Recommended Agroforestry/Multipurpose Trees for Borana Lowlands/Midlands and their Production Techniques

Sub-report

No. 4

FARM Africa/SOS Sahel

Yitebitu Moges (MSc)

Tropical Forestry

March 2004

1. Introduction

Definitions

Agroforestry is a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits.

Multipurpose tree a woody perennial purposefully grown to provide more than one significant contribution to the production or service functions (for example, shelter, shade, land sustainability) of the land-use system that it occupies.

Research on mltipurpose trees in Borana and candidate species for intervention

Research results from past efforts are very important for future interventions in Borana area. ILCA, CARE-Ethiopia and SORDU have conducted research on exotic fodder trees. Coppock (1994) synthesized the research results and are presented as follows. Although most sample sizes were small and conclusions therefore limited, a number of species had done well in Borana. On well-drained, red upland soils largely at Did Hara and Melbaba madda the most reliable performances have been observed for *Acacia albida*, *Cassia artemesioides*, and *Prosopis chalensis.* In depressions and other favorable sites where soil moisture was higher *Leucaena leucocephala* performed well.

In general trees appeared to grow faster at wetter sites in Did Hara. For lowland soils (vertisols) that are seasonally waterlogged, notable performances of *Sesbania seban* and *L.leucocephala* have occurred. An experiment conducted by Yohannes Alemseged (1989 as cited in Coppock 1994) found that *Cajanus cajan* has highest average productivity in Yabello area. *Sesbania sesban* can thrive at 500mm annual precipitation under cooler temperatures and appears to be best adapted to Borana area. *S. sesban* may be vulnerable to drought, however.

It was also learned that in Borana tree or herbaceous species extended merely as forages will not be high on the Boran's list of priorities and the best way to introduce new forages is through sustainable cropping systems using dual-purpose legumes which produce both food for people and feed for livestock (Coppock, 1994). *C. cajan* and *Moringa stenopetala* performing well in relative moist areas in Borena could be good candidates

During the fieldwork, discussion with local communities has revealed that post-harvest loss with weevil attacks, malaria and livestock parasites are major problems in their respective localities. Shade is also extremely essential in the

lowlands of Borana. Consequently, introduction of *Azadirachta indica* (neem) has been recommended through participatory discussion with local communities. Neem may need rather hot and arid climates in the lowlands. As mentioned earlier, currently, the pastoral and agropastooral communities do not show interest on multipurpose trees perhaps because of sufficient availability browse resources. However, there is one strong entry for introduction of multipurpose trees; improvement of soil fertility status of crop fields. This is especially true in Borana areas because the soil is naturally poor with regard to organic matter and important nutrients such as N and P. The fruits and leaves of these species could be used as fodder (supplementary feed for calves and goats).

Note: Use of Negarim microcathments is recommended for improved survival and performance of multipurpose tree growing.

2. Azadirachta indica (A.Juss) Neem

2.1 Introduction

Neem tree *Azadirachta indica* (A.Juss) is a true multipurpose tree species. It is a medium to large sized deep rooted tree. This broadleaved evergreen tree is native to Sub- Asian continent, especially Burma. Neem grows in almost all parts of tropical and sub-tropical regions of the world. Neem has some confusing similarity with *Melia azaderech*, West Asian tree commonly known as Chinaberry /Persian lilac, because of the taxonomically close relation.

Neem becomes fully matured or productive within 10 years, and from then onwards it can produce at an average of 40-50 kg fruit /tree/year. An individual neem tree lives 200 years.

The fruit is a smooth, ellipsoidal drupe, 1.0 - 2.0 cm long. When ripe, it is greenish yellow to yellow with a bitter test. The seed is composed of a shell and a kernel usually one or two kernels, some times three kernels, it is the kernels that the most effective part in pest control. In Ethiopia, neem produces fruits, usually in May to June in Awash area and August to September in Dire Dawa area respectively (personal observations and experience).

Neem has become widely distributed by introduction into the dry, arid and semi-arid tropical and sub tropical zones. The expansion was (and still is) driven by the tree's intrinsic value, its easily adaptation, and its many uses. In Africa, different routes of spread have been documented between 1919 and 1927.

Neem tree has numerous economically exploitable products as well as environmental benefits. It has long been used for shade, ornament, shelterbelt creation, fuel wood, construction materials, degraded land reclamation and soil

conservation activities, but some three decades ago neem has got additional attention at a global scale. In 1970s some research works have been started mainly in Germany at the Giessen Justus-Liebig and Munich Universities, after a locust plague, the swarms of the desert locust (S*. gregaria*) were repeatedly seen to settle on neem trees but to fly away soon afterwards without feeding on the leaves. This time onwards many research activities were begun on neem tree components and their effects on agricultural and non-agricultural insect pests. The result of these research findings strongly confirmed that neem products have strong effect on insect pests.

Since about 15-20 years there is a growing interest to plant and utilize neem and its products in many countries of the world, both poor and rich nations. And some countries begun to set up various sizes of plantations and started conducting research by allocating a huge budget for neem research and plantation development activities; mainly, the USA, Australia, China, Cuba, Dominican Republic, Haiti, Iraq, Iran, Saudi Arabia, the Sudan.

2.2 Environmental factors affecting distribution of neem

Elevation: Neem grows well from sea level to about 1000 m.a.s.l. In our country it grows higher up to about 1200 -1500 m.a.s.l.

Climate: It is an ideal tropical and sub tropical region tree crop, in hot and dry agroclimatic zone. And it can be established with and without irrigation, in rainfall deficient areas. Humidity and frost have negative effect on the growth, flowering and fruit setting nature of neem.

Rainfall: Optimum growth is obtained in rainfall areas of 500 to 1000 mm per year.

Temperature: Neem grows well where the maximum temperature reaches as high as 49 °C; it does not withstand frost and excessive cold. Low temperature causes shedding of leaves and eventually the death of trees will follow.

Geology and soils: Neem tree seem to grow in deep sandy soils that are well drained, but sometimes it can grow in all sorts of soil, where in the site sand is moderately dominant. It does better than most plant species in dry localities, on sandy, stony, shallow soils with waterless subsoil or in places where there is a hard calcareous / clay pan not far from the surface. However, neem will grow much better if the hardpan is broken up before planting (Benge, 1986)

Neem tree does not tolerate waterlogged soils, the best neem growth is found on sites with a soil pH – between 6.20 to 7.00. It also grows well on saline and an alkaline soils; however, neem has been reported to be susceptible to moderate salinity in Sudan.

2.3 Seed handling

The fruits fallen on the ground should not be collected as they will yield seeds of poor quality. It is observed that the fallen fruits are attacked by soil born fungus. The fungus is carried along with the pulpy fruit resulting in deterioration of seeds. The fungus starts attacking the fruits within a few hours of their fall as they are pulpy and rich in carbohydrates. Even if the fallen fruits look apparently healthy, there is a danger of fungal infestation and contamination, so that proper seed handling is necessary from the beginning of seed collection.

Seed Collection

Seeds should be collected from the tree of desired genotypes, the selected plus trees or parent trees. When fully ripe, fruits are gathered from beneath trees by using canvas sheet to protect fungal infestation and to obtain pure seeds.

Seed separation

For successful reproduction purpose or seedling production the collected fruit has to be rubbed and washed to remove or separate the flesh (mucilage) from the seed after washing. Then the seeds shall be dried under the shade, and stored preferably in dry airtight container.

There is some variation in seed weight at different places, though it is 2000-3000 fruits/kg at an average.

Seed treatment

Neem seeds germinate in about two weeks after sowing. Fresh neem seed germinates quite readily and scarification is generally not needed. Research at the Royal Botanical Gardens in Great Britain indicates that germination is improved if the inner shell is removed to expose before planting. It is recommended that the seed be cut across with a sharp blade and if the cotyledons are green the seeds are sound, but if they have turned yellow or brown, they will not germinate.

It has been reported that germination is best when seeds that have fallen from trees during the preceding weeks are soaked in water for about 3 days, de-pulped and cleaned .Seeds has to be stored with 10 – 15 % moisture content and then sown directly into the nursery in damp soil. The soaking procedure breaks the dormancy by neutralizing the germination inhibiting chemicals found in the shell of neem seed.

Seed storage and viability

Seed storage condition directly or indirectly affects the seed viability. The method of cleaning has no significant effect on germination and longevity; thus,

decomposing the pulp before washing by keeping the fruits in a heap is easier than peeling the pulp from fresh fruits. Neem seeds remain viable for only a few weeks, 1-2 months is probably normal. Therefore they have to be sown quickly but where mature seeds are de pulped and adequately dried they can be stored for longer periods.

