPE-TOC Mbita, Ministry of Agriculture, the Ministry of Livestock and Fisheries Development or other farmers. Desmodium seeds can be purchased from the Western Seed Company Ltd., Kitale, Kenya.

Planting Napier grass

Figure 3.20 Planting Napier grass.

1	2
 In the first year, plant Napier grass before the rains so that it will already be in place before the maize emerges. This will provide the young maize plants with protection from stemborer moths.	 Plant three rows of Napier grass around the edge of the plot. The spacing should be 75 cm between rows and 75 cm between plants within a row.
3	4
 Apply one teaspoon of triple superphosphate fertilizer or 2 handfuls of well decomposed farmyard manure in each hole before planting Napier grass.	 Place a three-node cane ensuring two nodes are covered into the ground or place the root splits into the planting holes and cover with soil.

Planting maize

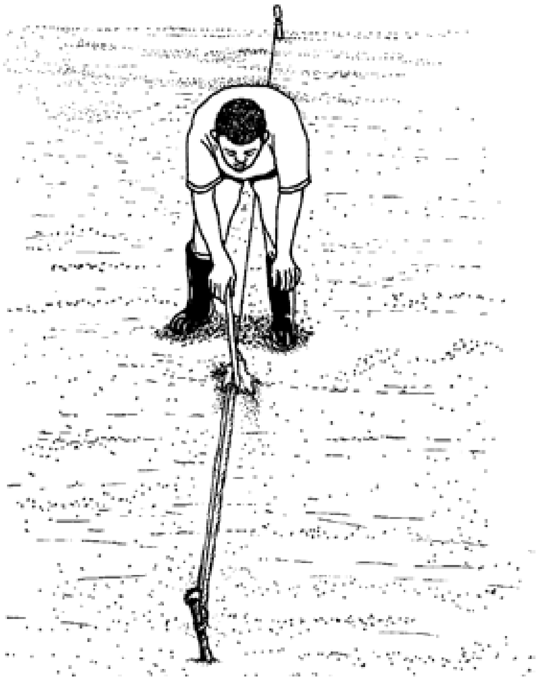
- Wait to plant maize until the field is already surrounded by Napier grass. Leave at least 1 m of space between the Napier grass and maize.
- Space the rows of maize 75 cm apart, with 30 cm between the hills in each row.
- Plant two maize seeds per hole and then thin to one plant per hill after the first weeding.
- Apply one teaspoon of triple superphosphate or two teaspoons of single superphosphate per hole.

Figure 3.21 Planting maize surrounded by Napier grass.

Planting Desmodium

- Plant Desmodium at the onset of the rainy season for maximum germination.
- Plant the Desmodium in rows between the rows of maize (with 37.5 cm between the Desmodium and the maize rows on each side). A single row of Desmodium should also be drilled on all sides of the outer rows of maize. Again, the Desmodium and maize should not be planted in the same row.

Figure 3.22 Making rows for drilling Desmodium seeds.



- Mix the Desmodium seeds with an equal portion of superphosphate fertilizers. If you cannot afford fertilizer, just mix 1 part Desmodium seed with 3 parts fine dry sand. Sow it into the furrows you made and cover with a light amount of soil. 1 kg of Desmodium seed should be enough to cover 0.4 ha of land.

Figure 3.23 Mixing Desmodium seed with dry soil or sand for drilling.

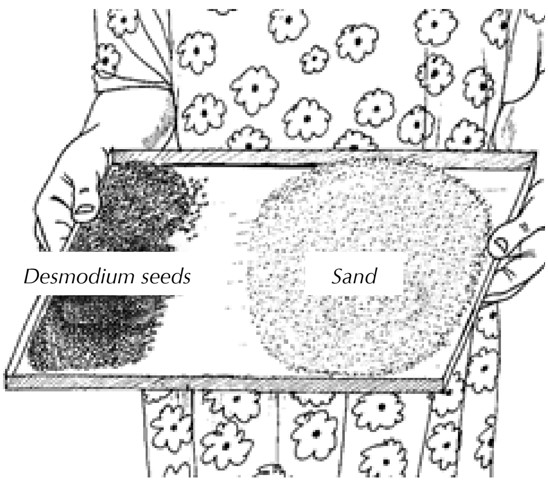
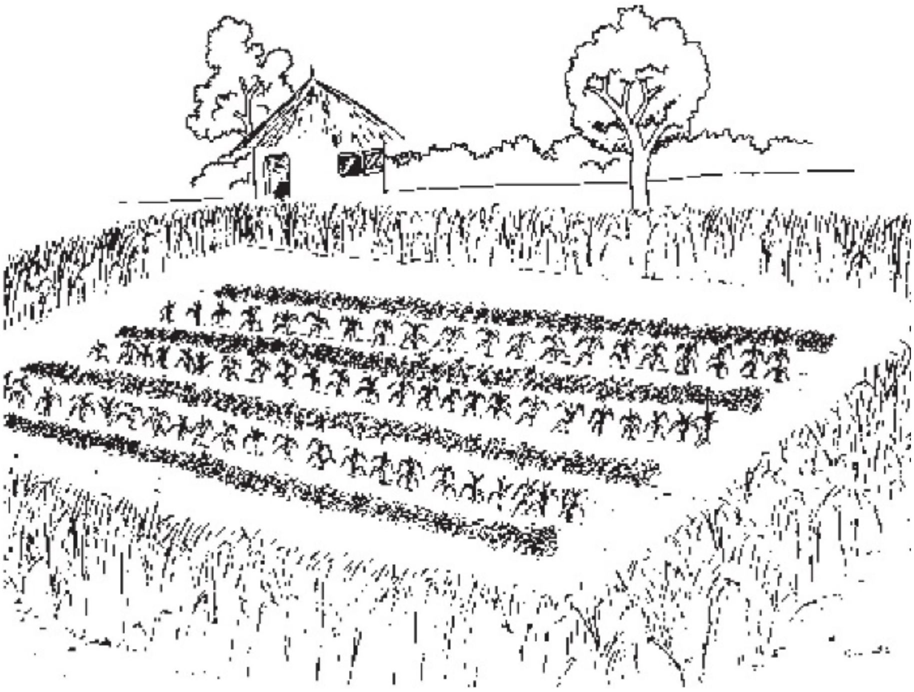


Figure 3.24 Alternate Desmodium and maize rows.



Weeding (first season)

Early weeding is very important for the successful establishment of a push-pull plot. Carry out the first weeding when the maize is 3 weeks old and the second weeding when the maize is 5 weeks old.

First season, first weeding

- At this stage, hand-picking of weeds is recommended to avoid damaging plants along the drilled Desmodium line.

Figure 3.25 Hand weeding Desmodium rows and weeding the space between maize and Desmodium with a hoe.

- Thin maize to one plant per hill.
- Napier grass rows should also be weeded.
- In striga-infested areas, apply nitrogen fertilizer (CAN) to the maize at the rate of one teaspoonful per plant after the first weeding.

Figure 3.26 A push-pull plot after the first weeding.

First Season, Second Weeding

- The second weeding should be done when the maize is 5 weeks old.
- Napier grass rows should also be weeded again.
- Top-dress the maize and Napier grass with CAN fertilizer at the rate of one teaspoonful per plant.
- Care should be taken again to distinguish between Desmodium and weeds.

Figure 3.27 Push-pull plot after second weeding.

Differentiating Desmodium from weeds

During both weedings, you need to be careful not to mistake Desmodium plants for weeds. Below, find depictions of Desmodium at various stages of maturity. If in doubt, consult the nearest extension staff.

Figure 3.28 One-week-old silverleaf Desmodium (left) and greenleaf Desmodium (right) plants.

Figure 3.29 Five-week-old silverleaf Desmodium (left) and greenleaf Desmodium (right) plants.

Crop management (first season)

Napier grass

- You can start harvesting Napier grass when it is 3 months old or 1-1.5 m high after planting.

Figure 3.30 Farmers start harvesting Napier grass when it is 3 months old.

- Start with the inner row nearest the maize and harvest this row around the field first. Leave a stem height of 10 cm from the ground at harvesting to encourage it to re-grow quickly.

Figure 3.31 Cutting of the inner row of Napier grass while leaving the two outer rows.

- After the first forage has been harvested from the inner row, you can start harvesting the second row. This gives time for the inner row to grow again.

- The third row should be harvested only when the inner row is again 1–1.5 m high. This will ensure that there is always Napier grass of approximately 1–1.5 m high to trap the stem borers.
- The inner row can be harvested again when it reaches 1–1.5 m high, which means a period of 6-8 weeks between cuts.
- Always chop the fresh harvested Napier grass and Desmodium to reduce wastage while feeding it to the livestock.

Maize

- Harvest the maize once it attains maturity.
- Maize stover (stalks) left over after crop harvest can be used as livestock feed, particularly during the dry season.
- Always store the maize stover in a dry place to minimize spoilage.

Desmodium

- After harvesting your maize crop, Desmodium can either be harvested as forage for livestock, or left to produce seed before it is harvested for forage.

Leaving Desmodium for seed production

Figure 3.32 Flowering/podding Desmodium after harvesting maize.

- If your Desmodium is flowering and podding, you may leave it for seed production.
- After harvesting the seed, you can harvest Desmodium forage for livestock feed.

Figure 3.33 Harvesting Desmodium forage after harvesting maize from the field.

- A farmer can get between 600–800 kg of green forage from a 0.4 ha (one acre) push-pull plot.
- In areas were the dry season is not severe, only cut enough Desmodium needed for your livestock each day. However in areas where the dry season is severe or long, cut the whole field and make hay.

Harvesting and processing Desmodium seed

One acre 0.4 ha (1 acre) of well managed and properly harvested Desmodium seed crop can yield 50-60 kg of seed. This can earn a farmer a very good price at market

- Harvest the seed weekly once the pods have turned brown. Hand-strip the ripe pods and place seeds in a tin.

Figure 3.34 Harvesting of Desmodium pods.

- Sun-dry and then thresh the Desmodium pods using a stone and an old rubber shoe sole

Figure 3.35 Sun drying of Desmodium seeds.

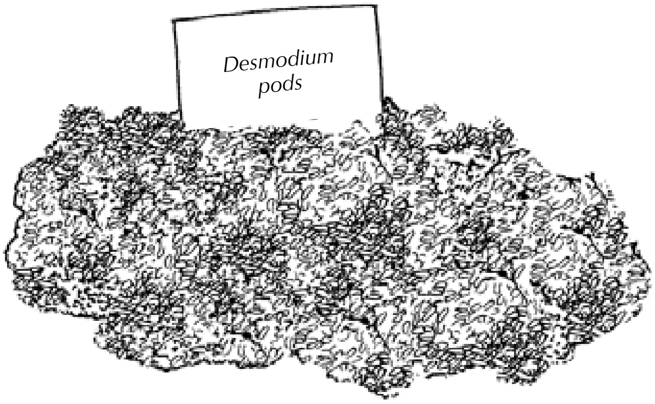


Figure 3.36 Threshing of Desmodium seeds on a stone using an old slipper.

- Winnow to get clean seed.

Figure 3.37 Winnowing Desmodium seeds.

- Store in dry, clean tin or airtight container.

Figure 3.38 Store Desmodium seed in a clean tin or airtight container.

In areas where moles and rats (rodents) are a problem, after the first season's harvesting, cut all the Desmodium and Napier after harvesting the maize and feed to your livestock.

Planting (second and subsequent seasons)

Figure 3.39 Push-pull plot ready for planting maize during the second season.

- Plant maize in between Desmodium rows at a spacing of 75 x 30 cm (Figure 3.22).
- Apply TSP or DAP fertilizer on the maize at the rate of one teaspoonful per hill as top dressing.

Figure 3.40 Newly planted push-pull plot during the second season.

Second and subsequent seasons

After establishing a push-pull plot, if you follow a good management regime, you should be able to produce Napier grass and Desmodium in addition to maize for 5 or more years.

Land preparation and planting (second and subsequent seasons)

- Continue cutting and utilising Napier grass, starting with the inner row as before and weeding the cut Napier lines.
- Apply farmyard manure or CAN fertilizer after cutting and weeding.

- Cut back the Desmodium and feed to livestock. Clear the land of maize stover and feed to livestock.
- Before planting maize, dig or plough between the rows of Desmodium. Care should be taken not to disturb / uproot the Desmodium lines as Desmodium is a perennial crop (Figure 3.40).

Weeding (second and subsequent seasons)

Weeding continues to be a priority in the second and subsequent seasons, with the added concern of making sure that Desmodium does not grow out of control and threaten neighbouring crops.

