Nitrogen Fixing Tree Start-up Guide

version 1/99

Nitrogen fixing trees (NFTs) have the ability to take nitrogen from the air and pass it on to other plants through the cycling of organic matter. Nitrogen is an essential nutrient for plant growth, and NFTs are a major source of nitrogen fertility in tropical ecosystems. When integrated with a farm, orchard, garden, or forest, NFTs can be a major source of nitrogen fertilizer and mulch for crops. Using NFTs can greatly reduce the need to purchase synthetic nitrogen fertilizers, thus lowering cash outputs and increasing self-sufficiency.

Aside from their nutrient and organic matter contribution, NFTs have many other uses on the farm, including animal fodder, bee forage (for honey production), living fences, wind shelter, and human food.

This guide provides basic information on how NFTs work, and details on how to plant, manage and use them to enhance soil fertility.

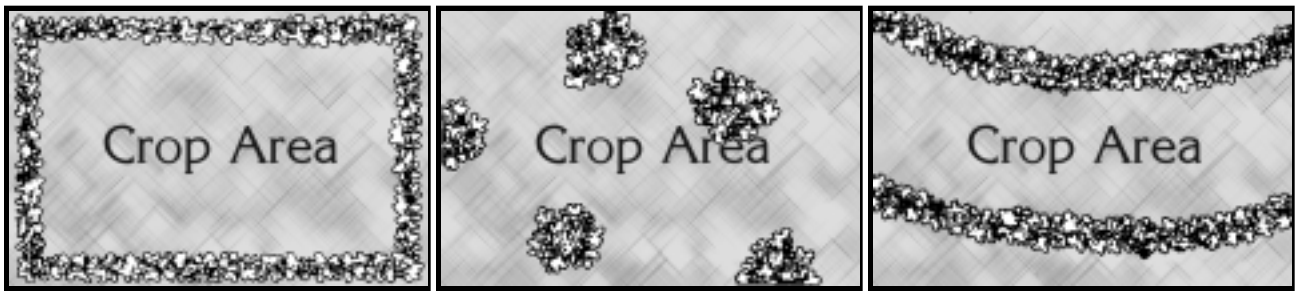
What are nitrogen fixing trees?

Nitrogen fixing trees (NFTs) are trees and shrubs that have the ability, through a symbiotic association with certain soil bacteria, to take nitrogen out of the air and use it for growth. This handbook focuses some on NFT species that are important in agriculture.

How NFTs get their nitrogen

Nitrogen is an essential nutrient for plant growth. Although the lack of nitrogen is often viewed as a problem in agriculture, nature has an immense reserve of nitrogen everywhere plants grow—in the air. Air consists of approximately 80% nitrogen gas (N_2), representing about 8000 lbs. of nitrogen above every acre of land (or 6400 kg above every hectare). However, N_2 is a stable gas, normally unavailable to plants. Nitrogen fixation is a process by which certain soil bacteria on the roots of nitrogen fixing plants "fix" or gather nitrogen from the air, and allow their NFT hosts to incorporate it into their leaves and tissues.

Uses of NFTs in Cropping Systems



Windbreak	Mulch bank	Contour hedgerows
Living fence	Fodder bank	Alley cropping
Fodder	Timber/pole wood	Fodder hedges
Timber	Wildlife Habitat	Erosion control
Wildlife Habitat	Shade	
	Bee forage	
	Nurse trees	

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Nitrogen fixing trees in nature and agriculture

In nature, when nitrogen fixing trees drop their leaves or die back, the organic matter and fertility they accumulated in their tissues is passed on to other plants. This process is the major source of nitrogen fertility in tropical ecosystems. When nitrogen fixing trees are incorporated in a farm system, they can be cut back repeatedly, and the cuttings applied to the crops as mulch. With proper management, NFTs can be a major source of fertility for crops and also provide the benefits of mulch and organic matter.

Benefits of using nitrogen fixation

Because nitrogen is essential for plant growth, farmers often purchase nitrogen fertilizers to maintain their productivity. Aside from being costly, synthetic nitrogen fertilizer is produced using an energy intensive process, and the end product is nitrogen in a form which can be detrimental to soil microorganisms and which can pollute ground water due to rapid loss through leaching. Incorporating nitrogen fixing trees is a way for a farmer to restore natural fertility processes to the farm system, growing a source of nitrogen fertilizer on-site, rather than having to buy it.

In farm systems using NFTs, it is estimated that 100-1000 lbs. of nitrogen per acre (50-400 kg per hectare) are accumulated every year by the NFTs, depending on species, soil and climate, *Rhizobium* efficiency, and management.

Incorporating nitrogen fixing trees in certain kinds of farm systems can enable the farmer to grow almost all of the nitrogen fertility necessary for crop production right on-site. Fertility provided by nitrogen fixing plants can promote healthy plants and soil life naturally. One study in Hawaii, for example, found that by using 15% of the land for NFTs, approximately 10 tons of mulch could be produced per acre per year, containing 185 lb nitrogen, 11 lb phosphorous and 72 lb potassium.