Cold storage adversely affects the viability of neem seed; seeds stored at room temperature 26^0C-28^0 C retained some viability for about 16 weeks while viability lasted for only about 12 weeks at cold storage at 6^0C -7^0C. Recent information on neem from different seed sources suggests that recalcitrant, intermediate as well as orthodox types exist. It was reported that Indian and Thai neem showed recalcitrant seed storage behaviour, while neem in Africa showed intermediate and orthodox seed storage behaviour. Recalcitrant seeds have high moisture contents (MCs) when they are shed, which allows them to maintain high level of metabolism.

Germination rates rapidly decline during storage so that care has to be taken in the collection of seeds when they are fresh to obtain a high germination percentage. They should be collected when thoroughly ripe and keep with 10-15% moisture and sown as soon as possible.

2.4 Nursery and propagation

Most commonly, neem seedlings are propagated in the nursery and seedlings are transplanted to plantation sites, although direct sowing is successful in areas where timely rainfall is adequate.

In the nursery, seedlings are grown either in plastic bags and root trainers or in the seedbeds. Germination starts in about 7 to 8 days and continues up to three weeks. Seeds are sown directly into the polybags or in other containers, which filled with 1:2:1 ratio of sand, soil and manure respectively, and then they will be ready for transplanting within 16 to 24 weeks to the plantation sites depending upon the nursery management

Seedbed seedling production

In irrigated nursery seeds have to be sown directly and they should be lightly covered with soils and spring watered so as to keep the soil loose to prevent soil caking. Seeds should be sown thickly in lines 3 cm apart, selectively thinned when the seedlings are about 8 cm height to a space of 8 cm, and again thinned out in 4 to 5 months with only the best stocks remaining at a space of 20 to 23 cm then seedlings transplanting will be conducted at the beginning of rainy season into the pits at plantation sites.

Root balls

Seedlings that have not been planted during the first year have to be kept until the following season, year old seedlings will be carefully up-rooted from the nursery with a ball of soil around the roots, and can be transplanted to plantation sites as soon as possible at the beginning of rainy season.

2.5 Weed and Livestock

Weed

Neem is intolerant of grass competition and need thorough weeding, especially in dry areas to obtain good growth. Weed competes for moisture and nutrients, early growth of seedlings is much retarded due to weed, and regular weeding and cultivation required in order to stimulate a better growth and vigour. Seedlings that are not weeded will die by weed suppression.

Totally weeding and the loosening of soil to prevent caking (in some soils), which promotes soil aeration and increase moisture percolation is found to be most beneficial. Experiments have shown that some tillage and weeding during and at the end of wet season has a remarkable effect on the growth, health and survival of neem seedlings or young trees in the first year.

Livestock

Livestock in some neem growing area attacks mostly neem seedlings and young trees. Camels and goats are known to severely browse young plants and kill them immediately.

2.6 Pests and pathogens

Pests:

Although, there are various insect pest species, which attack neem trees, most plantations are insect free, evidently due to the tree repellent compounds. But in some cases insects eat off the radicle of germinating seeds unless it covered well with the soil. Occasional insect infestations by species of *Microtermes* and plant parasite *Lorantium* have been observed in Nigeria, but the attacked trees almost invariably recovered.

In India, in its original home the larvae of *Enarmonia koenigana* feed on rolled leaves and bore into shoots, and also the larvae of *Cleora cornaria,* defoliate the leaves and nine other insect pests can attack the neem trees. In some localities, especially in Africa rats and porcupines girdle neem seedlings and young trees, gnawing the bark from around the base and killing them.

By and large, most neem trees are reputed to be remarkably pest free; however, in Nigeria 14 insects and one parasitic plant have been recorded as neem pests. In addition, in recent years a more serious threat has emmerged.

In Africa, a scale insect*, Aonidieal orientalis,* as CAB-IIBC, reports it feeds on sap and may kill young plants.

Pathogens:
The recorded pathogens which attack neem trees are; *Ganoderma lucidum,* causing root rot; *Corticium salmonicolor*, causing stem and twig blight; *Cercospora subsessilis*, causing leaf spots; *Oidium species,* causing powdery mildew; and *Pseudomonas azadirachtae*, causing leaf spot and leaf blight.

2.7 Nutrient deficiencies

Zinc (Zn) and Potassium (K) deficiencies reduce neem growth as evidenced by Chlorosis of leaf tips and leaf margin, particularly on the older leaves. Potassium deficiency is evidenced by leaf tip and marginal chlorosis and necrosis. Neem seedlings are usually killed by frost and fire, and large trees are frequently snapped off by high wind.

2.8 Growth management and biomass production

Growth:
Neem tree is well known tree to grow relatively fast, but varies greatly depending upon its environment, site characteristics and the genetic capability of the plant materials. Slower growth results at higher elevations, and at colder temperatures. It has been reported that 66% of the tree's total growth occurs in the first three years, during this time it reaches at an average height of 4 to 7 meters

Allelopathy:
There is some concern that Neem tree compounds may be allelopathic, but no hard evidence supports this contention, perhaps neem tree can be /is allelopathic to some crops. There are many conflicting statements as to its compatibility as an intercropping with food crops; some agree that it has poor agroforestry potential because of its interference with other crops or vice versa. There is no clear explanation made as to the intolerances, either of neem tree to other crops or vice versa. Or the reason may be that since neem fruits produces a systemic, somewhat repugnant chemical, food crops may take up these chemicals from fruits falling on the ground once the tree begins bearing fruits (4-5 years). Food crops might then have a bitter taste; hence the reference that neem is not a good species for agroforestry. Research is surely needed to prove or disprove neem tree's incompatibility as an inter crop and agro forestry species.

Biomass production:
According to (Michael-Kim and Brandt, 1980) estimate the yield of neem between 10 to 100 tons of dried biomass / hec / year. Even though it depends the microenvironment, 40 tons at an average would be achieved easily; about

50 % of the biomass is contained in the leaves, 25 % in the fruit and other 25 % in the wood. It is assumed that this is sustained yield

2.9 Medicinal uses and pest control

Medicinal Uses:

The medicinal uses of neem tree (*Azadirachta indica*) dates back to some hundreds years. It was highly valued product in ancient Indian **Ayurvedic** (herbal medicinal systems). Earliest Sanskrit Medical writings refer the benefits of neem trees' products.

The tree itself is highly revered in East Asian countries, because of the spectrum of diseases it is claimed to cure. It has relieved many pains; fevers, infections, and other complaints of human and livestock, hence, it has been referred to as the **"village pharmacy"**

The leaves and stem bark are popularly used in treating Malaria; the oil from neem seeds is also used to treat a number of human and livestock diseases; in addition to pesticidal property neem products have, antibacterial and antiviral property and it also treats many diseases caused by different microbes, especially fungus like; Ringworms, Athlete's foot lesion.

The treatments are believed to be highly effective. Nevertheless: these claims have inspired a number of scientists to initiate exploratory investigations to ascertain the neem products validity, a team of America and German scientists carries out particularly these research works. And today a number of biologically active compounds have been identified in neem, which also have helped in the formulation and standardization of useful medicinal products. Although, some of the results of these researches are only exploratory or preliminary, the present commercialisation and widespread use of neem products appear to have raised enthusiasm among potential users, these products occur as cosmetics and pharmaceutical preparations in forms such as tablets, tonics, elixirs, emulsions and ointments. Other forms include teas, toothpastes, soaps, mouthwash; about 20 % of toilet soaps in Indian market contain neem oil. Therefore, the discovery of neem products for clinical treatment is indeed a medical breakthrough.

Grain storage pest control

Products of neem tree have proven to be effective in protecting a number of pests of stored grain or products. In Indo-Asian and recently in some African countries, both neem leaves and chopped or ground seeds / kernels are often added to stored grains to protect insect damage. In these countries farmers traditionally mix dried neem leaves with the stored grain or they sock empty sacks overnight in water containing neem leaves and then dry these sacks before filling them with grain. Treating jute sacks with neem oil or neem aqua extracts prevents storage pests particularly weevils and flour beetles for several months.

Neem oil

Neem seeds are pressed in mechanical expellers to obtain neem oil. Neem oil is brownish-yellow in colour, which has a pleasant odour and bitter taste. Neem oil is the most commercially important part which contain high boiactive compounds that have promising potential in the manufacture of pesticides and pharmaceutical preparations. Moreover, neem oil is used for high quality antiseptic soap, wax, production and also it used as fuel for lamps, as a lubricant for machinery as well. Reports on the amount of oil in neem seed vary from as low as 17 to over 59 %.

3. Leucaena leucocephala

3.1 Introduction

During the 1970s and early 1980s, *Leucaena leucocephala* (Lam.) de Wit (leucaena) was known as the 'miracle tree' because of its worldwide success as a long-lived and highly nutritious forage tree, and its great variety of other uses. As well as forage, leucaena can provide firewood, timber, human food, green manure, shade and erosion control. It is estimated to cover 2-5 million ha worldwide (Brewbaker and Sorensson 1990). However, a better understanding of its constraints, particularly the arrival of the psyllid insect, has now given us a more balanced view of the value of this species.