Second season, first weeding

- Weed the maize when it is 3 weeks old. Napier grass and Desmodium should also be weeded at this time.
- Desmodium at this stage can smother maize if not trimmed. It is recommended that you trim it when the maize is 3 weeks old.
- Thin maize to one plant per hill.
- In striga-infested areas, top-dress the maize with CAN fertilizer at the rate of one teaspoonful per hill.

Second season, second weeding

- The second weeding should be done when the maize is 5-6 weeks old.
- Desmodium should be trimmed again at this stage.
- Top-dress the maize with CAN fertilizer at a rate of one teaspoonful per hill.

Crop management (second and subsequent seasons)

Napier grass

- Continue harvesting Napier grass for your livestock 6-8 weeks after the onset of the rains.
- Start cutting the inner row, followed by the middle row, then the outer row.
- Always maintain a 1 m high row of Napier grass surrounding the tender maize, and be sure to give time for the previously cut row to grow before cutting the next.
- Caution: Leaving maize without a Napier grass border or row of 1 m high will encourage stemborers to attack your maize.

Maize

- Continue harvesting maize upon it reaching maturity.

Desmodium

- After the second trimming (5-6 weeks after planting maize), leave the Desmodium to grow until the maize is harvested.
- The rest of the management practices are similar to those for the first season.

General recommendations

Below are some general recommendations for applying the push-pull strategy.

- Do not trim Desmodium during the first season.
- Do not graze livestock in the push-pull plot, because animals will destroy the Napier grass and Desmodium.
- Do not intercrop Desmodium with Napier grass in the same row.
- Do not plant any other crop with the Napier grass.
- Do not allow Desmodium to spread into the maize rows in the second and subsequent seasons until the maize is 6 weeks old. This reduces the competition between the two crops.
- Never cut all the three rows of Napier together. This avoids 'windowing'. Always cut one row all around your maize at a time.
- Do not let Napier grass over-grow because it will not be effective in controlling stemborers and will become hard and coarse for cattle to feed on.
- Do not plough under the Desmodium rows. Replanting the Desmodium is very expensive and is not necessary as it can grow for up to 5 years or more.

Additional infromation can be found at www.push-pull.net

Doubled-up Legumes

Advantages of intercropping legumes

You are probably familiar with the practice of "intercropping", or growing two or more crops together in a field. The main advantage of intercropping is that it allows you to produce more crops for forage, food or income from a limited amount of land. Being able to grow crops on the same land as others is helpful, especially since it might not be worth cultivating certain crops if you had to devote land to plant them on their own.

Usually, intercropping involves a cereal or forage grass like maize and a legume like groundnut or cowpea. However, there have been many successful experiments recently with farmers intercropping two different legume crops. Certain combinations of legumes have beneficial interactions that allow these "doubled up" legume crops to produce more than either crop would produce on its own.

Intercropping pigeon peas with other legumes

Most double-up legume systems involve pigeon pea plus another legume. Pigeon pea can be intercropped with either groundnuts or soybeans without the two crops competing too much for water, nutrients and sunlight.

The reason why this combination works is because pigeon pea grows very slowly for the first 2 months after planting and does not start rapid growth until the soybean or groundnut crop is already near maturity. Groundnuts or soybean mature about 4 months after planting and are typically harvested in the month of May. After this pigeon pea continues to grow as a sole crop, forms pods, and will be harvested later.

Another benefit is that both legume crops add fertility to the soil. By "doubling up" fertility, a farmer can boost the output of his or her farm while adding an extra legume crop to supplement household nutrition or income.

Cultivating double legume crops

Both the soybean/groundnut crop and the pigeon pea crop will be planted on the same day.

Planting soybeans with pigeon peas

Step 1: Planting soybean: Soybeans need moist soil for germination. They must not be dry planted and should not be planted until it is clear that the rainy season has properly started (i.e., wait until after a few days of rainfall!).

Ground preparation: Make ridges that are 75 cm apart, just as for maize, so that the normal ridging system is not disrupted by the production of soybeans. Avoid ridges wider than 75 cm as this wastes land.

Planting: Remember to use Rhizobia inoculants if you are using varieties that require inoculation (see how to grow soybean guidelines for details)

Plant soybean on 2 shallow farrows (3 cm deep at most) that can be made with a stick on each side of the ridge. Two rows per ridge (instead of only one) will ensure a high plant population (over 250,000 plants per hectare), resulting in good soybean yields.

Within a row, drop (sprinkle) the soybean seeds at about 5-8 cm apart. These seeds must be planted no more than 3 cm deep, otherwise germination will not be good. About 90 kg of seed is required to plant one hectare (about 35 kg per acre). A farmer planting 30 x 40 m field size requires only 10 kg soybean seed For varieties with small seeds, less quantities of seed will be required.

Weeding: Weeding should be done at least twice, especially early in the season. Soybeans have ability to shade out other plants, so high soybean population is helpful to control weeds.

Step 2: Planting pigeon peas with soybean

Planting: On the ridges already planted with soybean, plant 3 pigeon pea seeds per planting station, 90 cm apart. This single row of pigeon pea must be at the center (top) of the ridge. Only 8 kg pigeon pea seed is required to plant 1 ha of a soybean/pigeon pea doubled up system. A farmer planting 30 x 40 m field size requires only 1 kg pigeon pea seed.

Done properly, this should result in about 44,000 plants/ha.

Planting groundnuts with pigeon peas

Step 1: Plant groundnuts: If maximum yields are to be realized, groundnuts must be planted early, with the first effective rains. A delay in planting will cause a marked drop in yield.

Ground preparation: Make ridges that are 75 cm apart (just as for maize and soybean), so that the normal ridging system is not disrupted by the production of groundnuts. Avoid ridges wider than 75 cm as this wastes land.

Planting: Plant two rows of groundnut on either side of each ridge, at about 5-8 cm depth. The depth of planting is important. If the seeds are planted too shallowly it will result in patchy germination as the surface soil can dry out if there is no further rainfall after planting. Planting too deeply will delay germination

Within each row, plant groundnut seeds at 10-15 cm apart.

Planting in this way will ensure high plant populations (> 200,000 plants/ha), and good harvests

Seed requirements per hectare range from 80-100 kg, depending on the groundnut variety and seed size. A farmer planting 30 x 40 m field size requires only 10 kg groundnut seed.

Weeding: Keep fields weed-free by early weeding and pulling off late weeds by hand from the field

Step 2: Planting pigeon peas with groundnuts

Planting: On the ridges already planted with groundnuts, plant 3 pigeon pea seeds per planting station at 90 cm spacing. This single row of pigeon pea must be at the center (top) of the ridge.

A farmer planting 30 x 40 m field size requires only 1 kg pigeon pea seed.

Planting in this way should result in about 44,000 plants/ha.

In this intercrop, groundnuts are harvested earlier, and then the pigeon pea remains as the only crop in the field. The benefit of the pigeon pea to next year's crop on that field (usually maize) is due to the large amount of pigeon pea leaves that fall to the ground as the crop matures and adds a lot of organic mulch that enriches soil fertility.

Fertilizer management: When a doubled-up legume crop of pigeon pea plus soybean or groundnut is grown in rotation with a crop that had received NPK fertilizer the previous season, there is no need to apply any additional fertilizer.

There is no need to apply urea fertilizer on doubled-up legumes, as the legume crops naturally manufacture their own urea. Urea should be saved for other crops (e.g., maize) that require it.

Harvesting and residue management: In doubled-up legume crops, the soybeans or groundnuts are harvested earlier, and then the pigeon pea remains as the only crop in the field. Harvest pigeon pea when the pods are brown. Sometimes, pods that are ready to harvest will produce a rattling sound upon shaking.

Figure 3.41 Groundnuts, pigeon peas, soybeans.

At maturity, there will be a carpet of pigeon pea leaves on the ground. The leaves will provide nitrogen fertilizer for the next crop. Therefore, it would be wise to plant maize or another crop on this field next season.

Never burn the residues. This wastes all of the fertilizer that the pigeon pea crop can provide. Instead, leave the residues to enrich the field as mulch or to produce more manure through composting

e. Preservation: Silage making–sweet potato vines

Sweet potato normally has a high risk of spoilage due to its high water content. However, there are special methods for creating sweet potato silage that allow for the preservation of the vines and roots within a silo. Well-made sweet potato silage can provide nutritious feed for dairy cattle. Sweet potato silage consists of chopped, fermented vines and roots. The chopped vines and roots should be combined in a ratio of up to 30% roots or a grass like Napier. A ferment starter, like molasses, is then added to aid the process of fermentation and increase nutrient content.

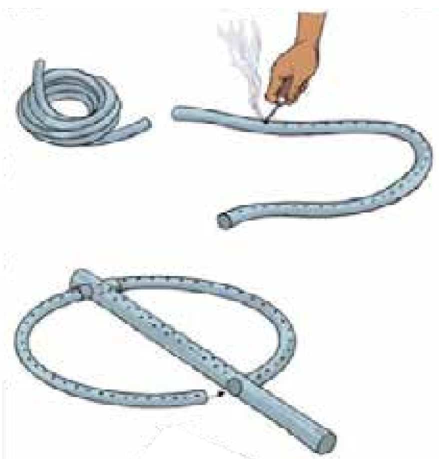
The keys to preserving sweet potato silage are making sure that it is not exposed to air and that excess water does not accumulate in the bottom of the container. To accomplish this, you will need to construct a special type of plastic tube silo. One of these silos should hold up to 500 kg of chopped, well compacted silage.

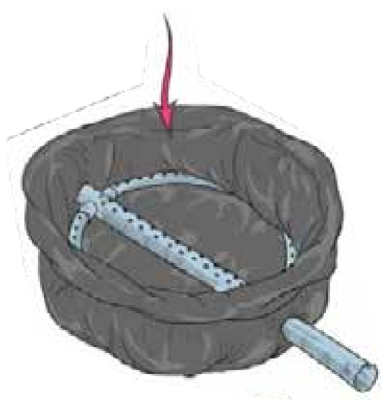
Building a silo: To make an improved plastic tube silo you will need:

- One 95 cm length, 4 cm diameter plastic (PVC) pipe (your drainage pipe).
- 2.5 m of 1000 gauge silage tubing (made of polythene), sold in 1 m diameter rolls.
- 2.3 m of flexible rubber tubing, 2.75 cm in diameter.
- One 4 cm plastic tap which should have the same diameter as the pipe or a piece of soft wood if a tap is unavailable.
- A metal rod 0.9 cm in diameter for making holes on the PVC pipe.
- 7 m of sisal twine.
- 3 wooden poles (can be cut locally), at least 1.2 m in length and 5 cm in diameter.
- 2 used 200 liter empty drums.
- 10 kg of molasses.
- 30 liters of water.
- 2 nails (length, 6 cm).
- 375 kg of fresh vines and 175 kg of fresh storage roots or napier grass or similar to make 500 kg silage.

Step 1: In the drainage pipe make 2 holes using a knife (4 cm from one end and 8 cm from the other end – this end will serve as the outlet), each 2.75 cm in diameter (the same as the diameter of the flexible pipe), and one on each side of the pipe as shown in the figure below.

Figure 3.42 Making the internal drainage system for the silage tube.





Step 2: Heat the nails with a wood or charcoal fire. Drill small holes for drainage using the hot metal rod through the PVC pipe and in the flexible rubber tubing at intervals of 1 cm throughout their entire lengths as shown in Figure 3.42 ans 3.43.

Step 3: Pass the rubber tubing through the top holes in the drainage pipe, so that the open ends of the tubing align at the bottom of the pipe as shown in the figure below.

Figure 3.43 Assembling the internal drainage system for the silage tube.

Step 4: To make a good seal at the bottom of the silage tubing, first open up the tubing. Then on one open end (that will be the bottom of the tube), make even pleats about 20 cm long starting from the end towards the centre on each side of the tubing. Then twist the pleats together and tie off with the rope making a strong knot. Then turn the tubing inside out, so that the tied knot is on the inside.

Figure 3.44 Sealing the bottom of the silage tube.