More than fertility—the importance of mulch and organic matter

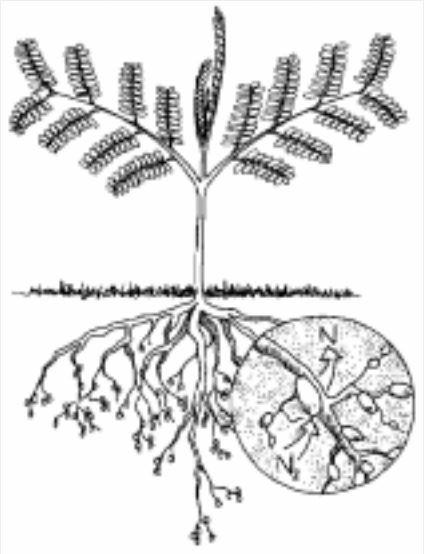
In addition to the fertility, the mulch and organic matter provided by nitrogen fixing trees is important for healthy plants and soil. Mulching improves nutrient and water retention in the soil, encourages favorable soil microbial activity and worms, and suppresses weed growth. When properly done, mulching can significantly improve the well-being of plants and reduce maintenance as compared to bare soil culture. Mulched plants have better vigor and, consequently may have improved resistance to pests and diseases.

Multiple uses and products of NFTs

Aside from the production of abundant fertilizer and mulch, many NFTs have other functions and products.

How NFTs Work: Biological Nitrogen Fixation

Working with a group of bacteria called rhizobia, NFTs are able to pull nitrogen out of the air and accumulate it their tissue. The bacteria, which are normally free-living in the soil in the native range of a particular legume, infect (inoculate) the root hairs of the plant and are housed in small root structures called nodules. The plant provides energy to feed the bacteria and fuel the nitrogen fixation process. In return, the plant receives nitrogen for growth.



There are thousands of strains of rhizobia, and they need to be matched up with the proper species of NFT to be effective. Certain strains of rhizobia will infect many hosts, certain hosts will accept many different strains of rhizobia. Some hosts may be nodulated by several strains of rhizobia, but growth may be enhanced only by particular strains. Therefore, when introducing NFTs to a new area it is recommended to also introduce a known effective symbiotic rhizobia strain. Such effective strains have been identified for thousands of the important nitrogen fixing legumes, and can be purchased at low cost for the value returned. Soil from nearby inoculated plants can also be used to inoculate seedlings of the same species.

Services provided by NFTs can include windbreak, soil stabilization, living fence, and shade. Products include fuel wood, animal fodder, and nectar for honey bees. Therefore, when selecting NFTs for a project, it is beneficial to consider not only mulch production, but other products and services that could be of value to the farm now or in the future (see chart on pages 5-6 for specific species products and services).

Factors to consider in species selection

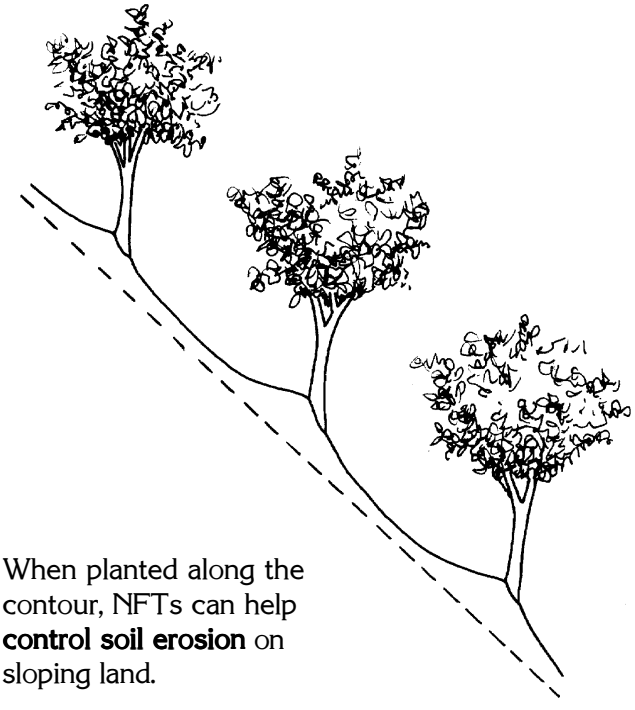
The goal with species selection is to put the right tree in the right place. The environmental tolerances of the tree (rainfall, temperature, etc.) should be the most important consideration in choosing the appropriate species for your area. Other factors to consider include:

- Growth rate—Do you want a highly productive species, or one with less vigorous growth? How many times per year do you want to prune?
- Weediness—Can you manage a potentially weedy species, or should you take care to use only non-invasive ones because the trees might bear seeds unless they are regularly pruned back?
- Other products—Might you in the future want to use your NFTs as animal fodder, firewood or bee forage? Which secondary product needs are highest priority?
- Other functions—Does your site have a particular need for wind protection or erosion control?

