

Fodder Tree Establishment

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Livestock play an important role in small-scale farming systems throughout the world. Most often livestock graze fallow fields, pastures and woodlands deriving most of their sustenance from crop residue, grasses and other herbaceous plants. A smaller but important component of livestock diets comes from tree fodder. Farmers harvest tree fodder from natural forests, savanna and woodlots. Additionally, they often deliberately propagate trees on their farms to expand fodder resources. Many of the most important fodder trees are nitrogen fixing species. This article covers the propagation, establishment, and maintenance of this important group of nitrogen fixing trees used for fodder.

Site Preparation

To minimize weed growth and competition, site preparation should occur immediately before fodder tree establishment. Removal of vegetation can be achieved by manual, mechanical, chemical or a combination of means. To assure adequate establishment of nitrogen fixing fodder trees, it is necessary to practice thorough site preparation. This is particularly important in grass ecosystems, where fodder trees are often planted. The objective of site preparation is a seed bed with limited weed competition, where tree seedlings can thrive. At a minimum, remove all vegetation within 50 cm of the position where seedlings or seed will be planted. Both above ground and below ground plant biomass (i.e., stems and roots) must be removed. If rows of fodder trees are being established, meter-wide seed beds the length of the rows must be prepared. For individual fodder trees, seed beds one meter-diameter are sufficient.

A few precautions are warranted. The use of burning as a site preparation method is not recommended, unless experienced personnel are present. The removal of 100% of the vegetation from a site is not advisable. Complete removal of the vegetation is costly and leaves the site vulnerable to soil erosion. Furthermore, some of the existing vegetation may provide useful fodder, mulch, fuel or other products.

Seed Preparation

Nitrogen fixing fodder trees are usually established by directly sowing seeds or by transplanting seedlings. The seed of many of fodder species have hard, waxy or thick seedcoats that inhibit water absorption and delay germination. Under natural conditions, seedcoats are degraded by exposure to sun, rain, wind and animals.

Uniform seedling size can be achieved through seed scarification—a process designed to penetrate the protective seedcoat and allow seed to absorb water and germinate at a uniform rate. The most common scarification treatments are cool water, hot water, acid and nicking.

Cool water Seeds are soaked in cool, room-temperature water until they swell. The volume of water should be five times the volume of seeds. Soaking time is 12–48 hours depending on species, provenance, age and quality of seed. This treatment is appropriate for seeds with a thin or soft seedcoat, recently harvested seed, seed of small-size, and large quantities of seed.

Hot water —Boiling water is poured over the seeds at a volume five times the volume of seeds. The seeds must be stirred gently during the 2–5 minute soak. Hot water can kill the seed—it is important not to soak the seed for too long! Pour off the hot water, replace it with cool water and soak for 12 hours. This treatment is appropriate for seeds with hard or thick seedcoats, old seed, and large quantities of seed. It is best to treat a small quantity of seed first to make sure your technique is correct before attempting to treat large quantities of seed.

Acid (CAUTION—Very dangerous—for laboratory professionals only) Cover seeds with sulfuric acid for 10–60 minutes. Seed should be completely submerged but just below the surface of the acid. Acid can kill the seed—do not soak the seed for too long! Gauge the length of acid treatment by the appearance of the seed. The waxy gloss of the seedcoat should be replaced by a dull appearance. A pitted appearance indicates damage—remove the seeds before this occurs. Remove seed from acid, rinse with water for 10 minutes and soak in cool water for

12 hours. Do not pour water into the acid or a violent reaction will occur! The acid can be used several times. This treatment is appropriate for seeds with hard and thick seedcoats. Acid treatment can be dangerous! In most circumstances it is not recommended!

Nicking Cut or scrape a small hole in the seedcoat. A knife, nail clipper, file, sand paper or sanding block can be used for this operation. To avoid damaging the seed embryo, cut or scrape the seedcoat opposite the micropyle. Soak the nicked seed in water for 12 hours. This treatment is appropriate for all types of seed, although nicking seed by hand is time consuming and only feasible for small quantities. Large quantities of seed may be nicked using a meat grinder, gristmill or thresher.