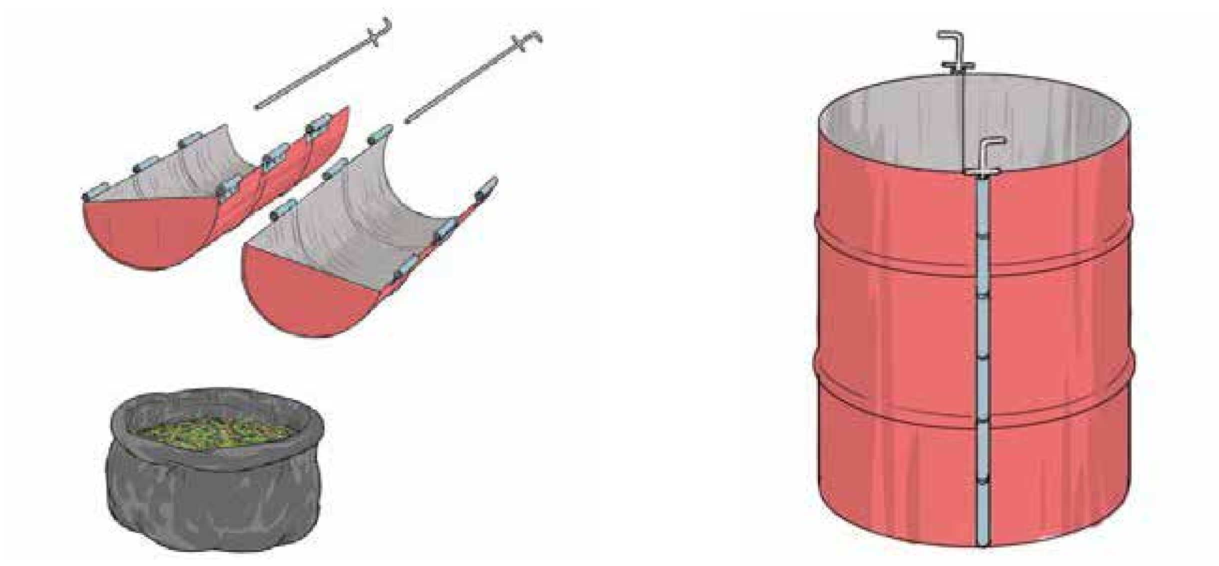
Step 5: Make a 3.5 cm diameter hole using a knife at the side of the tube, about 43 cm from the tied knot. Then take the joined drainage pipe and rubber tubing and fit it into the inside of the silage tubing so that the bottom of the drainage pipe goes through the newly made hole, extending about 20 cm beyond the hole. Using the twine, tighten the plastic around the drainage pipe as shown below.

Figure 3.45 Making the external drainage system of the silage tube.

Step 6: Fit a plastic tap or a piece of soft wood to the bottom of the exposed drainage pipe so that no effluent can flow out when the tap is turned off.

Step 7: To make a compacting drum measuring 86 cm in diameter and 120 cm in height first remove the top and bottom of each drum to make it hollow. Look for a shaded place to make and store the silage. Then cut each oil drum on one side, so that when joined the total diameter matches that of the silage tubing. To join the 2 drums together running lengthwise, have a welder make on each side 3 joints and one 75 cm long rod bent on one end to fit through the joints as shown below.

Figure 3.46 Making the compacting drum.



Step 8: Place the silage tubing inside the closed compacting drum, letting the excess tubing fold over the sides of the drum at the top. Ideally, the diameter of the tubing should be the same as or slightly larger than the drum for best results.

Figure 3.47 Placing the silage tube inside the compacting drum.

Step 9: To prepare the material for ensiling, chop the sweet potato vines and roots to be ensiled into pieces not more than 2.5 cm long.

Figure 3.48 Preparing sweet potato vines and roots for ensiling.

Step 10: Prepare the molasses and water mixture by mixing 10 kg of molasses with 2–3 times as much water until the mixture can flow easily.

Figure 3.49 Preparing molasses.

Step 11: Fill the tubing with alternate layers of the chopped vines and roots and the molasses/water mixture. Each layer of vines and roots should be 20–30 cm high; then sprinkled with the molasses mixture until it is thoroughly wet on top. Each layer must be compacted before adding the next layer. One person can compact using feet as shown in the figure below.

Figure 3.50 Compacting the sweet potato vines and roots in the tube.

Step 12: Bunch the excess tubing at the top together, remove all excess air so the plastic is in touch with the ensiled material and tie a tight knot, using the twine.

Place heavy stones on top of the silo to ensure continued compaction during fermentation.

Figure 3.51 Sealing the tube after ensiling.

Step 13: Remove the rods to remove the compacting drum. Anchor the filled tube silo with three poles to prevent the silo from collapse due to drainage of excess effluent from the silo.

Figure 3.52 Anchoring the silage tube firmly on the ground.

Step 14: For the first five days, open the drainage tap daily and leave open until all the effluent comes out, then close (Figure 3.14). Then open the tap every 4–5 days thereafter and let any effluent come out. Fermentation is usually complete after 30 days.

Figure 3.53 Removing excess effluent from the silage tube.

Determining silage quality

Well-prepared sweet potato silage is bright or light yellow-green in color, has a strong smell similar to that of fermented milk and a firm texture. Poor quality silage tends to smell similar to rancid butter or ammonia.

Sweetpotato tube silage should be stored under shade, for example in a store. Rodents like rats that could tear the tube need to be controlled. When feeding, open the tube and after removing the amount needed, remember to re-tie without trapping air inside.

Figure 3.54 Anchoring the silage tube firmly on the ground.

Haymaking

The goal of haymaking is to capture the nutrients in grass in a storable form to make them available as a forage feed in the winter months/dry season.

Timing: One of the most critical factors in making quality dry hay is timing. Producers need to time haymaking to coincide with the right stage of plant growth and weather conditions. Although maximum growth of the plant and peak yields occur around that time, the nutrient value is greatest earlier in the season, when plants put most of their energy into vegetative growth and contain high concentrations of starches, proteins and minerals. As plants mature, their lignin content (a component of fiber) increases and traps the nutrients within indigestible cell walls. Although cutting hay early will result in lower yields, the increase in nutritive value will compensate for reduced yields. The second, third and fourth cuttings that grow back are leafyand high in quality and often harvested when the weather is hotter, making the hay easier to cure. Sometimes growers need to make a little sacrifice by getting an early first crop from the field during periods of rainy, early summer weather in order to get the next crop growing.

Mowing: The first step in haymaking is mowing the hay. The maturity of the grass is the determining factor for starting the first field of the season. The grass should be in the early vegetative stage, and not headed out, with enough growth to make mowing worthwhile.

Tedding: Once the hay starts to dry, it needs to be worked to promote curing. Tedding, the next step in hay making, fluffs up the cut hay and allows the air and sun to contact the under-surfaces to promote.

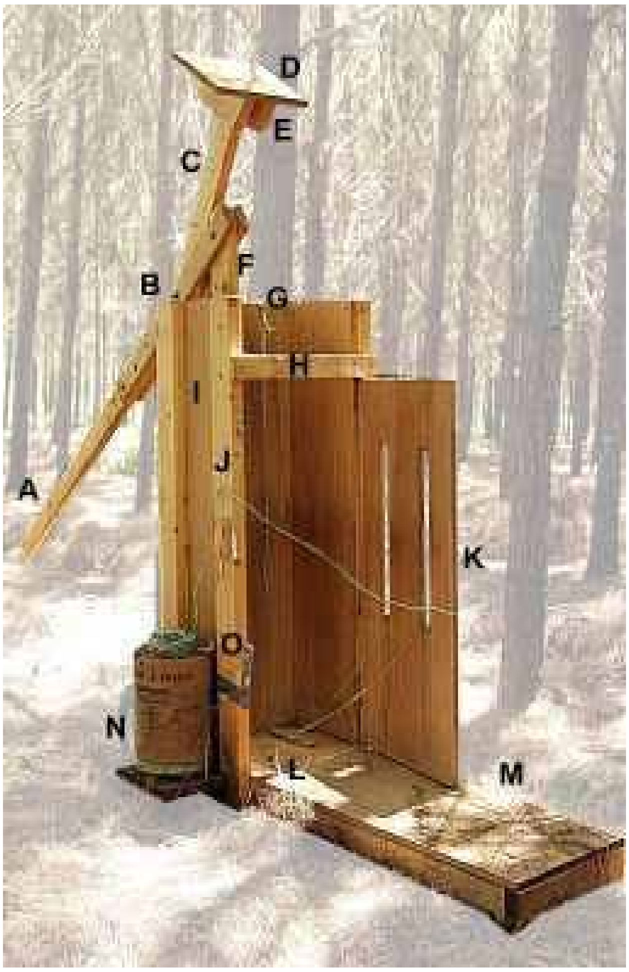
Drying: Some people ted immediately after mowing to spread out the swath. Hay mowed early in the morning could be tedded that afternoon, as long as the mowed swath is dry on the top surface. It may require a second tedding the next day to speed up the drying process. Too much tedding can shatter leaves of alfalfa or clover, lowering the quality of the hay. Proper tedding can be the key to timely haymaking.

Raking: Once the hay has been tedded and is nearly dry, it is ready to rake. Raking turns the hay one more time to dry the bottom and forms it into a windrow ready to be baled. The windrows shouldn't be rolled too tightly, as this creates a roping effect that prevents the hay from drying properly and causes it to clog as it enters the baler. As a rule of thumb, wait to rake hay until after the dew has dried and the sun nears its peak, or around 11:00 am. If possible, let the raked hay sit for an hour or two before baling to allow more drying time. Haymakers have several types of rakes available.

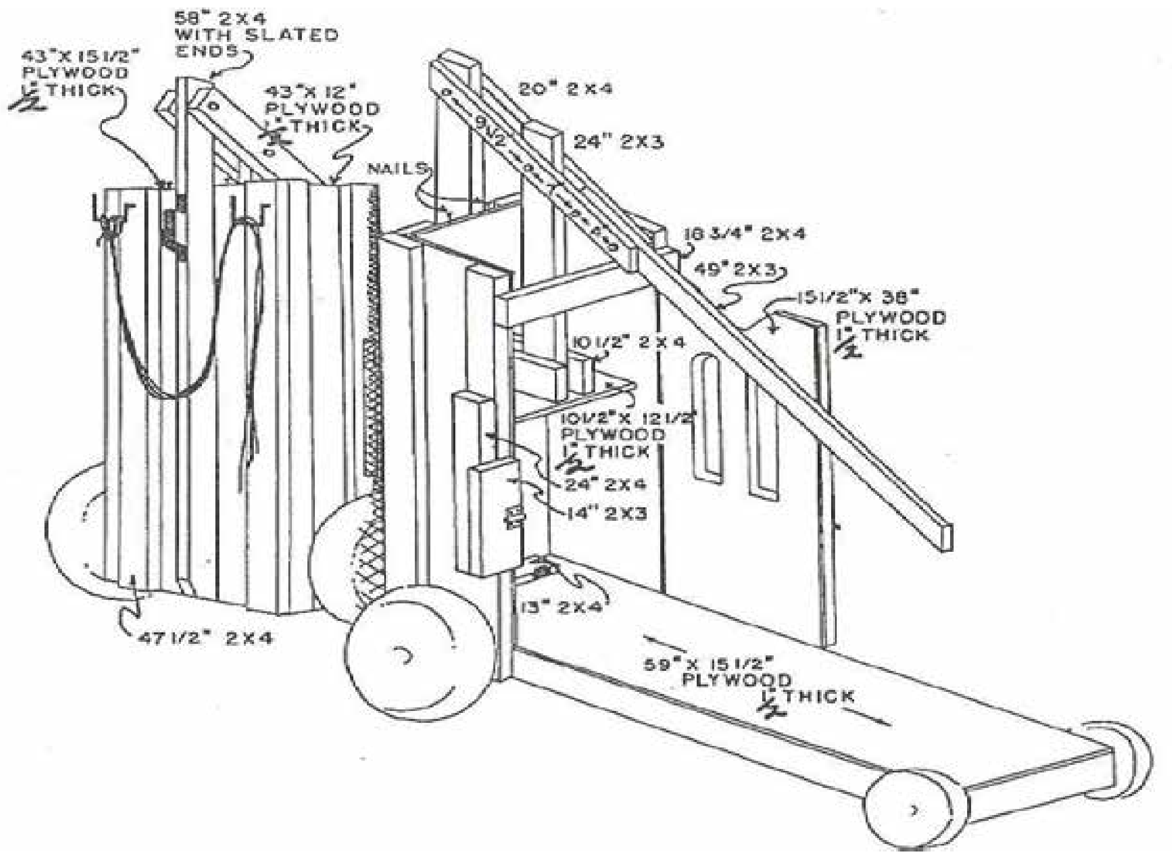
Baling: Science and art converge in haymaking with the critical decision of when to start baling. Baling hay too early will trap moisture in the bale and result in spoilage. Baling too dry will cause leaves to shatter and break, lowering hay quality. It takes close visual observation and handling of clumps of hay from several windrows to "feel" if it is ready. Hay ready to bale will have no bunches of green grass. It will have a brittle, crisp feel. To test its readiness, grab a clump of hay and hold one end of the clump in each hand. Pull vigorously with both hands. If the stalks break on the first pull, the hay is ready to bale. If it takes several pulls, it's still too green. It takes a clear, sunny day to make hay. Although you may feel tempted to speed up the haymaking process when it is overcast or sprinkling lightly, it isn't worth the risk of baling hay that will mold.