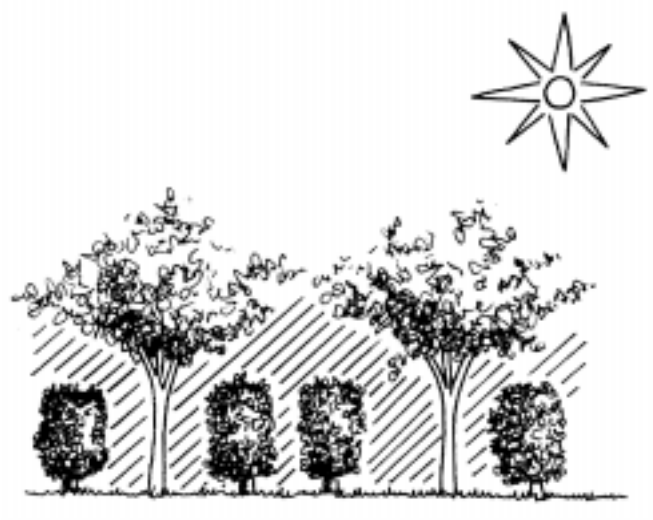
Once you have a list of promising species already present in your area, consider new species such as some of those presented in the chart on the following pages. A trial of several species is very valuable in determining which of the candidate species will thrive on your site. Within 6-12 months of observing growth, there is a good chance you will determine which species are best for you in your particular situation.

Certain NFT species provide excellent **fodder** for animals like goats, sheep, cows, and rabbits. In some cases, leaves or pods from NFTs can make up almost 50% of an animal's diet.

Many NFTs yield good quality **fuelwood**, and regrow when cut back rather than having to be replanted after harvest.



When planted along the contour, NFTs can help **control soil erosion** on sloping land.



Some NFTs can be integrated with crops that prefer light **shade**, such as coffee and cacao. The NFTs can then be cut back for mulch and to allow the crops to be in full sun when necessary to promote fruiting or flowering.

Functions of nitrogen fixing trees in nature	How this function can be used in farming
Providing fertility to other plants in the ecosystem by dropping their organic matter	NFTs can be cut back and the prunings used as an on-site source of mulch and fertilizer for crops
"Pioneering" harsh, damaged, or open areas, boosting fertility and moderating harsh conditions	To increase fertility and organic matter in a low-fertility area prior to planting
Stabilizing soil with an extensive root system	To help prevent erosion
Serving other roles and making other connections in a diverse ecosystem	To provide animal fodder, shade, wind protection, bee forage, fuel wood, etc. to other elements in diversified farms

Selecting NFTs for your project

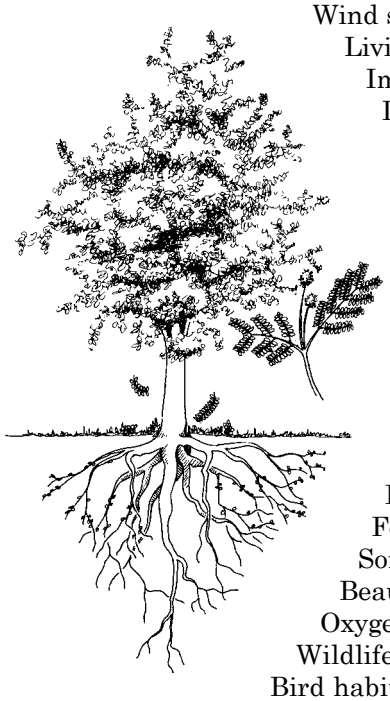
The best way to learn about new trees is to see how they grow and how they are being used by other farmers in your area. There is no substitute for experience. Start by talking with farmers in your area to see which NFTs grow well in your region. Important questions to ask are: How vigorous is the tree? How does the tree stand up to wind and drought? Does the tree readily regrow from cutting? Does it have undesirable characteristics, such as, abundant seed productions and a tendency to become weedy?

Tip: A walk, bicycle ride or drive through your community is a good way to start learning about NFTs that are already growing in your area.

Seed Sources

Once you have selected the appropriate species to try in your planting, you are ready to procure seeds or seedlings. The three organizations listed in the back of this guide can help you locate sources of seeds, or you can ask your local extension worker to help you. If possible, using select seed is recommended. For many species, such as *Leucaena* and *Gliricidia*, university programs have worked to select improved trees for many years. Trees from select seed often yield better, are better adapted to a wide range of sites, provide improved fodder quality and are more resistant to pests and diseases. Such seed may cost 2-3 times as much as unselected seed of the same species, but can easily pay for itself many times over due to increased productivity.

NFTs can provide:



Shade
Wind shelter
Living fence
Improved fallow
Improved pasture
Mulch
Fodder
Bee forage
Human food
Fuel wood
Timber
Fiber
Resins
Dyes
Tannins
Medicine
Food
Fertility enhancement
Soil stabilization
Beauty
Oxygen
Wildlife habitat
Bird habitat
Increased self-sufficiency
Nutrient cycling
Farm diversity

How to use the chart of NFT uses/products to help you select species for your project

The chart below is meant to help guide you in selecting the best species for your needs, goals, and site conditions. To use it:

1) Determine your farm's environment: Humid, Arid/Semi-arid or Upland (see Key for guidance).
2) Determine the most important product (for example, organic matter). Find that product on the top of the chart, and look for species with a '•' or a '>' symbol in that column. When you see a species with that symbol in that column, that is a good species to try.
3) Look for other uses and tolerances that are desirable for species for your project. For example, perhaps you need species that can tolerate acid soils, and you'd like one with potential to be used as a windbreak component too. Again, look for species that have a '•' or '>' sign in the column under that use or tolerance.