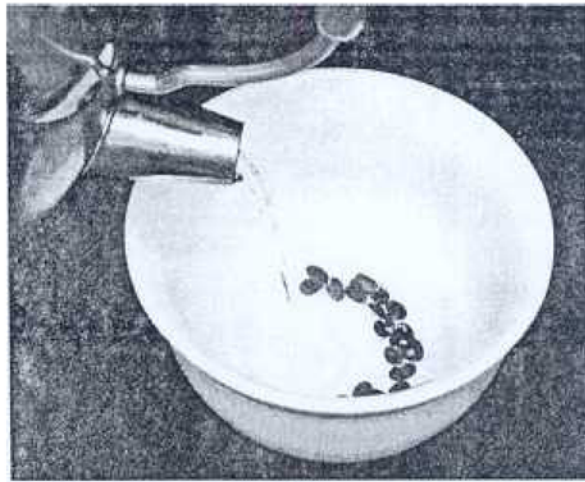
No treatment Some seeds germinate quickly without treatment. Application of the above methods may be impractical, make seed difficult to handle or decrease viability. No treatment is needed for tiny seed (i.e., *Desmodium* spp.); seeds with thin or in-

complete seedcoats; and recalcitrant seed (i.e., *Erythrina edulis*).

The length of the initial soak in cool water, hot water or acid will vary according to species, provenance, age and quality of the seed. If large numbers of seedlings will be produced, or nursery operations will last for several years, it is recommended that several soaking times be tested in order to determine the most suitable time length for local conditions. As noted, with all methods the last process is to soak seed in cool water for 12 hours. This final process allows seed to absorb water, results in visible swelling and further hastens germination. To improve this process, and thus germination, this period may be increased up to 48 hours. Once removed from the final soaking sow seed immediately! If sowing is delayed, the seed will dehydrate resulting in decreased seed viability and weak seedlings. The table below summarizes appropriate seed scarification methods for common nitrogen fixing fodder trees.

Seed scarification treatments for selected nitrogen species (Revised from Macklin et al 1989). (Key:A—Hot water; B—Acid; C—Nicking; D—Cold water; E—No treatment)

Species	Treatments	Species	Treatments
<i>Acacia acuminata</i>	C; D	<i>Chamaecytisus palmensis</i>	A for 4 min.
<i>Acacia aneura</i>	A; C	<i>Dalbergia</i> spp.	D
<i>Acacia angustissima</i>	C; D	<i>Desmodium</i> spp.	E
<i>Acacia holosericea</i>	A for 1 min.; C	<i>Enterolobium cyclocarpum</i>	C; D
<i>Acacia leucophloea</i>	A; B for 10–30 min.; C	<i>Erythrina edulis</i>	E (recalcitrant seed)
<i>Acacia melanoxylon</i>	A; B for 15 min.; C	<i>Erythrina poeppigiana</i>	D; C
<i>Acacia nilotica</i>	A; C; D	<i>Erythrina variegata</i>	A
<i>Acacia polyacantha</i>	D	<i>Faidherbia albida</i>	A; B for 20 min.; C; D
<i>Acacia saligna</i>	A; C	<i>Flemingia macrophylla</i>	A; B for 15 min.; D
<i>Acacia senegal</i>	C; D	<i>Gliricidia sepium</i>	C; D; E
<i>Acacia seyal</i>	A; B; C	<i>Leucaena</i> spp.	A; B for 5–15 min.; C
<i>Acacia tortilis</i>	A; C; D	<i>Ougenia dalbergioides</i>	D for 24 hours
<i>Adenanthera pavonina</i>	A for 1 min.; B	<i>Paraserianthes falcataria</i>	A; B for 10 min.; C
<i>Albizia lebbeck</i>	A; C; D	<i>Pithecellobium dulce</i>	C; E
<i>Albizia odoratissima</i>	A for 1 min.; D	<i>Pongamia pinnata</i>	E
<i>Albizia procera</i>	A; C	<i>Prosopis</i> spp.	A; C
<i>Albizia saman</i>	A; C	<i>Robinia pseudoacacia</i>	A; B for 20–60 min.; C
<i>Cajanus cajan</i>	D; E	<i>Sesbania grandiflora</i>	C; D
<i>Calliandra calothyrsus</i>	A; C; D	<i>Sesbania sesban</i>	A; C; D