Improperly cured hay (hay above 22% moisture) can also heat in the barn and cause a fire by spontaneous combustion. Generally hay is baled at a moisture content between 15 percent to 18 percent. Hay stored at more than 22% moisture in a barn or stack is at risk of spontaneous combustion. x

Figure 3.56 Details of haymaking machine.



Part	Description	Stock (cm)	Length (cm)
A	Handle	5 x 7.5	125
B	Lever		
	bolt 1-2	5 x 7.5	24
	bolt 2-3	5 x 7.5	18
C	Compressor Arm	5 x 10	60
D	Compressor Pad	12 mm plywood	27 x 32
E	Pad supports	5 x 10	27
F	Lever fulcrum	5 x 10	50
G	String holder see Fig. A-2	Nails	6.5
H	Front brace	5 x 5	46
I	Plywood sides	12 mm plywood	110 x 30
	Plywood back	12 mm plywood	110 x 40
J	Corner Supports	5 x 10	110
K	Door	12 mm plywood	40 x 97
L	String retainers see Fig. A-3	I-bolts	2.5
M	Deck	12 mm plywood	150 x 40
N	String	nylon	



f. Urea mineral molasses blocks

Supplementing dairy cattle's nutrition with urea mineral molasses blocks

Even when cultivating your own forages, it can be difficult to provide dairy cattle with all of the protein, minerals and vitamins necessary for them to stay healthy and produce high-quality milk. Sometimes this is because the forages do not contain all of the nutrients the animal requires. Other times, it is because the animal has difficulty digesting the forages, reducing the amount of nutrition the animal actually receives.

Supplementing an animal's diet with urea mineral molasses blocks (UMMB) can provide them with additional nutrients and help them to digest other feeds more effectively. Adding UMMBs to an animal's diet can increase the total amount of nutrition the animal receives by up to 30%.

Ingredients

The common ingredients used in making UMMBs:

- Molasses
- Urea
- Fibrous cereals or forages (bran, finely chopped hay, leaf meal, etc.)
- Salt
- Minerals (e.g., calcium carbonate, dicalcium phosphate)
- Cement (a binding agent)

Molasses gives the UMMB a sweet taste, making it appealing to animals. It also provides energy and other nutrients like sulfur. A UMMB should not contain more than 40–50% molasses or it will break too easily and take too long to dry.

Figure 3.57 Molasses.

Urea is commonly used as a fertilizer for crop production. In a UMMB urea improves digestibility and provides additional protein. The amount of urea should be limited to 10% to avoid poisoning.

Figure 3.58 Urea.

Figure 3.59 Cereal (wheat bran).

Fibrous cereals or forages provide protein and help to hold the block together. Cereal bran is the most common ingredient in UMMBs, though finely chopped hay, finely ground leaves from leguminous shrubs or cotton seed cake can also be used.

Salt is added to UMMBs to supply minerals and control the rate of consumption. Salt should make up no more than 5–10% of a UMMB.

Vitamin and mineral supplements are sometimes added to give the UMMB extra nutrition. For example, calcium carbonate and dicalcium phosphate can be added to provide additional calcium and phosphorus. Dried poultry litter, oilseed cakes or brewery byproducts can be added to supply protein. Trace mineralized salt can be used to provide additional minerals.

Cement is used to make the block hard. A UMMB should only contain about 5–10% cement, otherwise the block will become too hard for the animal to eat. Clay (the type used in brick making) can be mixed with the cement to improve hardness, reduce drying time and reduce the overall cost for making a block.

Making UMMBs

A general formula for UMMB blocks

Table 3.25 UMMB formulas.

Ingredient	Proportion	Amt. for 25 kg block (kg)
Magnesium sulphate	6.25%	1.56
Vegetable oil	1.00%	0.25
Molasses	35.00%	8.75
Urea	10.00%	2.50
Salt	10.00%	2.50
DCP 18	20.00%	5.00
Magnesium oxide	8.25%	2.06
Cottonseed meal	4.50%	1.13
Premix	0.3%	0.07
Cement	5%	1.25

The specific process for making UMMBs can vary slightly depending on local conditions. Generally, the process can be divided into four stages:

- Preparation of ingredients
- Mixing
- Moulding
- Drying

Preparation of Ingredients

The amount of each ingredient depends on the size of the block and the formula being used.

Mixing

Mixing the ingredients well is the key for making good UMMBs. You need to mix the urea thoroughly and break up any lumps, otherwise there will be pockets of highly concentrated urea that could harm animals.

When mixing ingredients, you should:

- Carefully weigh the amount of each ingredient based on the formula you are using.
- Pour the molasses into a container.
  - The molasses can be heated in the sun to improve handling and mixing.
  - Never add water to the molasses. It needs to be thick to make a good UMMB
- Add urea to the molasses while continuously mixing.
  - Stir the urea into the molasses for about 20 minutes.
- Add any fibrous material (cereal bran, chopped hay, leaf meal, etc.) according to the formula and mix thoroughly.
- In a separate container, mix together water and cement to make a paste.
  - Mix the salt into the cement to accelerate hardening.
- Add the cement and any remaining ingredients to the urea-molasses mixture. Mix thoroughly.

Figure 3.60 Mixing urea, molasses and bran.

Moulding

Once the ingredients are thoroughly mixed, place the mixture into a mould. You can use any local container as a mould, such as cardboard box or a bucket. You can line the mould with a plastic sheet to make it easier to remove the finished UMMB.

Figure 3.61 Moulds made from metal sheets, tubes, wood.

Drying and storage

Remove the UMMBs from the moulds after 2 days in the sun then place the blocks on racks to dry. Leave the UMMBs to dry for at least 5 days, depending on weather conditions.

Characteristics of a well-made UMMB

We suggest making a small number of UMMBs for practice before attempting to make a large quantity.

A block is considered to be of good quality when:

- The ingredients are well-distributed throughout the block (it does not have lumps of urea and lime).
- The UMMB is hard enough that it is does not get squashed when you squeeze it between your fingers and does not break when a person steps on it. High levels of molasses and urea tend to make UMMBs soft, so if it is not hard enough try decreasing the amount of molasses and urea or increasing the amount of cement or clay next time.
- You can feel the sticky molasses when you hold the block. If the block does not feel sticky, then you need to increase the amount of molasses next time.

Feeding UMMBs to animals

- Feed UMMBs to ruminant animals (sheep, goats, cattle) only. They are potentially toxic to other animals.
- UMMBs should be fed as a lick, so that only the top surface is accessible to animals. This prevents animals from pushing the blocks around, breaking them up or consuming large chunks that could cause urea toxicity.
- Introduce UMMBs to your animals slowly, after they have already consumed adequate forage. This prevents animals from consuming too much UMMB at any one time.
- UMMBs should never be used as your animals' main source of feed. They are only meant to supplement a regular diet of forages.

- Block hardness is important. If UMMBs are too soft, animals will consume them too rapidly and might suffer from toxicity. If UMMBs are too hard, animals might not consume enough.
- High levels of urea will make UMMBs unpalatable and will make anything else the animal eats afterwards taste bitter, reducing overall intake.
- Excessively high levels or imbalances in minerals may cause animals to consume too much of the UMMBs and suffer urea poisoning.
- Precautions should be taken to avoid this problem of over-consumption in drought-prone areas, particularly towards the end of the dry season when feed is scarce.

Dairy hygiene and milk transport

The importance of dairy hygiene

In previous lessons we reviewed how to identify productive dairy cattle and keep them well-fed and healthy. We also discussed how cultivating forage is a low-cost way to provide cows with the nutrition they need to produce high yields of high-quality milk.

However, simply making sure that cows produce high-quality milk is not enough. All of the time, money and effort that a farmer spends on helping cows produce high-quality milk will be wasted if the milk is contaminated during the milking process or while the milk is transported to market. If the plant rejects your milk due to contamination, you will not earn any income from your milk.

This lesson will review ways to protect the quality of milk during production and transport, so you will be able to sell it at a high price and earn a good profit.

Protecting milk from contamination

Milk is valuable because it is extremely nutritious. Fresh milk contains a mixture of water, sugar, fat, protein and minerals, all of which are essential for helping calves and humans to grow and stay healthy. Dairy farmers can receive good prices for milk, so long as it is fit for human consumption.

Unfortunately, the same nutrients that make milk good for humans can also feed the growth of bacteria. Milk from the udder of a healthy cow contains very few bacteria. However, if even a small amount of bacteria gets into milk, the bacteria will grow rapidly. Contaminated milk can spread disease to people who drink it, making it worthless at market.

To earn a profit, it is critical for farmers practice good dairy hygiene. In the following sections, we will review the contamination risks and safe handling methods for each step of the dairy handling process. The major steps include:

- Preparation
- Milking
- Handling, storage and preservation
- Transportation

Preparation

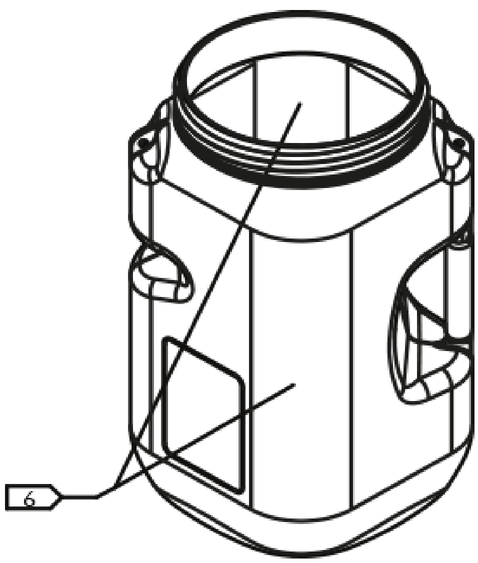
Environment: Dairy farmers should construct a permanent or moveable milking shed (parlor) for milking their animals.

- A permanent shed with a cement floor is ideal, as it is easier to clean.
- Sheds should not be placed in areas with a foul smell, as foul smells indicate that there might be large amounts of bacteria in the area.
- Animals should not be allowed in the shed except during milking.
- The shed should be thoroughly cleaned after every milking.
- When not in use, the floor of the shed should be kept clean and dry.

Equipment

Milk Containers: The best option for collecting, storing and transporting milk is the 10-litre "Mazzi" can. Mazzi cans are a new, improved type of milk container designed specifically to prevent spoilage.

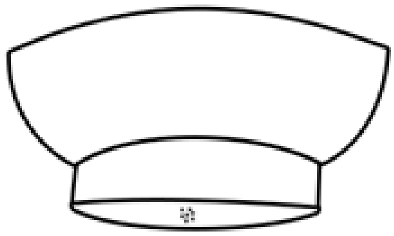
Figure 4.1 Mazzi container.



The advantages of Mazzi cans include:

- Less expensive than metal cans.
- Made of durable, high-quality plastic that can be dropped or kicked without breaking.
- Has a very wide mouth that makes it easy to clean.
- Notches on the side to make it easy to tie to a bicycle or sling over your shoulder.
- Easy-to-read markings on the outside of the can to let you see exactly how much milk is inside.
- Comes with a black funnel designed to fit under a cow's udders, attach securely to the container and make it easier to see signs of mastitis and other contaminants.

Figure 4.2 Mazzi plastic container funnel.



If Mazzi containers are not available in your area, use seamless aluminium or stainless steel cans for milking and storing milk.

Figure 4.3 Metal milk cans.

Do not use regular (non-Mazzi) plastic containers. While regular plastic containers might be less expensive than metal containers, plastic containers are difficult to clean and increase the risk of contamination.

Other utensils

- Keep a separate "strip cup" for testing cows for mastitis prior to milking.
- If available, obtain a thermometer to check the temperature of milk during storage.

Cleaning equipment

When cleaning equipment and containers, always follow the procedures outlined below.

Utensils

- Clean all utensils as soon as possible after milking.
- Rinse with cold water.
- Scrub with a brush using hot water and detergent (un-perfumed liquid soap).
- Rinse with cold water.
- Place on a rack to dry in the sun. Exposure to sunlight will kill additional bacteria during drying.
- Store containers and utensils in a safe, clean and well-ventilated room when not in use.

Containers

Do the following immediately after emptying milk containers:

- Clean all containers immediately after emptying milk. If a container is emptied but not cleaned, there is a high risk that bacteria will begin to grow.
- Rinse with cold water.
- Scrub with a brush using hot water and detergent (any un-perfumed liquid soap).
- Rinse with cold water.
- Sterilize (sanitize) with boiling water or steam (if available) or dairy sanitising solution such hypochlorite or commercial preparations. If using commercial preparations, follow the manufacturer's instructions exactly.
- Place containers upside-down on a rack to dry in the sun. Exposure to sunlight will kill additional bacteria during drying.
- Store containers in a safe, clean and well-ventilated room when not in use.