Leucaena has its origins in Central America and the Yucatan Peninsula of Mexico where its fodder value was recognised over 400 years ago by the Spanish conquistadores who carried leucaena feed and seed on their galleons to the Philippines to feed their stock (Brewbaker *et al.* 1985). From there it has spread to most countries of the tropical world where leucaena was used as a shade plant for plantation crops.

3.2 Botanical Description and Genetic Variation

Leucaena leucocephala, formerly known as *L. glauca,* is a thornless long-lived shrub or tree which may grow to heights of 7-18 m. Leaves are bipinnate with 6-8 pairs of pinnae bearing 11-23 pairs of leaflets 8-16 mm long. The inflorescence is a cream coloured globular shape which produces a cluster of flat brown pods 13-18 mm long containing 15-30 seeds. Botanically, leucaena belongs to the family Mimosaceae; it is the best known species of the *Leucaena* genus and has a variety of common names. There are, however, at least 14 other species recognised in the genus.

There are two forms of the species *L. leucocephala* The most common is the shrubby free-seeding form or 'common' leucaena which tends to be weedy and low yielding (Jones 1979). It was this common form of leucaena which was transported around the world from the 16th to 19th centuries and is now pantropical in distribution. The true giant types are tall (up to 20 m) and

sparsely branched with better forage and wood production than the shorter varieties. Examples are K8 and K636.

3.3 Climate and Soil Adaptation

Temperature

Leucaena is a tropical species requiring warm temperatures (25-30°C day temperatures) for optimum growth (Brewbaker *et al.* 1985). At higher latitudes and at elevated tropical latitudes growth is reduced. Brewbaker *et al.* (1985) suggest that temperature limitations occur:

- above 1000 m elevation within 10°C latitude of the equator, and
- above 500 m elevation within the 10-25°C latitude zone.

Leucaena is not tolerant of even light frosts which cause leaf to be shed (Isarasenee *et al.* 1984). Heavy frosts will kill all above ground growth, although the crowns survive and will regrow vigorously in the following summer with multiple branches. There is some scope for breeding frost tolerance into leucaena Two- and three-way hybrids of *L. leucocephala* with frost tolerant *L. retusa* show promise (Brewbaker and Sorensson 1990). Kendall *et al.* (1989) suggested that populations of *L. leucocephala* originating from more elevated sites in northeastern Mexico showed greater frost tolerance than those originating from lowland sites. Leucaena growth is strongly seasonal in the subtropics with low yields in the cool months and the majority of growth occurring in the summer months (Cooksley *et al.* 1988). For these reasons the best opportunities for developing cool tolerant leucaenas lie with hybridisation of *L. leucocephala* with *L. diversifolia* and *L. pallida.* These latter two species can be found in elevated sites in Mexico and demonstrate cool tolerance. Hybrids of *L. diversifolia* (4x) x *L. leucocephala* averaged 4.5 m per year height increase in a 2 year period at Waimea, Hawaii at 850 m elevation and mean annual temperature 17°C (Brewbaker and Sorensson 1990).

Light

Shading reduces the growth of leucaena although this plant has moderate tolerance of reduced light when compared with other tree legumes (Benjamin *et al.* 1991). Leucaena seeds will germinate and establish satisfactorily under established leucaena hedgerows or under the weed species *Lantana camara* as a method of rehabilitating infested areas.

It has also been successfully grown under coconuts in Bali as a support for vanilla.

Rainfall requirements and drought tolerance

Leucaena can be found performing well in a wide range of rainfall environments from 650 to 3,000 mm. However, yields are low in dry environments and are believed to increase linearly from 800 to 1,500 mm, other factors being equal (Brewbaker *et al.* 1985). In Hawaii, it is naturalised on Diamond Head which receives only 300 mm p.a. In Australia the leucaena psyllid is much less damaging in drier areas (600-800 mm p.a.) and this is a major advantage for graziers cultivating leucaena in subhumid Queensland.

Leucaena is very drought tolerant even during establishment. Young seedlings have survived extended periods of dry weather and soil and plant studies have confirmed that leucaena exhibits better drought characteristics than a number of other tree legumes (Swasdiphanich 1992). Leucaena is a deep-rooted species which can extend its roots 5 m to exploit underground water (Brewbaker *et al.* 1972). In shallow duplex soils, roots have been observed to branch and grow laterally at only 30 cm depth due to an impermeable clay layer.

Leucaena is not tolerant of poorly drained soils, especially during seedling growth, and production can be substantially reduced during periods of waterlogging (see Figure 3.2.3). However, once established it can survive short periods of excess moisture.

Soil type

Leucaena does best on deep, well drained, neutral to calcareous soils; it is often found naturalised on the rocky coralline terraces of Pacific island countries. However, it grows on a wide variety of soil types including mildly acid soils (pH > 5.2). It is well adapted to clay soils and requires good levels of phosphorus and calcium for best growth.

3.4 Uses

Leucaena leucocephala has a wide variety of uses and it was this multiplicity of roles that led to the worldwide reputation of the species as a 'miracle tree'.
First and foremost, the leaves of leucaena are highly nutritious for ruminants and many excellent animal production data have been published confirming the fodder value of leucaena. Secondly, leucaena can be used in cropping systems. Contour strips of leucaena have been employed for many years in the Philippines and in Timor and Flores in Indonesia. The strips serve as erosion control on steep slopes and as a form of alley cropping in which leucaena foliage is mulched into the soil to enhance yields of inter-row crops. On some islands of eastern Indonesia, thickets of leucaena are regularly burnt prior to planting crops in an advanced form of 'slash-and-bum' agriculture.

Leucaena is capable of producing a large volume of a medium-light hardwood for fuel (specific gravity of 0.5-0.75) with low moisture and a high heating value, and makes excellent charcoal, producing little ash and smoke. It also can be used for parquet flooring and small furniture as well as for paper pulp. Leucaena poles are useful for posts, props and frames for various climbing crops (Brewbaker *et al.* 1985). The low seeding varieties are used to provide shade for cacao and coffee and support for climbers such as pepper and vanilla. The high seeding types are a nuisance in this regard because of the high population of seedlings that germinate and compete with the crop. There is opportunity to produce seedless triploid hybrids by crossing self-incompatible

diploid species such as *L. diversifolia* (2x) with tetraploid species such as *L. leucocephala* (Brewbaker and Sorensson 1990).

Leucaena hedges are useful as windbreaks and firebreaks, the latter due to the suppression of understorey grass growth.

Other uses include production of necklaces from seeds and the use of young leaves and seeds as vegetables for human consumption. Young green pods can be split open and the fresh immature seeds eaten raw or cooked. Only small amounts can be eaten in this way because of the presence in seed and young growth of the toxic amino acid mimosine. *Leucaena leucocephala* will occasionally produce a gum similar to gum arabic when stressed by disease or insect pests. When *L. leucocephala* was hybridised with *L. esculenta,* some segregating trees produced gum heavily in the dry season. The hybrids were seedless, had good vigour and were psyllid resistant (Brewbaker and Sorensson 1990).

3.5 Establishment

Slow establishment is still considered to be a major limitation to the expanded use of Leucaena. Slow seedling growth makes plants vulnerable to weed competition and attack by wildlife. However, leucaena seedlings are not naturally slow growing and have been shown to reach 2 m in height within 14 weeks when growing in a fertile soil well supplied with water and nutrients (Ruaysoongnern *et al.* 1985). Leucaena can therefore be established successfully and rapidly provided growth requirements are met.

Seed treatment

Freshly harvested leucaena often has a high degree of hard seed due to an impermeable waxy coat which must be broken before the seed will imbibe water and germinate. Scarification to break this dormancy usually involves treatment with hot water (boiling water for 4 s) or acid (concentrated sulphuric acid for 5-10 min). Seed must be inoculated before planting with a suitable *Rhizobium* strain. TAL1145 is recommended worldwide to ensure effective nitrogen fixation. Lime pelleting will protect the *Rhizobium* bacteria in very acid soils.

Planting

Leucaena may be planted as single plants, single hedgerows or multiple hedgerows depending on its use. In the latter case, hedgerows may be closely spaced (75-100 cm) to achieve maximum yield per hectare for cut-and-carry feeding or more widely spaced (3-10 m) for alley cropping or grazing. Intra-row plant spacings of 25-50 cm are adequate. In widely spaced rows for grazing, grasses may be planted between leucaena rows to increase total fodder supply to animals. In Australia, green panic (*Panicum maximum* var. Trichoglume), setaria (*Setaria sphacelata*), pangola (*Digitaria decumbens*) and buffer grass (*Cenchrus ciliaris*) have been successful companion grasses for leucaena.