Two common scarification methods: nicking seed coat (left) and treatment with near-boiling water (right). (photos: C. Elevitch)

Rhizobium Inoculation

The seed of nitrogen fixing trees should be treated with *Rhizobium* inoculum after scarification and prior to sowing. *Rhizobium* bacteria and NFTs form a symbiotic relationship that enables the trees to “fix” atmospheric nitrogen into a form useful for plant growth. This relationship allows NFTs to grow on infertile or degraded soils where available nitrogen is in low supply. The nitrogen fixation process occurs in nodules formed by the bacteria on the tree roots. To determine the health of nodules cut them open. A red or pink color indicates nodules are fixing nitrogen. Green, brown or black nodules are not fixing.

There are many strains of *Rhizobium* bacteria. These strains and NFTs often exhibit exclusive preferences for each other. Some bacteria will form nodules with some NFTs but not others. Likewise, trees may form nodules with many strains or just a few. A successful match will produce healthy nodules. If an NFT is native or naturalized in an area, the soil will likely contain appropriate *Rhizobium* strains. However, if the tree does not occur locally, or the site is degraded, populations of the appropriate *Rhizobium* strains may be too low to form healthy nodules.

To assure an effective *Rhizobium*-NFT match, it is best to use a *Rhizobium* inoculant. Inoculants are produced in laboratories and contain 1000 times the bacteria found in most soils. The bacteria in the inoculants are alive. They are sensitive to heat, dehydration, direct sunlight and low temperatures. It is best to use inoculants when received—viability decreases greatly after 6 months. When storage is nec-

essary, the inoculant should be placed in an airtight bag (being sure to exclude all air) and stored in a moist, cool and dark place. When ordering inoculants be sure to specify the NFT species you plan to inoculate.

To apply inoculants, first cover seeds with a sticker solution. Place seeds in a plastic bag or bucket and cover them with a solution made of gum arabic, sugar or vegetable oil. Either dissolve 40 g of gum arabic in 100 ml of hot water and allow to cool, or dissolve 1 part sugar in 9 parts water. Combine 2 ml of one of these mixtures, or 2 ml of vegetable oil, with 100 g of seeds and shake or stir until the seeds are well coated. Then add 5 mg of inoculant and shake or stir until the seeds are well covered with inoculant. Allow the inoculated seeds to dry for 10 minutes to eliminate any stickiness and sow immediately. Do not store inoculated seed—the bacteria will die.

Seedlings can also be inoculated in the nursery after germination. Mix inoculant in cool water and irrigate the seedlings with the suspension. Keep the mixture well shaken and irrigate until the inoculant is washed into the root zone. A 50 g bag of inoculant is sufficient to inoculate 10,000 seedlings. For more information on the NFTs-*Rhizobium* relationship and inoculation methods consult Keyser (1990), Postgate (1987) and Somasegaran and Hoben (1985).

It may not always be possible to obtain laboratory-produced inoculant. At such times, soil containing the appropriate bacteria can be gathered from under trees of the same species being grown in the nursery. Choose healthy trees that are growing well and have

abundant red or pink nodules. Some of this soil can be mixed with nursery potting mix or added to planting pits. Inoculation by this method assures that the bacteria will be appropriate for the tree species and the local environment. However, this approach may not be as effective as using a correct laboratory-produced inoculant.

VAM Inoculation

Like *Rhizobium*, vesicular-arbuscular mycorrhizal fungi (VAM) are soil organisms that invade the roots of NFTs and other plants to form symbiotic relationships. Plants provide VAM food in the form of carbohydrates. VAM infection improves plant survival and growth by enhancing the root's ability to absorb moisture, macro-nutrients and micro-nutrients from the soil. Increased access to phosphorus is a specific advantage of VAM symbiosis. This relationship helps plants to colonize infertile or degraded sites. Unlike other mycorrhizae, VAM does not produce visible external hyphae; its branched hyphae are mainly contained within the infected root. The spores of VAM are formed near infected roots in the organic layer of the soil. They are large and are not disseminated by wind like the spores of other mycorrhizae. To assure the VAM plant association, seedlings or seed should be inoculated in the nursery. Inoculation is particularly important when trees are to be planted on degraded sites where the organic soil has been removed.