(From this example, in the Humid Tropics, desiring species that yield organic matter, tolerate acid soil, and be used as a windbreak component, you should find that *Calliandra calothyrsus* and *Leucaena diversifolia* are good species to try.)

Key For Characteristics Chart

• = experience for this purpose
> = potential for this purpose

Uses

org mat = organic matter for fertilizer and mulch
fodder = animal fodder uses
food = food uses for people
timber = wood suitable for building, crafts
live fence = component in living fence, fence posts
fuel wood = wood suitable for burning as fuel
shade = good shade tree for crops or pasture
ornament = particularly ornamental
windbreak = good component of a windbreak

Tolerances

salt = tolerates saline conditions
dry = tolerates drought, arid conditions
poor drainage = tolerates waterlogged soil
acid = tolerates acid soils
alkaline = tolerates alkaline soils

Height

in meters at approximately 10 years growth

	rainfall (in.)	rainfall (mm)	Average temp. (°F)	Average temp. (C°)
Humid Tropics	>40 inches	>1000 mm	>68°F	>20 C°
Arid/Semi-Arid	<40 inches	<1000 mm	>68°F	>20 C°
Upland	>40 inches	>1000 mm	<68°F	<20 C°

Chart of uses/products for some popular NFT's

HUMID TROPICS	org mat	fod-der	food	tim-ber	live fence	fuel wood	shade	orna-ment	wind break	salt	dry	poor drain	acid	alka-line	height meters
Acacia angustissima	•	>				>							•		3-5
Acacia auriculiformis				•		•	•	•		•	•	•	•	•	20
Acacia mangium		•		•		•									25
Albizia lebbeck	>	•		•		•	•	•	•	•	•		•	•	20
Albizia saman		•	>	•		•	•	•	>						15
Cajanus cajan	>	•	•			•					•		•		3-5
Calliandra calothyrsus	•	>				•		•	•		•		•		8
Dalbergia sissoo		>		•		•	•		>	•	•				30
Desmodium rensonii	•	•											•		2-3
Enterolobium cyclocarpum	>	•		•		•	•	•			•			•	35
Erythrina poeppigiana	>	•			•		•	•	•						30
Erythrina variegata	>	•			•			•	•						10
Flemingia macrophylla	•	>				>							•		2-3
Gliricidia sepium	•	>		•	•	•	•	•	>	•	•				10
Inga edulis	>		•			•	•	•	•		•		•		18
Intsia bijuga				•		•			•	•			•		20
Leucaena diversifolia	•	>				•	•		>				>		18
Leucaena leucocephala	•	•	•	>		•	•		•		•				18
Paraserianthes falcataria	•						•	•			•				45
Pongamia pinnata		•		•		•		•		•				•	15
Pterocarpus indicus				•	•	•	•	•	•		•				30
Sesbania grandiflora	>	•	•			•	•			•		•		•	10
Sesbania sesban	•	•	•						>	•	•	•		•	4
Tephrosia vogelii	•							•							3

Chart of uses/products for some popular NFT's

ARID & SEMI-ARID	org mat	fod-der	food	tim-ber	live fence	fuel	shade	orna-ment	wind break	salt	dry	wet	acid	alka-line	height meters
Acacia holosericea			•			•	•	•	•	•	•	•	•		5-10
Acacia confusa	>			•		•	•	•	•	•	•				10
Albizia guachapele				•		•	•	•	>						10
Albizia lebbeck	>	•		•		•	•	•	•	•	•		•	•	20
Albizia saman		•	>	•		•	•	•	>						15
Chamaecytisus palmensis	>	•	>			•			•		•		•	•	5-7
Cajanus cajan	>	•	•			•					•		•		3-5
Dalbergia sissoo		>		•		•	•		>	•	•				30
Dalbergia retusa		>		•		•	•		>	•	•				30
Enterolobium cyclocarpum	>	•		•		•	•	•			•			•	35
Leucaena leucocephala	•	•	•	>		•	•		•		•				18
Sesbania sesban	•	•	•						>	•	•	•		•	4

UPLAND	org mat	fod-der	food	tim-ber	live fence	fuel	shade	orna-ment	wind break	salt	dry	wet	acid	alka-line	height meters
Acacia angustissima	•	>				>							•		3-5
Acacia koa				•		•	•				•		•		40
Acacia mearnsii	•			•		•			•		•		•		10
Calliandra calothyrsus	•	>				•		•	•		•		•		8
Erythrina poeppigiana	>	•			•		•	•	•						30
Inga edulis	>		•			•	•	•	•		•		•		18
Leucaena diversifolia	•	>				•	•		>				>		18
Leucaena esculenta	•	•	•	>		•	•								8
Mimosa scabrella				•	•	•	•	•					•		15
Paraserianthes falcataria	•						•	•			•				45