Productivity

Dry matter productivity of leucaena varies with soil fertility and rainfall. Edible forage yields range from 3 to 30 t dry matter/ha/year. Deep fertile soils receiving greater than 1,500 mm of well distributed rainfall produce the largest quantities of quality fodder. Yields in the subtropics, where temperature limitations reduce growth rates, may be only 1.5-10 t of edible fodder/ha/year (Brewbaker *et al.* 1985).

The most suitable cutting or grazing intervals to promote high yields vary with environmental factors. In general, longer intervals between defoliation have increased total yield; however, the proportion of inedible wood may also increase leading to a decline in forage quality. At very productive sites, harvest intervals may be 6-8 weeks and up to 12 weeks at less productive locations. Harvest height has less influence on total yield than harvest frequency.

Leucaena and grazing management

It is recommended that regular heavy grazing of leucaena does not commence until plants are mature and well established. This may take 1-3 years depending on growing conditions. However, light grazing can occur in the first year when plants reach 1.5 m in height especially if frosts and wildlife may damage leucaena plants during winter. Grazing promotes branching, results in a protective thickening of main stems and can remove flowers and pods which reduce growth rates.

Regular grazing of well established rows of leucaena leads to the development of quite uniform hedgerows. Taller plants or branches are readily broken and reduced in size by hungry animals. In Vanuatu and Papua New Guinea, cattle graze in leucaena thickets which may be up to 10 m in height. Cattle graze lower branches and newly emerging seedlings and the upper canopy is kept as a drought reserve. The amount of leucaena material available for grazing is reduced in this system of management. Leucaena paddocks are normally rotationally grazed with cattle moved to new areas when most leaf and edible stem have been removed and before serious damage to the wooden framework of the plants has occurred.

Appropriate stocking rates vary greatly from less than 1 beast to 1.5 ha in low rainfall environments (750 mm p.a.) up to 6 beasts/ha in fertile well watered or irrigated stands.

3.6 Toxicity

The foliage and pods of leucaena contain the toxic amino acid mimosine which may reach 12% of the dry matter in growing tips but is less in young leaves (3-5% of dry matter) (Jones 1979). Although quite toxic to non-ruminant animals, mimosine is broken down by microbes in the rumen to DHP (3 hydroxy-4-(1H)-

pyridone) a goitrogen, which is normally broken down further by rumen microorganisms to non-toxic compounds.

The microbes are naturally present in ruminants in Indonesia and Hawaii and probably other countries of southeast Asia and the Pacific where there has been a long history of ruminant animals grazing naturalised leucaena. However, in some countries, notably Australia, Papua New Guinea and perhaps African countries, the appropriate rumen microorganisms are not naturally present leading to an accumulation of DHP which causes goitre (enlargement of the thyroid gland) which results in listlessness, loss of appetite, excess saliva production, hair loss and loss of weight. However, this effect only occurs if leucaena constitutes a high proportion of the animal's diet (>30%) for an extended period..

Procedures for the transfer of the appropriate rumen microbes among ruminants have been developed in Australia.

3.7 Pests and Diseases

Until relatively recently, there were few pests of leucaena because of the insecticidal properties of mimosine. However, following the rapid movement of the leucaena psyllid (*Heteropsylla cubana* westward from the Caribbean across the Pacific in 1985/86, large areas of previously productive leucaena in the Philippines, Indonesia and Australia have been affected. The psyllids or jumping lice are small aphid-like insects adapted to feeding on the young growing shoots of leucaena. Mild infestations cause distortion of leaves whilst heavy infestations result in loss of leaves and attack by secondary moulds which feed on the sticky exudate of psyllids. The psyllid is native to Central America. Bray and Woodroffe (1991) reported that psyllids reduced the production of edible material by 52% and that of stem by 79% in southeast Queensland. There is some scope for biological control from the beetle *Curinus coeruleus,* the parasitic wasp *Psyllaephagus* nr. *rotundiformus* and from resistance in the *leucaena* genus (Anon. 1990).

The most probable control of the psyllid will occur through the development of psyllid resistant hybrids. Leucaena hybridises readily with the species *L. pallida* and *L. diversifolia* both of which contain psyllid resistance. Breeding programmes to develop open-pollinated and F1 hybrid cultivars are well advanced (Brewbaker and Sorensson 1993). The yield of these psyllid resistant lines far exceeds that of susceptible *L. leucocephala* lines in high psyllid environments and they are exciting prospects for future development.

A serious disease of seedling leucaena in nurseries is damping-off in moist soils caused by the fungal species *Pythium* or *Rhizoctonia* spp. (Brewbaker *et al.* 1985). This is controlled by good nursery techniques (overwatering

promotes the disease) and use of well-drained soil media. The use of fungicides such as Benlate or Captan are also an option.

The moth *Ithome lassula* which damages leucaena inflorescences and the seed beetle *Araecerus levipennis* reduce the production and viability of seed.

4 Balanites aegypticaca (L.) Del.

Balanitaceae

4.1 Botanical Distribution

Balanites aegyptiaca is a multibranched, spiny shrub or tree up to l0 m high. Crown rounded, dense (but still seen through) with long stout branchlets. Trunk and bark grey, deeply fissured longitudinally.

Leaves compound and spirally arranged on the shoots, dark green with 2 firm coriaceous leaflets; dimensions and shapes varying widely. Petiole canaliculate, from 5 mm to 20 mm with a short rachis. Most accounts indicate a maximum length of 8 mm for Uganda. Margin of each leaflet entire; lamina generally up to 6 cm long, 4 cm broad, although apparently smaller (1-3 x 0.3-1.5 cm) in the Sahara and in Palestine.

Inflorescence a sessile or shortly pedunculate fascicle of a few flowers. Flower buds ovoid and tomentose. Individual flowers hermaphroditic, pentamerous an actinomorphic, 8-14 mm in diameter and generally greenish-yellow. Pedicels densely greyish, pubescent and rarely reaching 10 mm in length, although 15 mm is reported for Zambia and Zimbabwe. The usual length is about 8 mm.

4.2 Ecology and Distribution

Natural habitat

B. aegyptiaca has wide ecological distribution; however, it reaches its maximum development as an individual tree on low-lying, level alluvial sites with deep sandy loam and uninterrupted access to water such as valley floors, riverbanks or the foot of rocky slopes. It is intolerant to shade after the seedling stage and therefore prefers open woodland or savannah for natural regeneration.

Natural limits

Altitude: 0-1 000 m, Mean annual temperature: 20 -30 deg. C, Mean annual rainfall: 250-400 mm

Soil type: The soils in its range tend to be deep sands, sandy clay loams, sandy loams or clays.

History of Cultivation

Booth and Wickens (1988) report that there are plantings of the species in the Cape Verde Islands, Curacao, the Dominican Republic and Puerto Rico. Plantings have also been reported in India. Individual trees are planted extensively in Africa, and small plantations have been established in Niger, Chad and northern Nigeria.

Reproductive behaviour

Flowering behaviour varies. There is no definite time for flowering in the Sahel, although flowering most likely takes place in the dry season. Flowering in Nigeria varies between November and April with ripe fruits becoming available in December and January and occasionally later, from March to July. Elsewhere, fruiting and foliage production occur at the height of the dry season. Pollination is presumably by insects as flowers are scented, and flower structure facilitates insect activity. The 1st fruiting is at 5-8 years, yields increasing until 25 years of age for the tree.

The fruit apparently takes at least 1 year to mature and ripen. Birds and mammals eat the fleshy and edible fruit, discarding, regurgitating or evacuating the stone.

4.3 Propagation and management

Propagation methods

Seeds may be collected from fruit that is being processed for other purposes, from dung, and directly from the trees. Soaking in water for some hours and then stirring vigorously separates the stones from the pulp. Seed germination can be improved by immersing the seeds in boiling water for 7-10 min then cooling slowly. The effect that passage through an animal's intestinal tract has on germination is unclear. However, seeds are said to germinate readily, although with some difference associated with date of collection.

Natural regeneration is primarily through seeding. The fruit is high in demand, which gives it high economic value; therefore, little fruit and thus few seeds are left for natural regeneration of the species. The tree also can generate by coppice shoots and its abundant root suckers.

Tree management

Coppices and pollards well and can regenerate after lopping and heavy browsing. Where fruit is the principal interest, pollarding and coppicing for obtaining fodder are seldom employed.

4.4 Uses

Products

Food: The fleshy pulp of both unripe and ripe fruit is edible and eaten dried or fresh. The fruit is processed into a drink and sweetmeats in Ghana, an alcoholic liquor in Nigeria, a soup ingredient in Sudan. Young leaves and tender shoots

are used as a vegetable, which is boiled, pounded, then fried or fat added to prepare it. The flowers are a supplementary food in West Africa and an ingredient of 'dawa dawa' flavouring in Nigeria. Flowers are sucked to obtain nectar.