Milking machines

Milking machines should be cleaned according to the recommendations in the manual. If you do not have the manual for your milking machines, the generally recommended practice is:

- Rinse with cold water.
- Circulate some hot water with detergent through the system (this is known as the the "cleaning-in-place" or "CIP" method). Select detergents and sanitizers that will not corrode the material from which the equipment is made.
- Rinse with hot water.

After each cleaning, examine the machine to see if any of the rubber parts are wearing out. If so, replace them as soon as possible.

Milking

Milking is the most important activity that takes place on a dairy farm. While it takes many seasons to raise a healthy cow and cultivate nutritious feed, all of that effort can be ruined in a few short minutes if milking is done improperly.

Animal health and hygiene

Obtaining clean milk starts with ensuring that the cow to be milked is healthy. An unhealthy cow will produce less milk, and potentially transmit diseases like tuberculosis and brucellosis to people who consume the animal's milk.

Recommendations for keeping animals healthy and dealing with sick dairy cows include:

- Vaccinate animals against brucellosis.
- Check animals periodically for all types of contagious diseases.
- If you suspect that a cow is sick, contact a qualified veterinary practitioner immediately.
- If the veterinary practitioner instructs you to give a cow antibiotics, then do not consume nor sell milk from that cow until the treatment is completed and the withdrawal period is over.

You should also check cows for mastitis. Mastitis is an inflammation of the glands in the udder caused by a bacterial infection. Mastitis can be controlled by observing general hygiene and proper milking procedure.

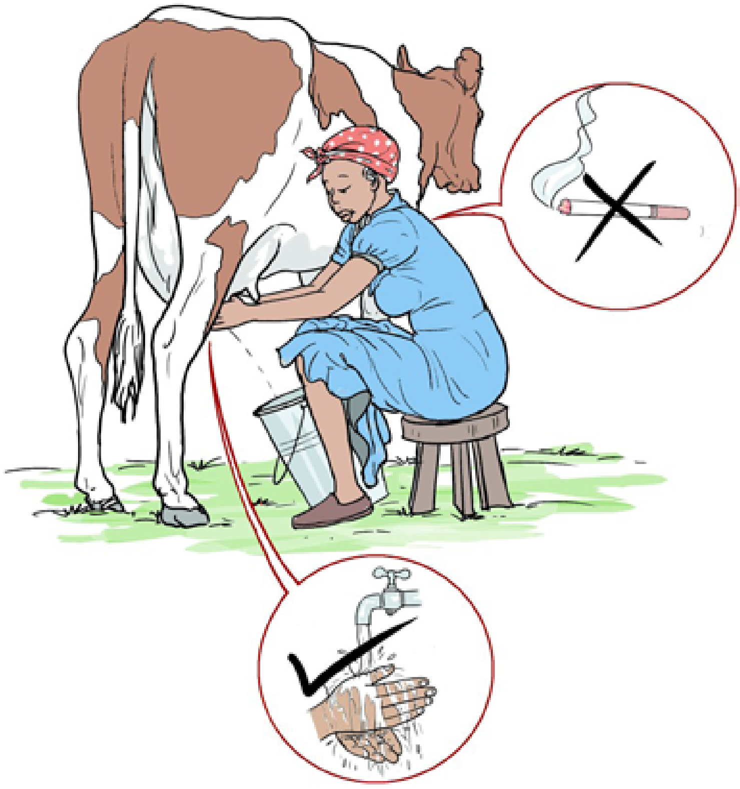
Personal hygiene

It is also possible for a farmer to contaminate milk with bacteria if they are not healthy and clean during the milking process. This is especially true if you practice hand milking.

Make sure that anyone involved in milking cows is healthy and clean. Fingernails should be kept short and people with long hair should cover their heads.

Never smoke during milking time

Figure 4.4 Good milking practice.



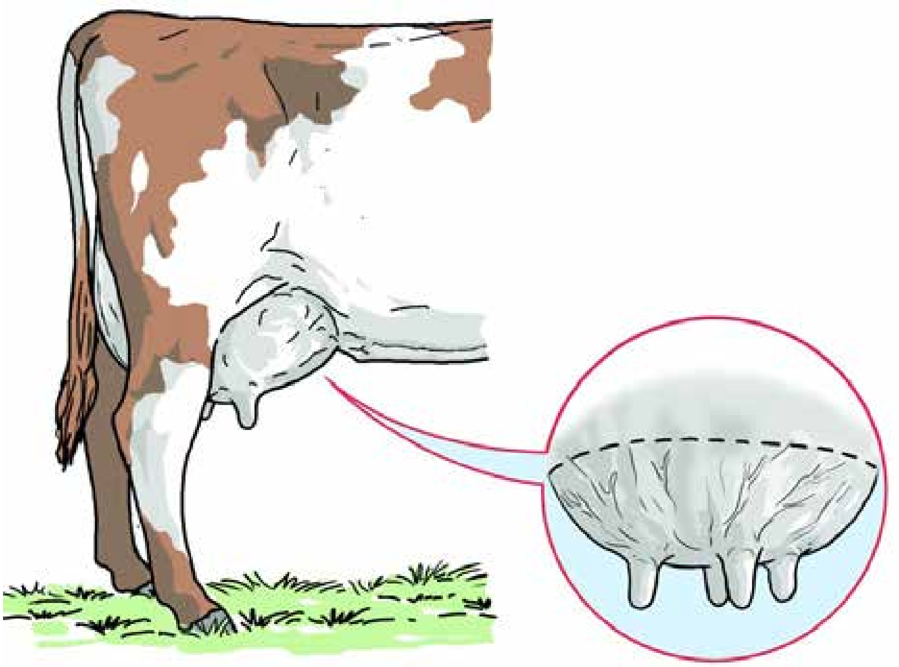
Techniques for milking cows

Milk can be extracted either by hand or by machine. If you use a machine, then follow the operating instructions. Hand milking is an art that requires practice to master.

Whichever method you employ, be sure to:

- Milk your cows frequently, to ensure that excess pressure does not fill up in the gland cistern. Excess pressure will make a cow more difficult to milk.
- Make sure that all of your equipment and containers are clean.
- Lead the cow to the milking parlour as calmly as possible. If an animal is frightened, it will tense up, reducing milk let-down.
- If hand-milking, restrain the animal by tying the hind legs with a loose knot above the hock joint. This will protect both you and the animal.
- Wash your hands thoroughly with soap and clean water then dry with a clean towel immediately before milking.
- Select a moderate-sized, well-shaped (symmetrical) teat. Make sure there is good tension in the muscle at the tip.
- Wash the udder with warm clean water with disinfectant using a clean towel. Warm water also stimulates milk let down. Dry udder using a dry towel.

Figure 4.5 The healthy udder.

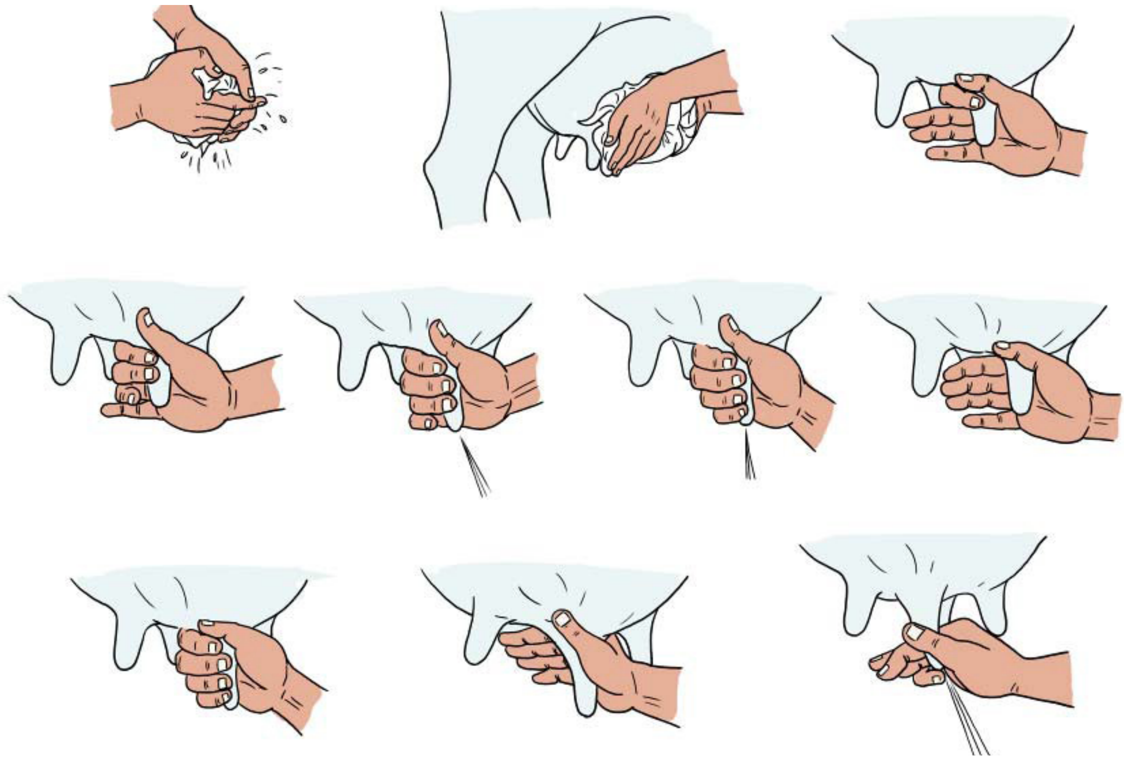


- If you are hand-milking, then we recommend applying some milking jelly to the teat, if available. This will prevent cracking of teats and generally make milking easier.
- Before you begin milking, test for mastitis using a strip cup – strip first few rays of milk into strip cup from each quarter and observe for any abnormalities. If mastitis is detected, then that cow should be milked last.

Figure 4.6 Using a strip cup.

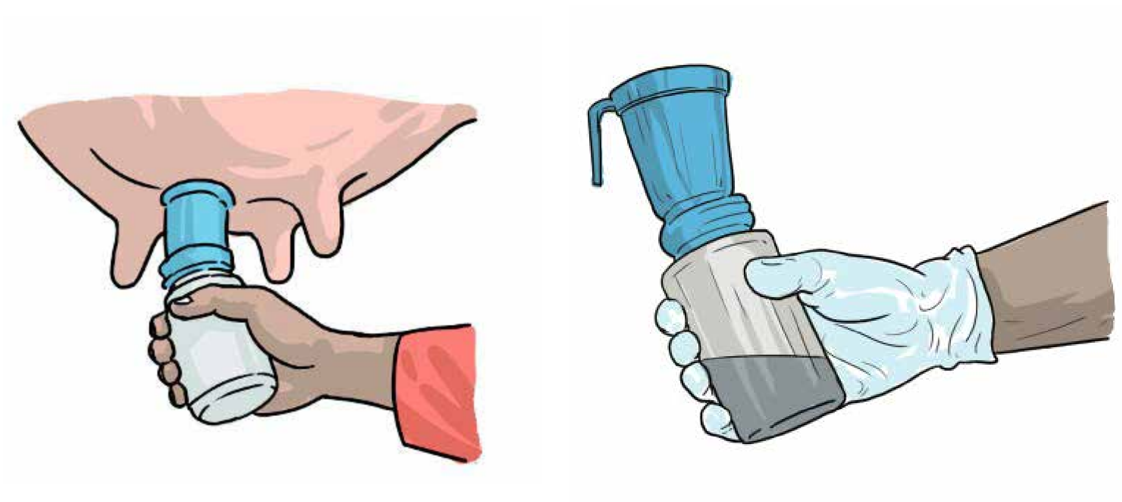
- Once you begin, milk quickly and completely, without interruption. Incomplete milking can lead to contamination and mastitis. Each cow should take 7–10 minutes at most.
- When milking, be sure to squeeze the teat. Do not pull.

Figure 4.7 Step by step method of hand milking.



- When finished, "strip" the animal to get the last drops out of the udder. Failure to do this can lead to mastitis.
- After an animal is done, dip the teats in a teat dip, if available (teat dip is a disinfectant that will prevent bacteria from entering the udder, which is vulnerable to infection immediately after milking).

Figure 4.8 Dipping cow teats in disinfectant.



Make sure that the animal remains in a standing position for at least one hour after milking. If the teat comes into contact with the ground while it is still loose, that risks infection.