Some Common Tree Legumes in Hawaii

Nitrogen Fixing:

Common Name	Botanical Name	Family	Primary Uses	Weediness
Acacia confusa	Formosa koa	Mimosoideae	windbreak, fuel wood, ornamental	highly
Acacia koa	Koa	Mimosoideae	timber, windbreak	—
Acacia koaia	Koaia	Mimosoideae	craft wood, windbreak, ornamental	—
Acacia mearnsii	Black Wattle	Mimosoideae	fuel wood, tannin	highly
Albizia lebbeck	White Monkeypod	Mimosoideae	shade, ornamental	moderately
Albizia saman	Monkeypod	Mimosoideae	shade, timber, fodder, ornamental	moderately
Enterolobium cyclocarpum	Ear pod	Mimosoideae	shade, fodder, timber	slightly
Erythrina variegata	Coral tree	Papilionoideae	shade, ornamental	slightly
Erythrina variegata var.	Columnar wili wili	Papilionoideae	hedge, fodder, living stakes	no
Erythrina sandwicensis	Wili Wili	Papilionoideae	ornamental, shade	—
Leucaena leucocephala	Haole koa	Mimosoideae	fodder, fuel wood, windbreak	highly
Paraserianthes falcataria	Albizia	Mimosoideae	pulp wood, organic matter	highly
Pithecellobium dulce	Opiuma	Mimosoideae	fodder, shade, windbreak	moderately
Prosopis pallida	Kiawe	Mimosoideae	fodder, shade, windbreak	highly

NFT environmental adaptation chart by use (Source: FACT Net (NFTA))

GREEN MANURE, SOIL EROSION CONTROL, ALLEY FARMING

Arid and Semi-Arid Tropics	Humid Tropics	Highland Tropics
Albizia lebbeck	Acacia angustissima	Calliandra calothyrsus
Cajanus cajan	Albizia lebbeck	Chamaecytisus palmensis
Chamaecytisus palmensis	Albizia saman	Leucaena diversifolia
	(syn. Samanea saman)	Paraserianthes lophantha
	Cajanus cajan	(syn. Albizia lophantha)
	Calliandra calothyrsus	Sesbania sesban
	Desmodium gyroides	
	(syn. Codariocalyx gyroides)	Temperate
	Desmodium nicaraguense	Albizia julibrissin
	(syn. Desmodium rensonii)	Chamaecytisus palmensis
	Enterolobium cyclocarpum	Lespedeza bicolor
	Gliricidia sepium	
	Leucaena leucocephala	
	Leucaena diversifolia	
	Sesbania grandiflora	
	Sesbania sesban	
	Tephrosia candida	
	Tephrosia vogelii	

QUALITY TIMBER SPECIES

Arid and Semi-Arid Tropics	Humid Topics	Highland Tropics
Dalbergia melanoxylon	Albizia saman	Acacia koa
Dalbergia sissoo	(syn. Samanea saman)	Acacia melanoxylon
Pterocarpus erinaceus	Dalbergia latifolia	Tipuana tipu
	Dalbergia retusa	
	Enterolobium cyclocarpum	Temperate
	Pericopsis elata	none
	Pterocarpus angolensis	
	Pterocarpus indicus	
	Pterocarpus soyauxii	

ROUGHCUT TIMBER SPECIES

Arid and Semi-Arid Tropics	Humid Topics	Highland Tropics
Acacia polyacantha	Acacia auriculiformis	Acacia mearnsii
Acacia saligna	Acacia crassicarpa	Alnus acuminata
Albizia lebbeck	Acacia mangium	Alnus nepalensis
Faidherbia albida	Paraserianthes falcataria	Mimosa scabrella
(syn. Acacia albida)	(syn. Albizia falcataria)	
Pithecellobium dulce		Temperate
		Alnus rubra
		Robinia pseudoacacia

NFT environmental adaptation chart by use (Source: FACT Net (NFTA))

FUELWOOD

Arid and Semi-Arid Tropics	Humid Topics	Highland Tropics
Acacia holosericea	Acacia auriculiformis	Acacia mearnsii
Acacia nilotica	Acacia crassicarpa	Alnus acuminata
Acacia saligna	Acacia mangium	Alnus nepalensis
Acacia seyal	Albizia saman	Casuarina cunninghamiana
Acacia tortilis	Casuarina equisetifolia	Cas. junghuhniana
Albizia lebbeck	Calliandra calothyrsus	Inga vera
Cajanus cajan	Casuarina cunninghamiana	Leucaena diversifolia
Casuarina equisetifolia	Casuarina junghuhniana	Mimosa scabrella
Dalbergia sissoo	Enterolobium cyclocarpum	
Faidherbia albida	Gliricidia sepium	Temperate
(syn. Acacia albida)	Leucaena leucocephala	Alnus rubra
Gliricidia sepium	Leucaena diversifolia	Caragana arborescens
Pithecellobium dulce	Mimosa caesalpiniaefolia	Elaeagnus angustifolia
Prosopis alba/chilensis		Robinia pseudoacacia
Prosopis cineraria		
Prosopis juliflora/pallida		