Fodder: The fresh and dried leaves, fruit and sprouts are all eaten by livestock. As shown in an experiment in Burkina Faso, *B. aegyptiaca* contributed up to 38% of the dry-matter intake of goats in the dry season. Kernel meal, the residue remaining after oil extraction, is widely used in Senegal, Sudan and Uganda as a stock feed. The tree is lopped for fodder in India (Maharashta, Madhya Pradesh, Tamil Nadu and Rajasthan).
Fuel: The wood is good firewood; it produces considerable heat and very little smoke, making it particularly suitable for indoor use. It produces high-quality charcoal, and it has been suggested that the nutshell is suitable for industrial activated charcoal. The calorific value is estimated at 4600 kcal/kg.

Fibre: A strong fibre is obtained from the bark.

Timber: The wood is pale yellow or yellowish-brown. Heartwood and sapwood are not clearly differentiated. The wood is hard, durable, worked easily and made into yokes, wooden spoons, pestles, mortars, handles, stools and combs. It shows no serious seasoning defects and no tendency towards surface checking or splitting. The wood saws cleanly and easily, planes without difficulty to a smooth finish and is easy to chisel. It glues firmly and takes a clear varnish. The timber has traditionally been a minor product. The usually small log size and the prevalence of stem fluting makes sawmill processing difficult.

Gum or resin: A greenish-yellow to orange-red resin is produced from the stems. It is sucked and chewed when fresh. It is used as a glue for sticking feathers onto arrow shafts and spearheads and in the repair of handle cracks and arrows.

Lipids: The kernels produce edible oil used for cooking. The oil remains stable when heated and has a high smoking point, and therefore its free fatty acid content is low. Its scent and taste are acceptable.

Alcohol: The fruit of *B. aegyptiaca* may be used to brew an alcoholic drink.

Poison: An emulsion made from the fruit or bark is lethal to the freshwater snails that are the host of miracidia and cercaria stages of bilharzia and to a water flea that acts as a host to the guinea worm. A fish poison can be obtained from the fruit, root and the bark. The active agent of the poison is saponin. The compound is toxic to fish but does not affect mammals and rapidly becomes inert, so that fish retrieved are edible. However, in the Fada region of Cote

d'Ivoire, the poison is reported to damage the sight of fishermen after they have used it for 5-6 years.

Medicine: Decoction of root is used to treat malaria. Roots boiled in soup are used against oedema and stomach pains. Roots are used as an emetic; bark infusion is used to treat heartburn. Wood gum mixed with maize meal porridge is used to treat chest pains. The bark is used to deworm cattle in Rajasthan.

Other products: The seeds are used for rosary beads, necklaces and in the game of warri played in Sudan.

Services

Shade or shelter: The usually evergreen behaviour potentially makes *B. aegyptiaca* an attractive element to introduce into shelterbelts, although because of its slow growth, it is not suitable as a principal species.

Boundary or barrier or support: As a thorny tree, *B. aegyptiaca* is useful for fencing. Boundary and amenity plantings are widespread in Africa. Cut branches are used to make livestock enclosures.

4.5 Pest and Diseases

B. aegyptiaca suffers from repeated locust and beetle attack and a high degree of parasitic infestation (in Gountoure, Burkina Faso, 50% of the population had leaf galls, bugs or scales). Two microfungi, Phorma balanitis and Septoria balanitis, are the only reported dependent fungi.

5.Moringa Stenopetala (Bac.) Cuf.

Moringaceae

5.1 Botanical Description

Moringa stenopetala is a tree 6-12 m tall having a diameter of 60cm (DBH) and a smooth bark; its crown is strongly branched, sometimes with several trunks, and its wood is soft.

The leaves are bi- or tri-pinnate, with about 5 pairs of pinnae and 3-9 elliptic to ovate leaflets per pinna.

The flowers are very fragrant with cream flushed pink sepals, white, pale yellow or yellow-green petals, white filaments and yellow anthers. The ovary is ovoid and densely hairy.

Pods are elongate reddish with greyish bloom having grooved valves.

5.2 Ecological Distribution

Natural habitat

M. stenopetala grows naturally in the *Acacia tortilis-Delonix elata-Commiphora spp.* vegetation-complex. This type of vegetation is often found in well-drained soils at altitudes of 900-1200 m. The species is quite drought resistant. In southern Ethiopia, it has been found in areas of mean annual rainfall ranging from 500-1400mm. Cold temperatures are limiting factor for the cultivation of the species in Ethiopia because it does not tolerate frost.

Natural limits

Altitude: 400-2100 m.
Mean annual temperature: 24-30 deg C.
Mean annual rainfall: 500-1400 mm
Soil type: The species does not have any specific soil requirements, except it does not grow on waterlogged or swampy soils. The soil PH ranges from acidic to alkaline but mostly exhibit neutral reaction.

5.3 Propagation and Management

Seed storage

Cold temperatures inhibit seeds of *M. stenopetala*; under low temperatures (at and below 15 deg C) an enforced dormancy has been found to occur.
The speed of germination of untreated seeds depends on temperature, humidity and watering. Seeds placed at 8 deg. C in a refrigerator for 24 hours before sowing showed 88% germination in an experiment.

The seeds remain viable for several years as evidenced by germination rates of 96-98% recorded for 44 month-old seeds.

Propagation methods

The most common method of propagating *M. stenopetala* is by direct sowing without pre-treatment of seed. But standard nursery raised seedlings are also commonly used. Removing the spongy seed coat improves germination. In a nursery it needs 7-10 days to germinate. Use of wide polythene is advised as the bulgy root requires large enough space (12 cm diameter flat). In about 3 months the seedlings will be ready for planting out. Some farmers occasionally propagate the species by using branch-sized cuttings.

5.4 Uses

Products

Food: The leaves and fruits are eaten as vegetables and are rich in proteins, calcium, iron, phosphorous as well as vitamins A and C.

Fodder: The use of leaves and pods for animal fodder is currently of minor importance compared to their use for human consumption. Yet, due to their high protein content this is a promising potential use.

Fuel: Growing rapidly, these trees have softwood that is not particularly suitable for fuel. But because the supplies are so scarce, it is often used as a fuel in its natural range.

Services

Ornamental: It is a valued ornamental in its natural range.

Boundary or barrier or support: It serves as a live fence in areas of its natural range.

Intercropping: The species is grown in mixed multi-storey stands with food crops. The home gardens in Ethiopia (Arba Minch area) for instance, include at least 5, and sometimes up to 15 M. stenopetala trees per 0.1 ha. Farmers practice permanent multi-storeyed cultivation with M. stenopetala at the uppermost level, Carica papaya, coffee and bananas in the upper-middle level, cassava, maize and sugar cane in the lower-middle level and cotton and pepper in the lowest level.

Pollution control: One of the most promising potential uses of M. stenopetala is to purify turbid water. The seeds of this and some other species of the Moringaceae have flocculating and anti-microbial properties. The active substances are found only in the cotyledons of the seeds.

5.5 Pest and Diseases

M. stenopetala is more resistant to insect pests than other species of its family. Most farmers in its natural range report that they never saw diseases or pests on this tree. On deep generic ferrasols, the seeds have been found to be attacked by insects after sowing.

6. Cajanus cajan (Druce)

Fabaceae

6.1 Botanical Description

Cajanus cajan is a glandular-pubescent, short-lived perennial (1-5 years) shrub, usually grown as an annual, 0.5-4 m high, with thin roots up to 2 m deep; stems up to 15 cm in diameter; branches many, slender.

Leaf rachis 1-2 cm long; petiole half as long or less; stipules acuminate, 2.5-5 mm long, persistent; leaflets lanceolate or narrowly elliptic, puberulent above and underside, the largest to 7.5-8 x 2.8-3.5 cm, acute apically, bases similar, venation strongly reticulate, prominent underneath.

Inflorescence axillary from a single peduncle, terminating at the insertion of 1-2 pedicels or continuing for 1-3 additional nodes, rarely branching, usually slightly shorter than the leaves, mostly with 2-6 flowers; bracts about 5 mm long; flowers about 2 cm long; pedicels to about 9 mm long; calyx tube 3-5 mm long, glandular and pubescent, the upper lobe bifid, the lower lobe longest, about 4 mm long; vexillary petal basally inflexed biauriculate, mostly with reddish striate, bicallose in the target area, glabrous, about 14 mm long, with a claw about 4 mm long.

6.2 Ecology and Distribution

Natural habitat

As the species is not found truly in the wild, its natural habitat conditions are uncertain. It prefers grassy habitats in tropical, cold-free zones with optimum 600-1000 mm annual rainfall. However, it grows in humid areas with 2500 mm annual rainfall and in semi-arid areas with only 400 mm of rain annually.