VAM inoculation is usually accomplished by incorporating the organic soil from beneath a healthy host-plant into the nursery soil at a rate of 5–10% per volume. This method is simple and appropriate for most farm-level or community nurseries. However, it entails moving large amounts of soil and may transfer pathogens from forest soils to the nursery. It is not possible to sterilize forest soils because the process will also kill the VAM. For larger nurseries, a second option is to construct a "VAM production bed." First, collect infected soil as described above and completely fill a nursery bed. Next, sow seed of the appropriate host plant at a close spacing. Once well established, the roots of the infected plants, and VAM, will permeate the soil in the nursery bed. Remove the soil and roots, and then finely chop and mix them into the nursery soil as an inoculant at a rate of 5–10% per volume. This method, while more expensive and management intensive than collecting soil beneath a healthy host-plant, is appropriate if many seedlings are to be produced over a number of years.

Healthy host-plants should be maintained in the VAM production bed to assure continued supply of VAM inoculant.

Recent advances in technology have made laboratory production of VAM inoculants practical. Several commercial inoculants are available which are appropriate for NFTs. Readers interested in more information on VAM and inoculation are encouraged to consult Casetellano and Molina (1989), Ferguson and Woodhead (1982), and Malajczuk *et al* (undated).

Seed Sowing

As previously mentioned, seed can be sown in the nursery or directly in the field. In either case, the seed bed or nursery soil should be well cultivated and free of weeds. Seeds should be sown in the soil to a depth of once or twice their width. In field plantings where rapid soil drying is likely to occur, the depth of sowing can be increased to 10 times the width of the seed. The seed should be covered with soil, sand or mulch. When using mulch, be sure it does not contain weed seeds! For most species germination will occur within 1–3 weeks. Young germinants are sensitive to dehydration, weed competition and insects. Care must be taken to guard against these dangers.

For nursery production, standard local nursery methods are recommended. Further information on nursery practices and management is available in standard texts on the subject. Depending on the species, seedlings are ready for transplanting to the field after 6–16 weeks in the nursery. Seedlings should be "hardened" in direct sunlight for at least one week before transplanting, preferably at the beginning of the wet season. Because of the large number of trees planted in most fodder production systems, establishment is usually achieved by direct sowing. This method is more cost-effective than nursery production, however, there is less control over the planting site. Direct sowing operations should be conducted only during the rainy season.

Vegetative Propagation

Some nitrogen fixing fodder species can be established from vegetative cuttings. Propagation techniques differ greatly from species to species but generalizations are possible. *Gliricidia sepium* and most *Erythrina* species are commonly propagated by large cuttings 1–3 meters in length. *Albizia* spp. and *Dalbergia* spp. and *Ougenia dalbergioides* are also repro-

duced by small stem cuttings 15–20 cm in length and 1.0–1.5 cm in diameter.

Straight and healthy stems, branches, coppice growth or roots are recommended for vegetative propagation. Branch cuttings may retain their original morphology resulting in crooked trees. While crooked trees are not aesthetically pleasing, their morphology has no negative effect on fodder production or quality. Cuttings are usually harvested at the end of the dry season or beginning of the rains. The use of sharp clean tools will produce healthy undamaged cuttings. The cuttings of some species can be stored for up to 15 days before planting. Storage should be in a cool, dry and shady place with good aeration. Do not pile cuttings directly on the ground. Large cuttings should be stored vertically.

Water accumulation on the tips of cuttings can cause stem rot. To avoid this problem the apical (top) end of cuttings should be cut at a 45 degree angle. Rooting is promoted by scarring the lower portion of the cutting which will be buried. Scarring should be done with a sharp knife and should penetrate the cambium. If available, treat scars with a rooting hormone. Cuttings should be planted, not pushed into the ground causes damage to the bark and result in weak roots. Large cuttings should have 30% of their length buried in the soil. Small cuttings should have 50–75% of their length buried.