FODDER

Arid and Semi-Arid Tropics	Humid Tropics	Highland Tropics
Acacia aneura	Albizia lebbeck	Calliandra calothyrsus
Acacia nilotica	Albizia saman	Chamaecytisus palmensis
Acacia tortilis	(syn. Samanea saman)	Leuceana diversifolia
Albizia lebbeck	Cajanus cajan	Paraserianthes lophantha
Cajanus cajan	Calliandra calothyrsus	(syn. Albizia lophantha)
Chamaecytisus palmensis	Desmodium gyroides	
Faidherbia albida	(syn. Codariocalyx gyroides)	Temperate
(syn. Acacia albida)	Desmodium nicaraguense	Lespedeza bicolor
Pithecellobium dulce	(syn. Desmodium rensonii)	Robinia pseudoacacia
Prosopis alba/chilensis	Enterolobium cyclocarpum	
Prosopis cineraria	Gliricidia sepium	
Prosopis juliflora/pallida	Leucaena leucocephala	
	Leucaena diversifolia	
	Sesbania grandiflora	
	Sesbania sesban	

HUMAN FOOD

Arid and Semi-Arid Tropics	Humid Tropics	Highland Tropics
Acacia aneura	Acacia pennata ssp insuavis	Erythrina edulis
Acacia nilotica	Cajanus cajan	Inga edulis
Acacia senegal	Enterolobium cyclocarpum	Inga feuillei
Cajanus cajan	Inga edulis	Myrica esculenta
Cordeauxia edulis	Inga vera	
Geoffroea decorticans	Leucaena leucocephala	Temperate
Inga vera	Parkia filicoidea	Elaeagnus spp.
Olneya tesota	Parkia javanica	Hippophae rhamnoides
Pithecellobium dulce	Parkia speciosa	Robinia pseudoacacia
Prosopis cineraria	Pentaclethra macrophylla	Shepherdia argentea
Prosopis juliflora/pallida	Pithecellobium dulce	
Sesbania grandiflora	Sesbania grandiflora	

Seed Pregermination Treatment

The seed of many nitrogen fixing trees requires pretreatment in order to stimulate germination. The hard seed coat must be scarified in order to break dormancy and allow absorption of water. See the table for many common NFTs whose seed requires pretreatment to germinate. There are several methods for scarification—mechanical and hot water are common. Mechanical methods of breaking the seed coat such as nicking with a nail clippers or file are appropriate for small seed lots. Nick the seed just enough to break through the outer seed coat. To avoid damaging the cotyledons and embryo nick the seed on the end opposite the point of attachment to the pod. Hot water works well for larger seed lots and small seeded species such as *Sesbania*. Generally, the water temperature should be 70-90C° (160°F). The volume ratio should be 5-10 parts water to one part seeds. Seeds may be soaked overnight at room temperature after hot water treatment.

Seed scarification—carefully nick the seed coat to stimulate germination

OR

Scarify with hot (NOT boiling) water for 0.5-2 minutes (see chart for specific times)

Steps for using NFT seeds:
1. Scarify
2. Inoculate
3. Sow

Some common NFT species requiring seed pretreatment for germination

Species Name	Pregermin. treatment	Approx # seeds per kg
Acacia angustissima	H(2 min)	90,000
Acacia auriculiformis	H(30 sec), S	30-90,000
Acacia confusa	N, H(1 min)	30,000
Acacia holosericea	H(1 min), S	70-80,000
Acacia koa	H(2 min), S	8-20,000
Acacia mangium	H(30 sec), S	80-100,000
Albizia lebbeck	N, H(2 min)	10,000
Albizia saman	N, H(2 min)	6,000
Cajanus cajan	none	7,000
Calliandra calothyrsus	N, H(2 min)	18,000
Dalbergia sissoo	S	15,000
Desmodium rensonii	none	200,000
Erythrina poeppigiana	S	3,000
Enterolobium cyclocarpum	N	1,000
Flemingia macrophylla	none	50,000
Gliricidia sepium	none	7,000
Inga species	none	100-200
Leucaena diversifolia	N, H(2 min)	30,000
Leucaena leucocephala	N, H(2 min)	15,000
Mimosa scabrella	H(3 min)	60-90,000
Paraserianthes falcataria	N, H(2 min)	40,000
Pterocarpus indica	S	1,500
Robinia pseudoacacia	H(2 min), S	35-50,000
Senna siamea	S	20,000
Sesbania grandiflora	N, H(1 min)	20,000
Sesbania sesban	N, H(1 min)	80,000
Tephrosia vogelii	N, H(1 min)	30,000

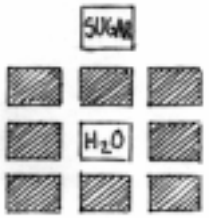
Pregermination treatments are marked as follows:
N = Nick
H(time) = Hot water (time)
S = Soak in water overnight