Handling and storage

Milk is highly perishable. Even if you keep yourself and your cows clean and healthy and follow proper milking procedures, there remains a high risk of spoilage during handling and storage. To ensure that milk is delivered to the processor in good condition, you should follow these guidelines:

Handling

- Make sure that anyone involved in handling milk is healthy and clean. If someone is sick or dirty, there is a possibility that they will contaminate the milk with disease-causing bacteria. If you are sick, seek treatment and do not resume work until the doctor says you are fit to do so.
- Always handle milk in clean, Mazzi containers.
- When transferring milk between containers, pour the milk directly from one container into the other instead of scooping it with a cup or bucket. Scooping greatly increases the chance of contamination and spoilage.

Storage

Some general guidelines for storing milk include:

- Filter milk immediately after milking and prior to storage: Use a white filter cloth or strainer. Disinfect, wash and dry the cloth/strainer after use.
- Store milk without chemicals in a cool, clean room set aside for milk only. Lock the room if possible to avoid accidental contamination.
- Do not store milk at high temperatures.
- If storing overnight, keep the milk in cold/chilled water.
- Do not mix warm (morning) milk with cool (evening) milk. Ideally, cool and warm milk should be delivered to the collection centre in separate containers. If this is not possible, cool the warm milk by placing the container in cold water before mixing.
- Deliver milk to the market as soon as possible, preferably in the cool morning or evening.

Cooling milk during storage

In a hot environment milk will spoil within 3–4 hours. Lowering the temperature of milk as soon as possible after milking and throughout storage can help to prevent the growth of bacteria.

There are several options for cooling milk:

- Keeping containers under a shade.
- Using cold water (10°C or less) in a bath, a flowing stream or by running it through cooling rings
- Keeping milk in a refrigerator or electric cooling tank.
- Constructing a community cooling centre.

If possible, milk should be cooled down to 20°C or less during storage.

Cooling Milk in the Shade

When cooling milk in the shade, you can loosen the lids of the cans to allow warm air to escape. Keep the lid closed if there are insects or dust in the area, to avoid contamination.

Using water to cool milk

When cooling milk in a cold water bath or stream, you can loosen the lids of the cans to allow warm air to escape. However, you must be careful that no water gets into the milk. Keep the lid closed if there are insects or dust in the area, to avoid contamination.

Electric cooling equipment

If using electric milk cooling equipment such as a refrigerator or charcoal-lined cooling tank with an evaporator, be sure to do to the following:

- Connect the cooler to a voltage stabilizer to provide for a constant supply of electricity.
- Have a standby generator in case of power failure.
- Ensure that the cooler always has enough refrigerant in the system.
- Avoid opening the milk cooler unnecessarily to prevent warm air from entering.
- Ensure that the evaporator is well ventilated for proper function of cooler.
- Clean and inspect equipment on a regular schedule.
- Replace any parts that wear out as soon as possible. Perform all recommended preventive maintenance. Major mechanical repairs should only be carried out by a trained technician.

Building a cooling centre

For smallholder farming communities, setting up a centrally located milk cooling centre can be an excellent solution. By sharing resources, farmers might be able to maintain better facilities, with access to cool water or refrigeration, than they could on their own. A cooling centre with a capacity of 1000–3000 litres will serve up to 300 smallholder farmers.

Centres can use various methods to keep milk cool:

- In all cases, it is advisable to build a structure to provide shade.
- Do not build the collection centre in an area with foul smells, as this indicates the presence of large amounts of bacteria.
- In highland areas with naturally low water temperature (10°C or less), milk cans can be immersed in a trough filled from a water tap or water spring.
- In hotter areas, milk should be cooled to at least 3°C below ambient temperature, ideally 5°C or lower) in a charcoal-lined evaporative cooling cabinet or electric.

Farmers should bring their milk directly to the cooling centre after milking, and pickups should be made on a regular basis.

Heating milk before storage (pasteurization)

Briefly heating milk before storing it can kill many bacteria and reduce the risk of spoilage. This technique is known as pasteurization. If you choose to employ this technique, you need to take care and adhere to the following guidelines. Properly heating milk can help it last much longer without spoiling, but improperly heating milk can give the milk a bad taste, reducing its value at market.

- The best method of heating milk is to immerse the milk can in boiling water for at least 30 minutes. Use a thermometer to monitor the temperature, and stop heating once it reaches.
- Once the milk has heated, leave it standing at that temperature for time interval 60 seconds. Then immediately cool the milk.
- Another way to preserve milk is to subject it to low heat (65°C) for a longer period, then cool

Chemical preservatives

Chemicals can be used to preserve milk, but you should seek advice from the staff at your collecting centre to ensure you use the correct types and amounts. Use of chemical preservatives are illegal in some countries.

If you treat milk with chemicals, do not consume it or sell directly to someone for consumption until it has been processed by a dairy plant.

Despite the risks, chemical preservatives can allow un-cooled milk to keep longer even in high temperatures. If used correctly, chemicals are safe and have little effect on the quality of the milk.

Transportation

After taking steps to protect the quality of milk during milking and storage, we want to do whatever we can to ensure that it does not spoil during transport to the dairy plant. This can be difficult, as preserving quality during transportation may depend on factors beyond a farmer's control.

There are three ways that milk can spoil during transportation:

- The milk temperature rises above 100°C.
- The milk is contaminated due to mishandling.
- The milk is contaminated after being mixed with low-quality milk from a neighbouring farm.

The degree of risk depends on the time it takes to reach the plant, the container used to transport the milk and the condition of the transport vehicle and equipment.

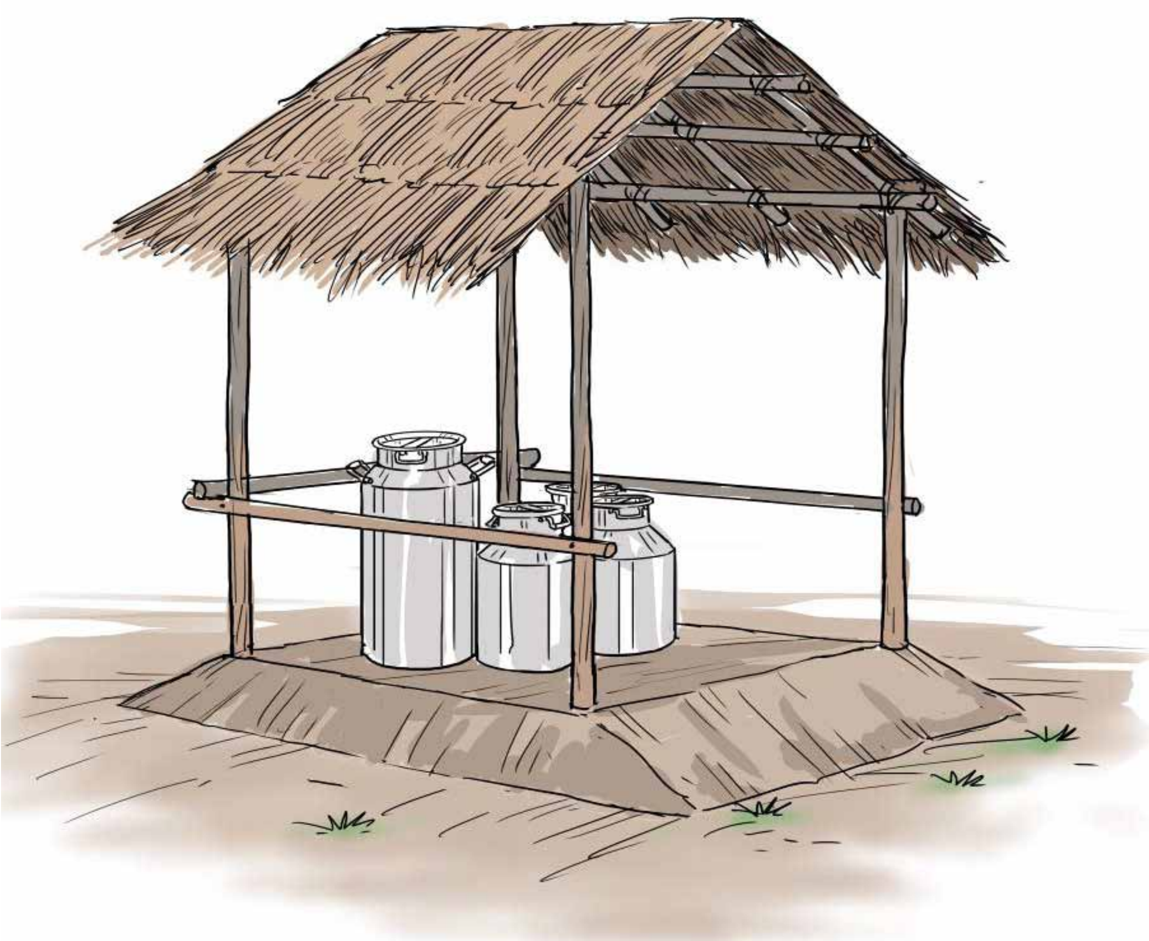
Time to reach the plant

The less time the milk spends in transport, the less chance it will spoil. Ideally, the transporter will arrive at the pick-up location on time, then only need to drive a short distance over good roads.

Providing shade at pick-up points

While you cannot change the distance to the plant or the condition of local roads, you can at least take steps to ensure that milk does not spoil while awaiting pickup. If milk is not picked up directly from a cooling centre or storage area, then it is advisable to build a structure at the pick-up point to provide shade. In any case, farmers should wait as long as possible before bringing milk to the pick-up point, to prevent it from being exposed to heat.

Figure 4.9 Provision of shade at pick up points is important.



Containers
Milk may be transported to the collection centre in a bulk tanker, milk cans, or Mazzi containers. Each of these options has advantages and disadvantages.

- Bulk Tankers: The advantage of bulk tankers is that they are insulated, which will help milk to remain cold until it reaches the plant. One disadvantage is that milk from multiple farmers might be mixed together in a single bulk tanker, and another farmer's poor-quality milk might contaminate your good-quality milk. Another disadvantage is that milk can be contaminated if the tanker and pump owned by the transporter are not kept clean.
- Milk Cans: The advantage of cans is that each farmer's milk will remain separate, so your milk cannot be contaminated by milk from a neighbouring farm or the transporter's equipment. The disadvantage is that cans are not insulated, so there is a greater risk that milk will heat up and spoil before it reaches the plant.
- Mazzi Containers: The advantage of Mazzi containers is that their tethered lid provides a leak-proof seal. Another advantage is that the lid also allows the containers to be stacked atop one another for more stable transportation from the farm to collection centres and chilling stations. Single containers are also easily carried by hand, bike, truck, or animal. The disadvantage, as with metal cans, is the lack of insulation which increases the risk that milk will heat up and spoil.

Between milk cans and Mazzi plastic containers, Mazzi containers are prone to less spoilage and spillage which helps to maximize the amount of milk that makes it to market successfully. If you have a choice between shipping milk in a bulk tanker versus cans or Mazzi containers, you should think about which risk is greater: overheating or the risk of contamination or spillage. The answer will depend on your specific circumstances.

Transport vehicle and equipment
It is important for your transporter to make sure their vehicle is in good repair and to keep their equipment clean and in good working order, especially if they are using a bulk tanker and pump. You might consider having a polite, honest discussion with your transporter about the steps they take to clean and maintain their vehicle and equipment.

Cleaning bulk tankers and pumps
Bulk tankers and pumps should be thoroughly cleaned immediately after entering by using the "cleaning-in-place" (CIP) method. As mentioned above, the steps in the CIP method are:

- Rinse with cold water.
- Circulate some hot water with detergent through the system. Select detergents and sanitizers that will not corrode the material from which the equipment is made.
- Rinse with hot water.

The equipment owner should set up schedules for cleaning and preventive maintenance and replace any worn-out parts as soon as possible. Any mechanical repairs should be carried out by a trained technician.

The valves, hose connections and lid of the tanker should be covered when not in use, to prevent milk from being contaminated with dirt.

Handling of milk cans
Milk cans are designed with rims at the bottom to resist dents during rough handling. Still, you should encourage your transporter takes reasonable precautions to make sure that cans are not damaged, opened or needlessly exposed to direct sunlight during transport.

Testing milk quality

Once milk has been transported to the collection centre, the final step before farmers receive payment is for the staff of the centre to inspect the quality of the milk. They will test a small amount of milk from each container and subject it to one or more tests. If the sample of milk does not pass the test, then the entire container will be rejected, and all of the farmer's effort and expense to produce the milk will be wasted.

There are four common tests that dairy plants perform to determine whether the quality of milk is acceptable:

- Sight and smell (organoleptic) test.
- Clot-on-boiling test.
- Alcohol test.
- Lactometer test.

These same tests may be carried out at the farm, to help you monitor the quality of your milk and identify possible sources of contamination.

Sight and smell (organoleptic) test

The first test involves assessing the milk based on its smell, appearance and colour. This test requires no equipment, though the tester should have a good sense of sight and smell. While a sight and smell test cannot guarantee that milk is free of contaminants, it can quickly identify obviously contaminated milk.