Biophysical limits

Altitude: 0-2000 m, Mean annual temperature: 18-38 deg. C, Mean annual rainfall: 400-2500 mm

Soil type: C. cajan is grown in a wide range of soils with varying physical and chemical characteristics. The major soils are alluvials, Vertisols and Alfisols, which range in pH from 5 to 7 or more. It is sensitive to salinity and has not been produced on saline soils. It is also susceptible to waterlogging.

History of cultivation

C. cajan originated in India and spread to Southeast Asia in the early centuries of our era. The species was known in ancient Egypt at least 4000 years ago, reached the rest of Africa 2000 BC or earlier, and found its way to the Americas with the conquests and

slave trade, probably through both the Atlantic and the Pacific. It is now grown all over the tropics but especially in the Indian subcontinent and East Africa.

Reproductive biology

The bisexual flower may remain open for about 6 hours, pollen having been shed the previous day. The flowers of C. cajan are cleistogamous, a condition favouring self-pollination. But bees visit the flowers and there is about 20% cross-pollination. The factors affecting the extent of cross-pollination are the flowering habit of the cultivar and the types and numbers of insect pollinators. Only heavy insects can trip the flowers by depressing the keel petal and releasing the staminal column. Large wild bees can do this, including Chalicodoma, Megachile and Xylocopa.

6.3 Propagation and Management

Seed storage

Seed storage behaviour is orthodox with no problems for long-term storage under preferred conditions. There are 5000-14 000 seeds/kg.

Propagation methods

The pods are picked when the seed has reached physiological maturity and is just beginning to lose its bright green colour. C. cajan is best established by direct seeding in a well-prepared field. No pregermination treatment of seeds is needed. Seedlings have hypogeal germination. Emergence is complete 2-3 weeks after sowing. Stem cuttings rarely succeed.

Tree management

For hedgerow intercropping, the hedges should be cut at height of 0.5-1 m when the grain crop is fully mature. The hedges can be cut 2-3 times a year in areas where the dry season lasts 4-6 months. At pod maturity, branches of C. cajan are cut at about 0.5 m. Higher levels of pruning can result in higher and unacceptable levels of plant mortality. As a field crop, C. cajan may be typified as rather undeveloped; the tall genotypes particularly are cumbersome in cultivation. Weeds must be controlled to alleviate slow initial growth. Wind may bend the plants, but staking is not practised. In intensive cropping of short-duration cultivars, irrigation may be required. C. cajan's response to fertilizers is rarely economic; a phosphate dressing is generally recommended at 20-100 kg/ha.

6.4 Uses

Products

Food: The seeds of C. cajan can be used as a vegetable. Very young pods are harvested before the seeds are distinct and are cooked in curries or used to make relishes. The dry seeds have several products such as tempe (a traditional Indonesian food prepared by fermenting with a Rhizopus mould then

soaked, dehulled and cooked legume seeds), and ketchup (pigeonpea sauce, a replacement for soy sauce in Indonesia that is made by fermenting C. cajan with Apergillus oryzae). C. cajan flour (mixed with wheat to improve the protein level of baked products) and clear noodles of a quality higher than that of mung bean are made from dehulled seed. Fresh seeds contain vitamins, especially provitamin A and vitamin B complex. Per a 100 g edible portion, dry seeds contain 7-10.3 g water, 14-30 g protein, 1-9 g fat, 36-65.8 g carbohydrates, 5-9.4 g fibre and 3.8 g ash. The energy content averages 1450 kJ/100 g.

Fodder: C. cajan fodder alone may be a bit low in energy. The leaves can provide a good substitute for alfalfa in animal feed formulations, particularly in areas not suitable for alfalfa. The pods are used as cattle feed but are limited by their low protein and high fibre content. They have therefore been used as a roughage source for cattle. C. cajan grain has been successfully used for poultry feed. In Hawaii, a mixture of equal quantities of cracked pigeon pea and cracked maize has been proved the best poultry ration.

Apiculture: Honeybees collect nectar from the plant, which is an important honey source. The honey has a distinctive greenish hue in the comb.
Fuel: C. cajan sticks are an important household fuel in many areas. The heat value is about 1/2 that of the same weight of coal, and it has several advantages over traditional trees, such as its rapid growth potential, possibility of producing other crops on the same land, and production of a seed crop. Farmers sow it instead of grain because of its wood. Its productivity levels more than make up for the comparatively poor fuel characteristics.
Fibre: On an experimental basis, C. cajan has been found to produce a pulp for paper similar to that of hardwoods, and the pulp might be suitable for making good-quality writing and printing paper. The branches and stems can be used for making baskets.
Timber: The wood is used in light construction such as in roofing, wattling on carts, tubular wickerwork lining for wells and baskets.

Medicine: It has many traditional uses as medicine. In Java, for example, the young leaves are applied to sores, herpes and itches.
Other products: C. cajan serves as a host for silkworm (in Madagascar) or the lac insect (in northern Bengal and Thailand).

Services

Erosion control: Extensively covering the ground with C. cajan prevents soil erosion by wind and water.

Shade or shelter: C. cajan is useful as a tall hedge on dry soil and on the bunds of paddy fields. It is often grown as a shade crop, cover crop or windbreak.

Nitrogen fixing: Using the nitrogen-balance method, it has been proved in northern India that long-duration C. cajan can fix up to 200 kg N/ha over a 40-week period.

Soil improver: The root system is reported to break plough pans, thus improving soil structure, encouraging infiltration, minimizing sedimentation and smothering weeds. Leaf fall at maturity adds to the organic matter in the soil and provides additional nitrogen. It seems to have special mechanisms to extract phosphorus from black Vertisol soils.

Boundary or barrier or support: In Southeast Asia, C. cajan is grown as a support for vanilla.

Intercropping: Due to its hardiness, ability to grow on residual soil moisture, and slow early growth, C. cajan is an ideal, non-competitive crop to plant with cereals. In traditional cropping systems, it is mixed with cereals, oil seeds, short-season pulses or cotton, with the cereal as the main crop and C. cajan as the bonus crop. In Kenya, it is an important food legume, cultivated commercially for dry seed and as a green vegetable. In Zambia, smallholder farmers generally grow it in their backyards and around the fields of annual crops. In Uganda, it is combined with millet in a cropping system.

6.5 Pests and Diseases

Because of its long flowering period, damage by pests such as agromyza fruitflies and heliothis borers may be compensated for by renewed flushes. Chemical control is cumbersome and expensive in the tree's tall, indeterminate forms. C. cajan has more than 100 pathogens. They include fungi, bacteria, viruses, nematodes (cyst nematode, reniform nematode, root-knot nematode) and mycoplasm-like organisms. A disease of economic importance is fusarium wilt (Fusarium udum), which is found in Bangladesh, Ghana, Grenada, India, Indonesia, Kenya, Malawi, Mauritius, Nepal and Tanzania. Control measures include cultural practices like rotation with tobacco over several years and breeding for resistance. Sterility mosaic is the most important disease of C. cajan in India and Nepal. Others include phytophthora blight and cercospora leafspot.

6.6 Experience in tropical Africa

Pigeon pea is a promising multipurpose tree for drylands. It is grown extensively throughout most semi-arid areas of Africa as a perennial garden crop and is commonly seen in Konso area of southern Ethiopia as an intercrop with sorghum and cotton. It is mainly consumed locally; the green immature pod's are frequently used as vegetable and dried peas as pulse. The nutritive quality of pigeon pea is excellent. Dried stalks may be used for fuel, even for charcoal production. This can contribute in alleviating the serious problem of

lack of energy source for fuel wood in the Semi-arid areas. The leaves are also a good source of fodder.

In addition, because of its drought resistance and its multipurpose use among the grain legumes pigeon pea (*Cajanus cajan*) deserves a special attention. Once established pigeon pea is one of the most drought resistant crops found in Africa. This is because it has very deep root, which can penetrate hard soil layers, which other crops cannot. The plant also has the ability to shade its leaves and greatly reduces growth during prolonged water stress and may yield after several months of dry weather.

Pigeon pea can also thrive on very poor soils. Pigeon pea is very important as intercrop and in rotation with cereal based cropping systems. There is a limited research work on this aspect in the country. Except in the Kobbo-Alamata plain some preliminary research results indicated that intercropping pigeon pea with sorghum has indicated that pigeon pea can be intercropped without material reduction in sorghum yields with an overall of slightly increased gross return. In fact, one of the promising intercrops with cereals particularly sorghum and maize is the late maturing pigeon pea. Even though early growth of the legume is reduced when intercropped with maize or sorghum, pigeon peas compensate by continuing to grow after maize harvest and produce large quantities of biomass about 3 t ha^{-1} of dry matter from leaf litter and flowers (Sakala 1994). Pigeon peas is easily intercropped with cereals and even the seed is harvested for food, the leaf fall is sufficient to N and organic matter accumulation.