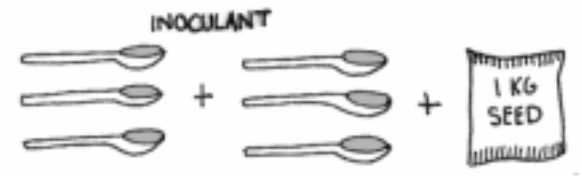
Inoculation

In order to optimize the ability of NFTs to fix nitrogen, seeds or small seedlings should be inoculated with a specific strain of *Rhizobium* bacteria. The best method for ensuring effective nitrogen fixation is to introduce a known effective strain of *Rhizobium* (purchased or gathered from soil) to the potting medium at the time of sowing. Large, healthy nodules may also be used to inoculate seeds. To determine if the nodule is effective, it may be cut open. Effective nodules will have a reddish pigment inside. Commercial inoculants, which are living cultures of bacteria, are perishable, and care should be taken to keep inoculants cool and slightly moist. Inoculation should take place immediately before sowing in moist soil or other potting media. Therefore, all seed handling such as cleaning and scarification should take place before inoculation. Seeds which have been treated with pesticides must be thoroughly rinsed in water before inoculating, or the living bacteria cultures may be killed. A sticking agent such as vegetable oil or sugar solution (1 part sugar to 9 parts water) is applied sparingly to seeds, and inoculant dusted into the mix. Do not expose inoculated seed to extremes in temperature or direct sunlight. If seedlings appear yellowish after 4-6 weeks, this may indicate inoculation was unsuccessful. It would then be advisable to re-inoculate the seedlings by watering in solution of 5 gm peat based inoculant per liter water.

Inoculation steps

1. Make a "sticking agent" to help the inoculant stick to the seeds by mixing 1 part sugar to 9 parts water and sprinkling on the seeds before adding inoculant





2. Add the inoculant to the seeds (about 6 teaspoons inoculant per kilo of seed)

3. Stir inoculant into seeds coated with sugar sticking agent, or place inoculant in bag with seeds and shake until seeds are thoroughly coated with inoculant

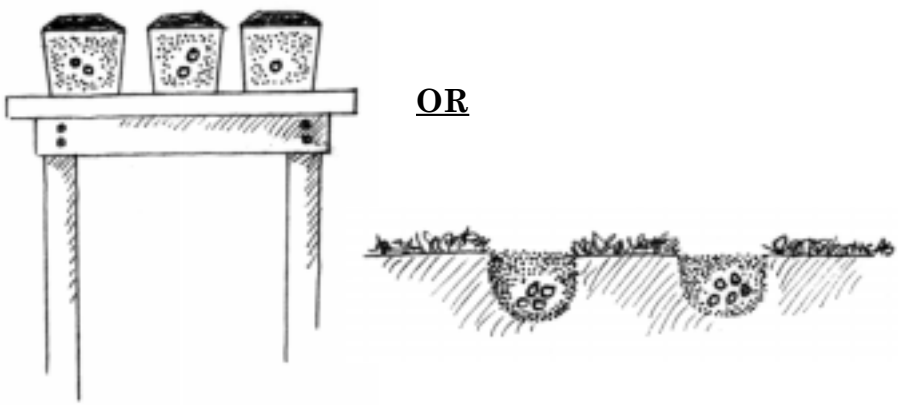
Sowing NFT Seeds in the Nursery

Sowing of scarified and inoculated seeds can take place in the nursery or, if rainfall and other conditions allow, directly in the field. For best results in the nursery, planting media should be well-drained and kept moist, but not wet. Do not over-fertilize with nitrogen fertilizers, as this will inhibit nodulation.

Direct Seeding

Direct seeding in the field should be done during a season when adequate rainfall is expected. Direct seeding works well in areas where weeds can be controlled, otherwise young tree seedlings can easily be shaded by weeds, wither and die. Seeding beds should be carefully prepared by first bearing the soil using hand tools such as a pick or power tools such as a weedeater blade. In certain situations, a one-time application of herbicide may be appropriate. The cleared area can then be limed and amended with other nutrients prior to seeding. It is recommended to place 1-2 handfuls of high quality weed free potting mix where seeds are to be sown. Sow the seeds at a depth about equivalent to the width of the seed, taking care to lightly tamp the soil around them. Mulching lightly with sawdust or similar material in the area over the seeds will greatly improve seedling growth and weed control during the early stages of growth. If regular rainfall is not expected during the first 4-8 weeks after sowing then irrigation may be necessary. The greatest cause of seedling losses is desiccation. Some predation by insects, birds and rodents is also to be expected—plant 4-6 seeds in each hole to assure survival of several seedlings. A few weeks after sowing, cull the smaller and weaker seedlings, leaving the strongest.

Tip: If you start some seedlings in the nursery on the same day that you seed in the field, the seedlings will be ready to fill in where necessary 2-4 months later.



Plant in the nursery or directly in the field. Plant seeds about as deep as the seed is wide.

Early maintenance and troubleshooting during establishment

a) Weed control is absolutely essential during the establishment of the trees. If properly mulched when planted, the new weed sprouts will not be as much of a problem as weed growth from the edges of the prepared area.

b) A certain amount of small seedlings will inevitably be lost to predators such as rats, slugs or birds. Lost seedlings should be replanted 4-6 weeks after the original planting. If not replanted early in the project, it will be very difficult to establish new seedlings in the shade of the older trees.