Procedure

- Open a container of milk.
- Immediately smell the milk. A plant will not accept milk that smells slightly sour or has foreign odours like paint or paraffin.
- Observe the colour of milk. Yellowish-white colour is normal. A bright yellow or reddish colour might indicate damage to the udder (red = blood, yellow = pus) and cause the plant to reject the milk.
- Check for any foreign bodies or physical dirt. If there is dirt in the milk, it might indicate that poor hygiene practices during milking, handling or transportation, and cause the milk to be rejected.
- Touch the milk container to see if it is warm. If the container is warm, the plant will likely perform a lactometer test (see below).

If your milk fails the sight and smell test, a few possible explanations might include:

- Abnormal smells
    - Type of feed (e.g., feeding sileage or brewer's waste close to milking time).
    - Pollution from the atmosphere (e.g., from the stall being located too close to a cistern or other source of bacteria).

Fermentation due to heat

- Cows being milked in late lactation, while in heat or soon after conception (hormonal changes during these times might affect the smell).

Mastitis

- Abnormal colour
    - Contamination from cleaning detergent (due to equipment not being rinsed properly).
    - Blood or pus from a damaged udder.
    - Separation of fat caused by chilled milk being shaken excessively during transportation.
    - Milk heating beyond the boiling point during transport.

Clot-on-boiling test

The clot-on-boiling test is a quick, simple way to detect milk that has developed high acidity after being kept for too long without cooling, or milk that has a very high percentage of colostrum (protein). High acidity indicates that milk has spoiled, and it will be rejected by the plant. Milk with high colostrum will not withstand the heat treatment that plants use to kill bacteria, and will be rejected.

Procedure

- Boil a small amount of milk for a few seconds in a spoon or other suitable container.
- Observe immediately for clotting.
- The milk will be rejected if there is visible clotting, coagulation or precipitation.

Figure 4.10 Clot-on-boiling test.

Alcohol test

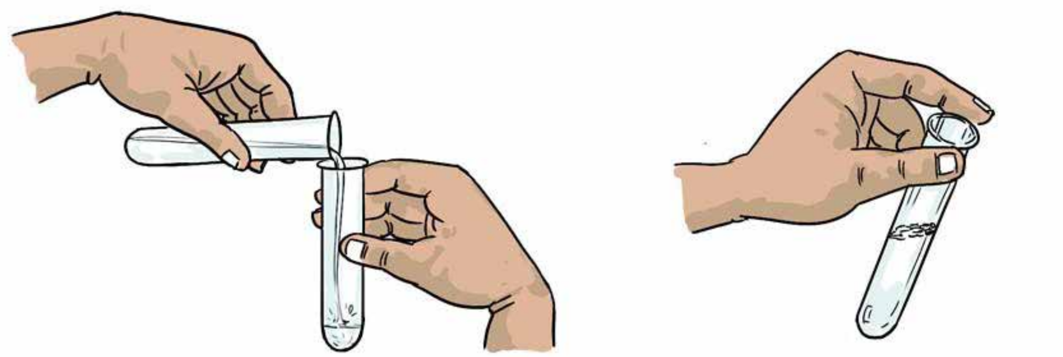
This is a more sensitive test for detecting highly acidic (i.e., spoiled) milk that might have passed the previous two tests undetected. It can also detect colostrum and signs of mastitis. A type of alcohol known as "ethanol" is mixed with a small amount of milk. If the milk coagulates, clots or precipitates, then it will be rejected.

Any milk that passes this test is likely to be relatively free of bacteria and can keep for at least two hours before it goes bad.

Procedure

- Use a syringe to draw equal amounts of milk and 70% alcohol solution into a small tube or glass cup (such as those used to administer medicine to children).
- Mix 2 ml milk with 2 ml 70% alcohol and observe for clotting or coagulation.
- If the tested milk sample coagulates, clots or precipitates, the milk will be rejected.

Figure 4.11 Alcohol test.



Mix 2 ml of milk with 2 ml of 70% alcohol. If the milk coagulates, it fails the test.

Lactometer test

This test uses a device known as a "lactometer" to detect whether milk has been adulterated with water or solids. Adding anything else to milk is illegal, as it can introduce bacteria and cause the milk to spoil quickly.

Milk is more dense (heavier) than water but less dense (lighter) than solids. If water or milk fat (cream) is added to milk, the density will decrease. If solids are added, the density will increase.

A lactometer can measure the density of liquid when it is immersed in a container filled with milk. If the readings are higher or lower than expected, the milk will be rejected.

Procedure

- Leave the milk to cool at room temperature for at least 30 minutes and ensure its temperature is about 20°C.
- Stir the milk sample and pour it gently into a 200 ml measuring cylinder or any container deeper than the length of the lactometer.
- Let the lactometer sink slowly into the milk.
- Take the lactometer reading just above the surface of the milk.

If the temperature of the milk is different from the lactometer calibration temperature (20°C), then use this correction factor:

- For each °C above the calibration temperature, add 0.2 lactometer "degrees" (°L) to the observed lactometer reading.

Figure 4.12 Lactometer test.

- For each °C below calibration temperature, subtract 0.2 lactometer "degrees" (°L) from the observed lactometer reading.
- Note: These calculations are done on the lactometer readings (e.g. 29 instead of the true density of 1.029 g/ml).

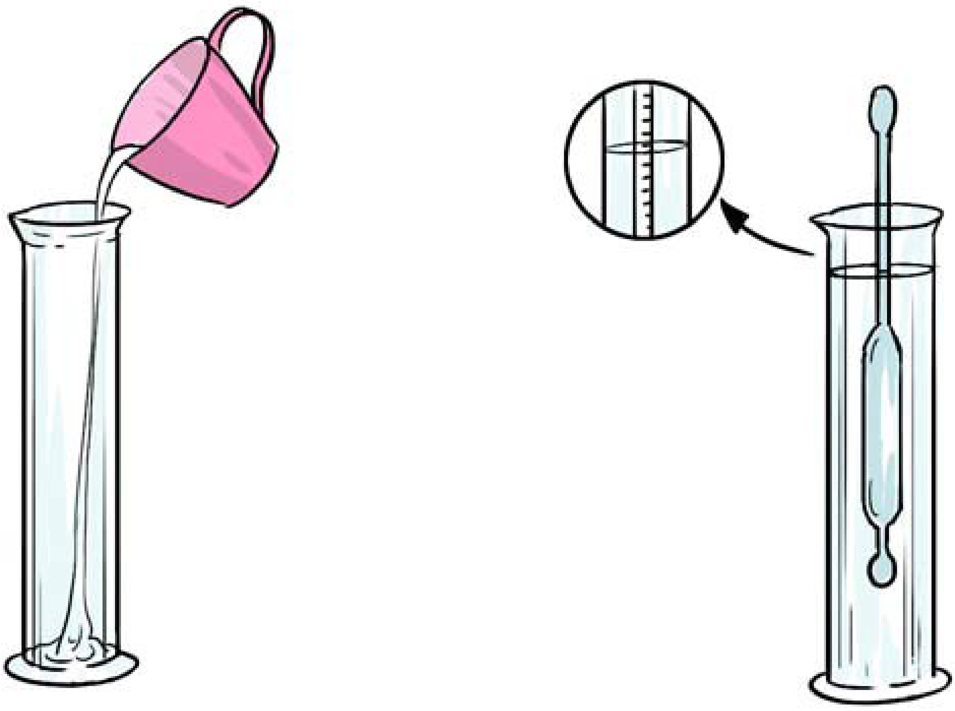


Table 4.1. Examples of how to calculate the true lactometer readings when the milk temperature differs from the calibration temperature of 20°C.

Milk temperature °C	Observed lactometer reading l	Correction l	True lactometer reading l	True density g/ml
17	30.6	- 0.6	30.0	1.030
20	30.0	nil	30.0	1.030
23	29.4	+ 0.6	30.0	1.030

If the milk is normal, its lactometer reading will be between 26 and 32. If the lactometer reading is below 26 or above 32, the milk will be rejected because it means that it has been adulterated with added water or solids.

Putting it together

Introduction

In this course we have focused on the aspects of dairy farming that are most crucial to improving farm productivity and milk yields. In turn, we've examined important aspects of animal husbandry and cow health, cow nutrition, fodder selection, production and preservation, finally we looked closely at milk transport and hygiene. While all these aspects of farming are very important, this knowledge alone will not make you a more successful farmer or make you more money.

To do this, you will need to be able to integrate your knowledge, and do so in the context of profitability. In short you need to start thinking of your farm as a business, and while one object of a business is to produce goods (milk), another very important aim is to do so efficiently, and that often means controlling costs.

Economics of feeding concentrates

Failure to feed enough supplements, especially early in the lactation, is the main reason why many cows give much less milk than they are capable of, which reduces the profit the farmer could have made. Also, soon after calving cows cannot eat enough bulk to provide all the nutrients they need and supplements, including concentrates, are especially needed at this time.

As much forage as possible should be fed before supplementing the ration with concentrates. Too little forage in the ration can also lead to a decrease in milk fat content. Concentrates are expensive – more expensive than forages – and they should be used to support additional milk production. A cow receiving as much good quality forage as she can eat will produce 5–10 litres of milk per day – if she is fed on stovers or mature (over 2m tall) Napier grass this amount will be much less. For higher quantities of milk the cow needs to receive concentrates. If the rules of concentrate feeding are followed (see below), money spent on concentrates will lead to higher milk yields and higher profits.

How much to feed? The amount of concentrates fed should depend on the level of milk production and the quality of forage. The most economical level of feeding concentrates is the point at which the last amount of additional concentrate added to the ration is just paid for by the extra milk produced by that unit of concentrate. But this is difficult to determine and it is influenced by changes in milk and feed prices – if the milk price drops, it may no longer be economical to feed as much concentrates.

Alternative approaches to feeding concentrates

Challenge feeding: This method of concentrate feeding is traditionally recommended for cows in early lactation. Begin with a low level of concentrates, such as four kg, and gradually increase the amount of concentrates fed each day until the point is reached when adding more concentrate does not result in an increase in the next day's milk production. Continue with this level of feeding for the first 12 weeks of the lactation. After 12 weeks, the amount of concentrates fed should depend on the milk yield. If the cow is fed on good quality forage it should be able to produce five to ten liters of milk per day on forage alone. For every litre of milk produced over and above five liters, feed half to one kilogram of concentrate. So, for a cow producing eight liters of milk per day after 12 weeks, feed one to two kilograms of concentrate per day.

Flat rate feeding: Feeding a constant amount of concentrates, for example two kilograms per day, throughout the entire lactation is not recommended. During early lactation the concentrate fed is insufficient, while during late lactation it will be too much.

Targeted concentrate feeding: If financial constraints mean it is not possible to feed as much concentrates as would be ideal, then it is best to feed all the concentrates available during early lactation. Cows produce more milk during early lactation and they need plenty of nutrients to support this. Also, the amount of milk they produce during this period influences the amount of milk they will produce later in the lactation - the more milk they produce in early lactation, the more milk they will give in late lactation.

Different types of concentrates

There are many different types of concentrates. They can usefully be classified according to the major nutrient supplied – some are good sources of protein others of energy and some are good sources of both protein and energy. Table 6 classifies concentrates as high, medium or low protein and high, medium or low energy.

Table 5.1 Protein and Energy content (dry matter basis) of concentrates commonly fed to dairy cattle in East Africa.

Protein Level (% CP) Energy Level (MJ/kg)	High (> 17)	Medium (10 - 17)	Low (< 10)
High (> 12)	Cottonseed meal Sunflower meal		Molasses Turnips mangolds sweet potatoes
Medium (10–12)	Groundnut meal Sweet potato vine silage Lucerne, Calliandra, Desmodium etc	Maize germ meal Brewer's waste, wheat bran, wheat pollard, dairy meal	Maize bran rice bran
Low (<10)	Poultry Litter		

Note: In addition some other concentrates have very high protein levels (50-95% crude protein), including blood meal, meat and bone meal and fish meal.

How to make your own concentrat: Commercial dairy meal is produced by mixing different feeds so that the final feed is relatively high in protein (about 16% CP DM) and has a good (but not overly high) amount of energy. Dairy meal is expensive, and may not be cost-effective, especially if the quality is sub-standard or the farmer has to pay high transport costs. It is possible to make a good quality and more cost-effective mixture using largely ingredients grown on the farm.

To make a mixture similar to dairy meal, refer to table 5.1. Mix 12 parts medium protein/medium energy feed, 5 parts high protein and 3 parts high energy feeds.

IMPORTANT! If feeds are fresh (wet) rather than dried, add three times as much, because the dry matter content of these feeds is much lower. The amount made should be consumed in two days.