The yield responses of a cereal crop following pigeon peas can also substantial. Research results indicate that grain yield of the first crop of maize following pigeon peas average 2.8 t ha^{-1} higher than that of continuous maize that received 35 kg ha^{-1} N each year. In Malawi MacColl (1989) estimated net nitrogen of 23 to 110 kg ha^{-1} from pigeon peas.

The Ethiopian Agricultural Research Organization, has now introduces several pigeon pea cultivars from the ICRISAT eastern Africa grain legume program to screen the cultivars, which fit the growing conditions of the dryland areas of Ethiopia. They were on quarantine trials for a year and now they are sent to different sites for further screening. Some of the cultivars have been released in more than 5 countries in Kenya and other eastern African countries with similar agroecologies and farming systems as the dryland areas of Ethiopia. Therefore, there is high probability that they will adapt in the dryland of Ethiopia too.

Botanical Distribution

7. Acacia saligna (Labill.) H.Wendl.

Mimosoidae

7.1 Botanical description

Acacia saligna is a dense and multi stemmed, thornless, spreading shrub or a single-stemmed, small tree up to 9 m in height; bark is smooth and grey to red-brown on branchlets becoming dark grey and fissured with age.

Leaves alternate, simple, flattened phyllodes, varying from very narrow to lance-shaped, about 10 times as long as wide, mostly 8-25 cm long and 0.5-2 cm wide, straight or slightly curved to the side, long, pointed and tapering at both ends like ribbons, hairless, often drooping, dull blue-green to whitish, with a permanent midvein and many fine side veins; large dotlike gland 1-2 mm or more in diameter at base of upper edge of phyllode.

Flower clusters (heads) like balls, mostly 2-10 (sometimes 1), on stalks along axis (racemes) to 8 cm long at base of leaf; round, bright yellow or deep golden heads, 7-10 mm in diameter, with many (25-55) crowded, tiny flowers, abundant and showy; flowers stalkless, 3-4 mm long, mostly hairless, composed of calyx 1.5 mm long with conical tube and 5 short, rounded lobes, often finely hairy on edge; corolla of 5 narrow, long-pointed petals, 2-3 mm long, united near base; many threadlike stamens, pistil with hairless ovary and slender style.

Fruits very narrow, 8-12 cm long and 4-6 mm wide, straight and flattened. There are 6 to 10 beanlike seeds, each 5-6 mm long x 3-2.5 mm wide, dark brown to black, shiny.

The generic name ‘acacia’ comes from the Greek word ‘akis’, meaning a point or a barb. The specific name means ‘willowlike’ and describes the phyllodes.

7.2 Ecological Distribution

Natural habitat

A. saligna grows mainly on sandy, coastal plains, but it is also found in a wide variety of environments, from swampy sites and river banks to small, rocky hills (often granitic) and slopes of coastal ranges. It is also found by creeks and disturbed roadsides. The plant tolerates salt spray, soil salinity and alkalinity. The associated vegetation types include open, dry evergreen forest, temperate woodland and semi-arid woodland.

History of cultivation

A. saligna was introduced to South Africa around 1876-1885 and to Libya for dune stabilization in 1920. In Ethiopia, it has been introduced to most medium and higher altitudes of the country through re-afforest ration programmes.

Biophysical Limits

A. saligna was introduced to South Africa around 1876-1885 and to Libya for dune stabilization in 1920. In Ethiopia, it has been introduced to most medium and higher altitudes of the country through re-afforest ration programmes.

7.3 Propagation and Management

Seed Storage

Seed storage behaviour is orthodox. There are about 14 000-25 000 seeds/kg.

Propagation Methods

A. saligna produces a large number of viable seeds, and young plants can often be found in their hundreds under mature trees, promoting the rapid spread of the species and directly contributing to its weed status. The seeds germinate easily. They are normally treated with boiling water for 1 minute, but nicking the seed coat, soaking seed in sulphuric acid, and exposing seed to dry heat are also effective. Successful micro-propagation techniques using tissue culture have also been used.

Tree management

Production for browse and wood can begin 3 years after planting out, gradually building to 6 years. The impact of various management methods on long-term productivity is not well understood. In Mauritius, the management options tried include trimming followed by direct grazing and direct browsing with periodic pruning. A rotation of 7-10 years or coppicing may be used. In Mediterranean countries, firewood from A. saligna is harvested on a coppice rotation of 5-10 years. Human interference and grazing should be discouraged for rapid success. Lupines should be sown where necessary to enrich the ground cover.

7.4 Uses

Products

Fodder: The phyllodes, young shoots, pods and seeds, whether fresh or dry, are rich in protein and are non-toxic and palatable to both sheep and goats. They are particularly valuable seasonally when other forage is scarce. The chemical composition of the leaves shows dry matter (50-55%), crude protein (12-16%), crude fibre (20-24%), crude fat (6-9%) and ash (10-12%). Re-growth of established bushes is so good that A. saligna can be completely grazed off without harming the plant.

Fuel: Plantations for firewood have been established in some Mediterranean countries. The wood is reported as sappy, light and not popular for firewood. A. saligna can withstand some shade and can be grown as an understorey beneath pines or eucalypts for energy in villages.

Fibre: In Tunisia the wood has been successfully processed into particleboard.

Timber: A. saligna is used for vine stakes and small agricultural implements.

Gum or resin: The damaged bark exudes copious amounts of a very acidic gum that shows exceptional promise for use in pickles and other acidic foodstuff.

Tannin or dyestuff: In the past, the tree was planted for tannin production from the bark.

Services

Erosion control: A. saligna is one of the best species for binding sand. It has been used in North Africa, the Middle East and South Africa for coastal sand dune fixation, and in Uruguay for gully erosion control.

Shade or shelter: A. saligna is useful for windbreaks.

Reclamation: In Australia it has been used in the rehabilitation of sand mining areas.

Nitrogen fixing: The tree nodulates with certain strains of Rhizobium. As with many other acacias, it forms associations with Vesicular Arbuscular mycorrhizal (VAM) fungi.

Ornamental: A. saligna is widely planted as an ornamental.

7.5 Pests and diseases

Various gall-exploiting insects invade the tree, and in parts of Western Australia more than 90% of the trees bear conspicuous galls. The trees are susceptible to white-scale insects, which attack the leaves and stems. Rodents sometimes attack the roots. Termites may cause serious problems in tropical countries. Older plants are susceptible to gall rust, Uromycladium tepperianum.

8. Sesbania sesban (L.) Merr.

Fabaceae

8.1 Botanical Description

Sesbania sesban is a narrow-crowned, deep-rooting single or multi stemmed shrub or small tree, 1-7 m tall. The trees usually have a main stem but may develop many side branches if widely spaced. The many branches give the tree a shrubby appearance, often tending towards a spreading habit due to its wide branching angle (45-60 deg. Mostly).

Leaves paripinnate, long, narrow; leaflets in many pairs, rounded or oblong, usually asymmetric at the base, often glaucous; stipules minute or absent.

Flowers attractive, yellow, red, purplish, variegated or streaked, seldom white, large or small on slender pedicels, solitary or paired in short axillary racemes, usually unpleasantly scented; all petals long clawed, standard orbicular or obovate.

Pods pale yellow, linear, usually 10-20 cm long, cylindrical or compressed, rarely oblong; up to 40 seeds are found in a pod; seeds oblong or subquadrate, brown or dark green mottled with black.

Two subspecies are recognized within S. sesban, namely ssp. punctata (restricted to northern portions of sub-Sahara Africa) and ssp. sesban.

8.2 Ecology and Distribution

Natural Habitat

S. sesban grows well in the subtropics and is significant in extending the nitrogen-fixing forage trees into cooler, higher elevation regions of the tropics. It has outstanding ability to withstand waterlogging and is ideally suited to seasonally flooded environments. When flooded, it initiates floating, adventitious roots and protects its stems, roots and nodules with spongy, aerenchyma tissue. It is common along streams, swamp banks and moist and inundated bottomlands. S.sesban shows some tolerance to moisture stress and tolerates soil alkalinity and salinity to a considerable degree.

Natural limits

Altitude: 100-2300 m, Mean annual temperature: (10 min.) 18-23 (45 max.) deg. C, Mean annual rainfall: 500-2000 mm

Soil type: Tolerates seasonal or permanently waterlogged soils as well as saline, acidic and alkaline soils.

History of cultivation

The origin of S. sesban is unclear, but it is widely distributed and cultivated throughout tropical Africa and Asia. Africa is its centre of diversity, and it probably originated there; its former name is S. aegyptiaca. From northeastern Africa, S. sesban var. sesban and its variants were spread across southern Asia.

Reproductive biology

S. sesban is assumed to be largely out-crossing, however interspecific hybridization is reported with S. goetzei; the carpenter bee is its main pollinator. Flowering starts shortly after the onset of the rains (in areas where there are 2

rainy seasons, it flowers and sets fruit twice). Pods are indehiscent and do not shed their seeds until well after pod maturity.