Management

The First Pruning

Tip: for faster regrowth leave 10% of foliage when cutting

The initial pruning should take place after the trees are well established. Depending on rainfall, it may take 6-12 months before the trees can first be cut back. Even though the trees are vigorous growers, cutting them back does compromise the health of the tree. It is best to cut them the first time during a period of active growth, when they can rapidly sprout new foliage.

Cutting Height

The height at which NFTs are pruned is determined based on how the trees are being used. For example, if the trees are being used to shade other crops (nurse trees), then the pruning height will usually be about 9 feet (3 meters). In alley cropping, the trees are usually cut at 3-4 feet (1-1.3 meters). If you plan to use mechanical means to cut the hedgerows, then the height at which you cut will be determined by the machinery. Most NFT species will regrow best from a height of 18 inches (0.5 meter) or more, so pruning below that height is usually not recommended.

Mulching

NFTs can provide large amounts of mulch for your crop trees. "Mulch" is a layer of decaying organic matter on the ground. Mulch occurs naturally in all forests; it is a nutrient rich, moisture absorbent bed of decaying forest leaves, twigs and branches, teeming with fungal, microbial and insect life. Natural mulch serves as a "nutrient bank," storing the nutrients contained in organic matter and slowly releasing these nutrients for plant growth. Mulch forms a necessary link in nutrient cycling vital for tropical soils. Please see the companion booklet, A Guide to Orchard Alley Cropping for Fertility, Mulch and Soil Conservation for details on effective mulching techniques.

Potential weediness of NFTs

By their nature many nitrogen fixing trees grow vigorously under adverse conditions and can seed prolifically. They are pioneers of degraded and disturbed land, and can proliferate freely in such conditions. Because most NFTs are woody, well rooted and hardy under varying climatic conditions, they can be difficult to remove once established. Therefore, it is wise to carefully select NFT species to reduce the risk of spreading new weed species into your area.

The following considerations are valuable in selecting an NFT species:

1. Select species which are known to have low seed production in your area, and are unlikely to spread. In Hawaii, *Gliricidia* and *Erythrina* are good examples of NFTs with poor seed production.
2. Select species which are already naturalized in your area. Managing weedy NFTs such as *Albizia* and haole koa if they are present in your area will enable you to take advantage of these prolific and useful trees.
3. Manage trees so that flowering and seed set do not occur. Pruning for organic matter production or grazing by livestock can be timed to take place just before onset of flowering. In this way, vegetative growth is stimulated, and reproduction is inhibited. Some seed will inevitably be produced, but in vastly reduced quantities.
4. If possible, obtain clonal material that produces very little seed or is seed sterile. In this way, vegetative growth is consistent throughout the life cycle of the trees, without the need for timely management as in 3 above.
5. Some species that are known to be weedy in certain situations in Hawaii include *Acacia confusa, Acacia mearnsii, Leucaena leucocephala, Paraserianthes falcataria, Pithecellobium dulce* and *Prosopis pallida.*

Farmer and happily mulched jackfruit tree.

Bibliography and Further Reading

Nitrogen Fixing Trees

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Agroforestry

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Rocheleau, D., et al. 1988. *Agroforestry in Dryland Africa*, ICRAF, Nairobi, Kenya.

Sources for Publications

agAccess Complete Agricultural Book Source, P.O. Box 2008, Davis, CA 95617-2008 Tel: 800-540-0170 or 916-756-7177, Fax: 916-756-7188. E-mail:books@agaccess.com Web: http://www.agaccess.com

Amazon.com, complete internet bookstore at http://www.amazon.com

Good Earth Publications, 1702 Mountain View Rd., Buena Vista, Virginia 24416 Tel: 800-499-3201 or 540-261-8775, E-mail: goodearth@rockbridge.net Web: http://www.goodearthpub.com

The Permaculture Activist, P.O. Box 1209, Black Mountain, NC 28711, Tel: 828-298-2812, Fax: 828-298-6441, E-mail: pcactiv@sunsite.unc.edu

Permaculture International Journal, P.O. Box 6039, South Lismore, NSW 2480, Australia Tel: Int. +61 2 6622 0020, Fax: +61 2 6622 0579 E-mail: pij@nor.com.au Web: http://www.nor.com.au/environment/perma

Other resources/organizations (with lists of seed sources and other information)

Forest, Farm, and Community Tree Network (FACT Net)
(Formerly the Nitrogen Fixing Tree Association(NFTA))
Winrock International
38 Winrock Drive, Morrilton, Arkansas 72110-9370 USA
Tel: 501-727-5435, Fax: 501-727-5417
Email: forestry@winrock.org
Web: http://www.winrock.org/forestry/factnet.htm

AgroForester
P.O. Box 428 Holualoa, Hawaii 96725
Tel 808-324-4427, Fax 808-324-4129
Email: email@agroforester.com
Web: http://www.agroforester.com

Educational Concerns for Hunger Organization (ECHO)
17430 Durrance Rd., N. Ft. Myers, FL 33917 USA
Tel: 941-543-3246, Fax: 941-543-5317
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