A Tool for ration formulation: Pearson's Square

Pearson's Square is a simple, quick way to calculate the amounts of feed necessary to meet a nutrient requirement of livestock and other animals. This method is most effective when only two feeds are being used. For example, when two grains are mixed for part of a total mixed ration or as a supplement to pasture feeding, Pearson's Square can be used to determine what quantity of each grain would be needed to achieve a specific nutrient level in the mixture.

The basic structure of a Pearson's Square can be seen in figure 5.1. In this example, soybean meal and corn are being used to meet the crude protein (CP) requirement of a lactating dairy cow. The nutrient requirement, in this case CP, could also be energy, total digestible nutrients (TDN), fat, and so on, depending on the information needed by the user.

The number in the center of the square or box is the animal's nutrient requirement. The two feeds being considered are listed at the top and bottom left-hand corners of the square. The nutrient concentration of each feed is listed as well.

The conversion factors for pounds and kilograms are below:

- To convert lb to kg:
  - 1 lb = 0.454 kg
  - 10 lb * 0.454 = 4.54 kg
- To convert kg to lb:
  - 1 kg = 2.2 lbs
  - 10 kg * 2.2 = 22 lbs

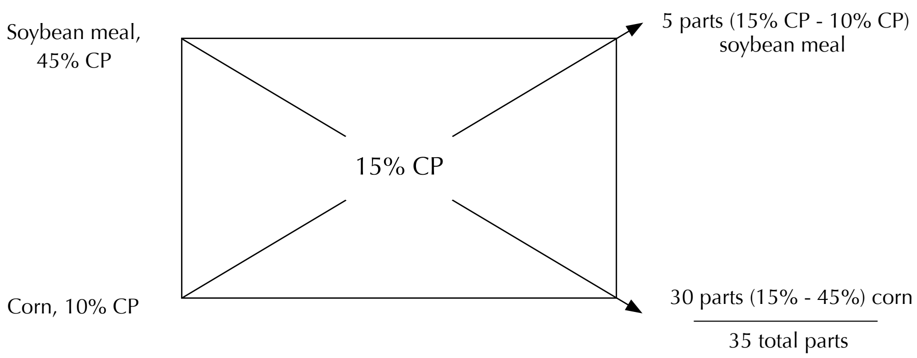
To use Pearson's Square:

1 Subtract the nutrient requirement (middle of square) from the nutrient concentration (on left of square) in the feed across the diagonal (top left – middle = bottom right; bottom left – middle = top right). Repeat this for both feeds. Make any negative numbers on the right side of the square positive. The answers on the right side of the square are the parts of each feed to include in the ration.

2 After subtracting across the diagonal, sum the parts of the two feeds to get the total.

3 Then, divide each part by the sum of the parts to calculate the percent of each feed in the ration.

Figure 5.1 Using Pearson's Square to calculate amounts of corn and soybean meal needed to meet crude protein (CP) requirement.



Pearson's Square calculations:

- Subtract across the diagonal:
  - 15-10% = 5 parts soybean meal
  - 15-45% = 30 parts corn
- Sum the parts:
  - 5 parts soybean meal + 30 parts corn = 35 total parts
- Divide each part by the total to calculate the percent of each feed to include:
- 5 parts soybean meal ÷ 35 total parts = 0.143 * 100 = 14.3% soybean meal
- 30 parts corn ÷ 35 total parts = 0.857 * 100 = 85.7% corn

So, in a 100 kg batch of this corn and soybean meal mix, 14.3 kg of soybean meal and 85.7 kg of corn are needed to achieve 15% CP in the mix (calculations shown below).

Soybean meal: 100 kg *(14.3 ÷ 100) = 14.3 kg SBM Corn: 100 kg *(85.7 ÷ 100) = 85.7 kg corn

There are a few important things to remember about using Pearson's Square for formulations:

- This method is only efficient when no more than two ingredients are being used.
- The animal requirement (number in center of the square) must fall between the nutrient concentrations in both feeds. For example, if the requirement is 60% TDN, then one feed must be greater than 60% TDN and one must be less than 60% TDN.

- Disregard any negative numbers calculated on the right side of the square. Treat them as positive numbers.
- Nutrient concentrations of the feeds and the requirement must be expressed on the same basis (for example, dry matter or "as-fed").
- Always CHECK THE MATH for accuracy.

Using Pearson's Square with supplement mixes

Though not always recommended, it is possible to use Pearson's Square to balance more than two ingredients. For example, with two separate grain mixes (A and B), each made up of two ingredients, for a total of four feedstuffs, Pearson's Square method can be used to calculate the amount of grain mixes A and B needed to meet the requirements. Energy (MJ) is the required nutrient in the following example.

Grain mix A is 40% corn and 60% soybean hulls (SBH), whereas grain mix B is 50% dried distillers grains (DDG) and 50% cottonseed hulls (CSH). The energy requirement being balanced for is 6.02 MJ/d. The energy contents of the feeds are listed in the table below.

Table 5.2 Energy concentrations of various feedstuff.

Feed	Energy (MJ/kg)
Corn	8.41
Soybean hulls	5.37
Dried distillers grains	8.24
Cottonseed hulls	2.01

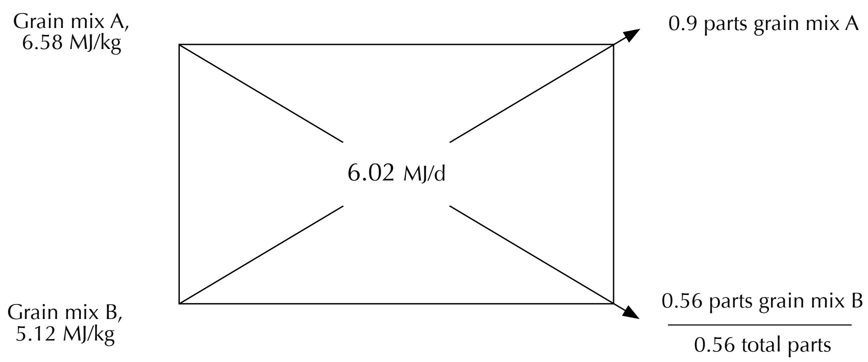
First, treat grain mixes A and B as the two feeds to use in the Pearson's Square. This means you must calculate the amount of energy (MJ/kg) available in each mix. These are the steps:

- Grain mix A
  - 40% corn at 8.41 MJ/kg, so 8.41 * (40 ÷ 100) = 3.36 MJ/kg
  - 60% SBH at MJ/kg, so 5.37 * (60 ÷ 100) = 3.28 MJ/kg
  - 3.36 + 3.22 = 6.58 MJ/kg
- Grain mix B
  - 50% DDG at 8.24 MJ/kg, so 8.24 * (50 ÷ 100) = 4.12
  - 50% CSH at 2.01 MJ/kg, so 2.01 * (50 ÷ 100) = 1.00
  - 4.12 + 1 = 5.12 MJ/kg

Second, make sure the energy requirement (1.44 Mcal/d) falls within the range of the energy content of each grain mix (5.12–6.58 MJ/kg); otherwise, the Pearson's Square method will not work.

Third, set up the Pearson's Square as in Figure 5.2.

Figure 5.2 Using Pearson's Square to formulate rations with more than two ingredients.



Pearson's Square calculations:

- Subtract across the diagonal:
  - 6.58 – 6.02 = 0.56 parts grain mix A
  - 6.02 – 5.12 = 0.9 parts grain mix B
- Divide each part by the total to calculate the percent of each feed to include. This step varies from the first example, because more than two ingredients are being used. Before dividing, multiply the parts of each grain mix by the proportions of each ingredient in the mix (this should sum to the total parts). The total ration will be 55% grain mix A (40% corn and 60% SBH) and 45% grain mix B (50% DDG and 50% CSH):
  - 0.616 * (40 ÷ 100) = 0.246 parts corn
  - 0.616 * (60 ÷ 100) = 0.369 parts SBH
  - 0.383 * (50 ÷ 100) = 0.192 parts DDG
  - 0.383 * (50 ÷ 100) = 0.192 parts CSH

For grain mix A:

0.09 parts corn ÷ 0.4 total parts = 0.225

0.13 parts SBH ÷ 0.4 total parts = 0.325

For grain mix B:

0.09 parts DDG ÷ 0.4 total parts = 0.225

0.09 parts CSH ÷ 0.4 total parts = 0.225

Converting units for ration balancing

When balancing rations, the most important thing to remember is ALWAYS to make sure the units match. Feed amounts can be reported in either kilograms or pounds.

Converting as-fed to dry matter

Feeds can be reported on a dry matter (DM) or wet/as-fed basis. Almost always, nutrient concentrations will be reported as a percent of dry matter. However, be sure to check this.

If the nutrient concentrations are reported as percent of dry matter and feed ingredient amounts are asfed, the math will not add up and nutrient content will be overestimated.

Example:

Corn at 85% dry matter and 8% CP (DM basis) 10 kg of as-fed corn* (8 ÷ 100) = 0.8 kg of CP

This is not correct, because 10 kg of as-fed corn at 85% dry matter will yield 8.5 kg of corn and 1.5 kg of water, and that water does not have any protein. So, to find out how much CP is in 10 kg of as-fed corn, first calculate the kg of dry matter corn. Then multiply the result by the %CP (shown below):

- Convert as-fed to dry (to match nutrient units):
  - 10 kg corn * (85 ÷ 100) = 8.5 kg DM corn
- Multiply kg DM corn by the CP concentration:
  - 8.5 kg DM * (8 ÷ 100) = 0.68 kg CP (DM basis)

Table 5.3 Nutritive value of common feed resources—take note of changes in Napier grass that occur with maturity.

Feed	Class	DM	ASH|**	CP**
Banana leaves	crop residue	12.20	8.80	9.90
Banana pseudostem	crop residue	5.10	14.30	2.40
Banana thinnings	crop residue	13.00	13.10	6.40
Bone meal	concentrate	75.00	49.00	6.00
Calliandra leaves	tree fodder	25.00	4.30	26.30
Couch grass	grass	30.20	7.40	8.80
Cottonseed cake	concentrate	92.00	7.00	33.0
Fish meal	concentrate	92.00	21.40	64.30
Grazing	grass	28.00	7.00	10.00
Hay	grass	90.00	5.60	4.30
Maize (green thinnings)	crop residue	25.00	4.50	6.20
Maize (whole)	concentrate	90.00	1.70	11.20
Maize bran	concentrate	85.40	2.20	9.40
Maize germ	concentrate	88.00	4.20	22.60
Maize stover (dry)	crop residue	85.00	7.00	2.50
Maize stover (green at harvest)	crop residue	13.00	8.50	6.00
Napier grass	grass	15.00	13.00	6.00
Napier grass (30 cm)	grass	12.10	12.10	9.20
Napier grass (60 cm)	grass	12.60	12.40	7.40
Napier grass (1 m)	grass	13.40	12.60	7.00
Napier grass (1.3 m)	grass	14.40	13.10	6.50
Napier grass (1.6 m)	grass	15.50	13.00	6.20
Napier grass (2 m)	grass	18.70	12.90	6.00
Napier grass (> 2 m)	grass	24.00	13.00	5.00
Rhodes grass	grass	90.00	9.10	6.30
Sesbania leaves	tree fodder	28.00	4.50	28.20
Star grass	grass	30.00	11.60	11.00
Sugar cane tops	crop residue	30.50	9.10	5.90
Sweet potato vines	other	25.00	9.40	19.20
Wheat bran	concentrate	88.00	2.40	17.80
Wheat straw	crop residue	86.00	9.40	3.30

Which cows should I keep? Many farmers believe that the answer to getting higher milk production is to acquire "better" cattle (ie: improved breeds with higher genetic milk potential). While this can be important, it is certainly not the answer. As has been shown in other modules and above, feeding is an extremely important and the type of cow (as well as the number) that should be kept will (or should) be strongly influenced by the type of feeding system that is employed.

Table 5.4 *Feeding systems and the type of cattle suited to them.*

Conditions	Indigenous	F1 Boran X Improved	Improved (Friesian, Jersey etc)
Milk potential (l/day)	3	12	25
Parasite resistance	Good	Moderate	Low-very low
Heat tolerance	Good	Moderate	poor
Nutritional resilience	Very good	Intermediate	Low
Minimum feeding system needed for good performance	Grazing, stovers, agricultural residues	Good quality pasture, well-managed Napier and forage legumes, some concentrates adequate fodder storage	High quality, well managed and fertilized pasture/fodder, high quantity of legumes and concentrate, sufficient preserved fodder to ensure no decrease in feed supply

So the important question is: what feed resources do you already have on your farm and what are you able/prepared to put in place to maximize these resources? When you have answered these questions, you will know what animals you should keep.

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