It should be noted that cuttings generally produce shallow root systems without a strong, deep taproot. Shallow root systems leave trees vulnerable to drought and blow-down during windstorms. Also, while cuttings provide quick establishment, time-and labor-costs per plant are greatly increased. Therefore in most fodder production systems, propagation by seed is preferred.

Field Management

After germination or transplanting, the top growth of most nitrogen fixing fodder seedlings is slow. Initially, the seedling's growth energy is allocated to root system development. While this growth pattern aids long-term tree survival, it does not assist young seedlings become established among pre-existing vegetation—even where adequate site preparation has been completed. In most ecosystems, competition for sunlight, soil moisture and soil nutrients is intense and young slow-growing trees are often the losers. Competition is particularly intense when trees are planted in grass ecosystems. Grasses, and other herbaceous plants, have intensive root systems



Even fast-growing nitrogen fixing trees benefit greatly from weed control, especially during establishment. This *Acacia koa* is stunted by pasture grass competition. (photo: C. Elevitch)

with many fine roots which densely permeate the upper soil layers. By contrast, trees have extensive root systems with thick roots which sparsely penetrate large volumes of soil. Grasses and trees are ecologically antagonistic, once present, grasses often prevent the establishment of trees.

When trees are small, grass and other weed competition must be controlled. While management regimes differ by site and species, a good recommendation is to remove all vegetation within 50 cm of the trees every 2–4 weeks. The objective is to deny weeds the opportunity to impede tree growth. As trees gain size, the frequency of weed control operations can be reduced. However, weed control must be maintained until the trees achieve a dominant position and begin to suppress competing vegetation. This usually occurs within 6–12 months of tree establishment. It is not necessary or desirable to remove 100% of the weed competition. Some vegetation—particularly grasses—are valuable fodder and improve the overall productivity of the fodder production system.

Fertilizer application can improve fodder tree growth and survival. However, little information is currently available concerning appropriate fertilization regimes for most fodder trees. A detailed study undertaken at the University of Queensland in Australia indicated that *Leucaena leucocephala* has a high requirement for phosphorus and calcium. On infertile soils, growth responses will occur at rates up to 225 kg P/ha and 230 kg Ca/ha. However, if the *L. leucocephala* plants have formed an association with VAM much lower rates of phosphorus fertilizer give the same response.

When fertilizers are applied it is essential to practice thorough weed control. The intensive root systems of herbaceous weeds respond quickly to fertilizer application. Trees respond more slowly. Left unchecked, weeds will suppress trees. Fertilization without adequate weed control results in decreased fodder tree survival and growth. In rural areas, fertilizers can be expensive or unavailable. For these reasons, fodder trees on small-scale farms are generally not fertilized.

The longevity of fodder trees is increased when the first harvest is delayed until trees are 9–21 months old. Actual age at first harvest depends on environmental conditions and tree growth. Under arid or poor soil conditions, growth will be slow and the first harvest should be later. When growth is fast, the first harvest can be sooner. The goal is to allow trees to establish deep roots. The resultant healthy plants will have ample carbohydrate reserves to resprout quickly and vigorously after harvesting. Fodder production per harvest and long-term fodder production both increase when the first harvest is delayed. The first harvest, whether by cutting or grazing, may terminate the downward growth of the roots. This is an important consideration, particularly in arid and semi-arid environments.

Fodder trees are a valuable crop that can sustain or increase livestock production. They should be managed intensively. Most often fodder trees are established in integrated systems with grasses or other fodder crops. While trees and herbaceous plants are ecologically antagonistic, their fodder products are complementary, together forming well-balanced livestock diets. Fodder trees should be managed to improve the livestock production system, not necessarily to maximize tree growth or tree fodder production.

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Roshetko, J.M. and R.C. Gutteridge (Editors). 1996. *Nitrogen Fixing Trees for Fodder Production: a field manual*. Forest, Farm, and Community Tree Network (FACT Net), c/o Winrock International. Morrilton, Arkansas, USA.

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This excerpt was originally published as *The Overstory* #91.