8.3 Propagation and management

Seed storage

Seed storage behaviour is orthodox. Viability can be maintained for 2 years in open storage at room temperature. There are 85 000-100 000 seeds/kg.

Propagation methods

S. sesban has a hard, impermeable seed coat, and scarification is recommended to ensure uniform germination. For research purposes, soaking in sulphuric acid followed by rinsing in water is common. Hot water treatment or soaking in cold or tepid water for 24 hours may also be effective. The seed germination rate is 65% in about 16 days. Vegetative propagation using stem cuttings is not a widespread practice; *S. sesban* can also be established by tissue culture.

Tree management

One of the major advantages of sesbania over other forage trees and shrubs is its rapid early growth rate, which can be exploited by intercropping it with other slower establishing species for earlier yields. In India, it has been reported to attain a height of 4-5 m in 6 months. S. sesban thrives under repeated cuttings and coppices readily, with many branches arising from the main stem below cutting height. Cutting frequencies are generally 3-4 cuts/annum, but up to 8 cuts are made in some areas. Yields have ranged from 4 to 12 t/ha dry matter per year, depending on location. Cutting height can also influence yield, with cutting heights of 50-76 cm favouring plant survival and productivity.

The rhizobium requirements of S. sesban vary. There is a host-strain interaction, and different accessions of S. sesban require different strains of bacteria.

8.4 Uses

Products

Food: S. sesban flowers are edible and are included perhaps as a decorative or festive ingredient in foods such as omelettes.

Fodder: The tree has a high percentage of foliage nitrogen and is an excellent supplement to protein-poor roughage in ruminant diets. Ruminants readily eat leaves and young branches. The crude protein content of the foliage is generally greater than 20% and often above 25%. In vitro dry-matter digestibility is 75%. Nylon-bag dry-matter digestibility of dried leaf of S. sesban is 90.7% and nitrogen digestibility is 96.7%. These characteristics, together with

the generally low crude fibre content and high phosphorous levels, indicate the potential of the species as a high-quality forage source.

When grazed, the brittle tree may break too easily and expose the tree to fungal attack. It has been successfully fed as a sole diet to goats and as a supplement to low-quality forage for sheep.

Fuel: S. sesban is popular for firewood and charcoal because it produces a high woody biomass in a short time, which, although soft, is relatively smokeless, quick kindling and hot burning. The calorific yield for a 3-year-old tree is approximately 4350 kcal/kg.

Fibre: S. sesban is used for making ropes and fishnet and has potential for pulpwood production.

Gum or resin: S. sesban seeds and bark produce gum.Poison: The saponin, stigmasta-galactopyranoside, which is isolated from the seeds, has glucuronide derivatives of oleanolic acid, which has molluscicidal activity against Biophalaria glabrata, one of the known snail vectors of schistosomiasis. The saponin also shows spermicidal and haemolytic activity. Using S. sesban leaf meal in poultry diets (as 10% of the diet) is fatal to young chicks, and the provision of either cholesterol or sitosterol with the diet significantly improves chick survival.

Medicine: Fresh S. sesban roots and leaves are used to treat scorpion stings, boils and abscesses. The Hausa of Ghana use decoctions of leaves as a drench for cattle to repel tsetse fly. Among the Haya people of Tanzania, it is used to treat sore throat, gonorrhoea, syphilis, spasmodic fits in children and jaundice during pregnancy. The leaves are used in some countries as a tea and are considered to have antibiotic, anthelmintic, antitumour and contraceptive properties. Oil from the seeds is accorded special properties in ayurvedic medicine and is reported to have bactericidal, cardiac depressant and hypoglycaemic actions.

Services

Shade or shelter: S. sesban has been used to shade coffee, tea and cocoa. It has also been used as a windbreak for bananas, citrus and coffee.

Soil improver: *S. sesban* will increase soil nitrogen through symbiotic interaction with bacteria, has the ability to stabilize soil, and in Asia has been used as green manure for rice. Its branches have been used as mulch and leaves as a green manure. *S. sesban* improves soil fertility in a short-term rotation fallow and is useful in combating striga weed (Striga hermonthica). Some studies indicate that in 1 year a S. sesban fallow can increase maize yields from 2 to 4 t/ha without application of nitrogen fertilizer.

Intercropping: *S. sesban* is a promising shrub for alley cropping because it is easy to establish, it grows rapidly, coppices readily and provides mulch of high nutrient content (particularly N). In some climates, such as in the highlands of Kenya, it may have a sparse canopy, and weed competition can be a problem. This characteristic makes S. sesban a good intercrop.

Boundary or barrier or support: Suitable for use as live trellises for pepper.

8.5 Pests and Diseases

S. sesban is attacked by nematodes, insects, fungi and viruses. The leaf-eating beetle Mesoplatys ochroptera can completely defoliate S. sesban, leading to mortality. Caterpillars, Hymenoptera, and stem borers are normally associated with S. sesban. Some potentially destructive root-knot nematodes have been recorded in India as associated with S. sesban.

For further information and technical help:
Contact:
Forestry Research Center,
Dryland Forestry research Project Coordinator,
Addis Ababa
Tel: 460151/460451/460444

References

Coppock DL(1994) The Borana Plateau of Southern Ethiopia: Synthesis of pastoral research development and change, 1980-1991. ILCA, Addis Ababa.

Azadirachta indica

Andreas Drews (undated) *Biological control in small scale farming in the tropics*. Experience Reports and User Manual. GTZ GmbH IASAT, Germany.
BOSTID (1982. *NEEM: A tree for solving global problems.* National Research Council, National Academy Press, Washington D.C.
Chaturvedt V.S (1996). *Neem in Ayurveda.* India
Dodowa. *The potential of the Neem tree in Ghana.* October 1998. GTZ, GmbH-Echborn, Germany.
Gaby Stoll. *Survey on Non-chemical Crop Protection and Need for a Farmer Oriented Research,* Germany.
Global neem update. Vol 1. No 3, 1996, Quarterly Newsletter,
Neem Foundation, India
Handa & MK Kaul (undated). *Cultivation and Utilization of Medicinal Plants.* Regional Research Laboratory. Council of Scientific and Industrial Research, Jammu-Tawi

Henery Schmutterer, K.R.S Ascher and H. Rembold (eds). *Natural pesticides from the Neem tree* (A*zadirachta indica* A.Juss) in Proceeding of the first international neem conference, Nairobi, Kenya, 16-18 June 1980
Mechael D. Benge (ed). *NEEM, The Cornucopia tree.* Agroforestation, Technical Series No 5, RM, 515-E, SA 18. Agency for International Development-Washington D.C, 20523
Mechael D. Benge (ed). *Selected Neem Reprints*, S&T/FENR Agro forestation, Technical Series No 5, RM, 515-E, SA 18. Agency for International Development-Washington D.C, 20523

Leucaena leucocepala

Anonymous (1990) leucaena an important multipurpose tree. *NFT Highlights* 90-01, NFTA, Hawaii.
Benjamin, A., Shelton, H.M. and Gutteridge, R.C. (1991) Shade tolerance of some tree legumes. In: Shelton, H.M. and Stür, W.W. (eds), *Forages for Plantation Crops.* ACIAR Proceedings No. 32, Canberra, pp. 75-76.
Bray, R.A. and Woodroffe, T.D. (1991) Effect of the leucaena psyllid on yield of *Leucaena leucocephala cv.* Cunningham in southeast Queensland. *Tropical Grasslands* 25, 356-357.
Brewbaker, J.L. and Sorensson, C.T. (1990) New tree crops from interspecific *Leucaena* hybrids. In: Janick, J. and Simon, J.E. (eds), *Advances in New Crops.* Timber Press, Portland, pp. 283-289.
Brewbaker, J.L., Pluckett, D. and Gonzalez, V. (1972) Varietal variation and yield trials of *Leucaena leucocephala* (Koa haole) in Hawaii. *Hawaii Agricultural Experiment Station Bulletin* 166, 26.
Brewbaker, J.L., Hegde, N., Hutton, E.M., Jones, R.J., Lowry, J.B., Moog, F. and van den Beldt, R. (1985) *Leucaena - Forage Production and Use.* NFTA, Hawaii. 39 pp.
Cooksley, D.G., Prinsen, J.H. and Paton, C.J. (1988) *Leucaena leucocephala* production in subcoastal south-east Queensland. *Tropical Grasslands* 22, 21-26.
Davison, S. (1987) Adopting leucaena - achievement and a new problem. *Rural Research,* 134, 22-27.
Isarasenee, A., Shelton, H.M. and Jones, R.M. (1984) Accumulation of edible forage of *Leucaena leucocephala cv.* Peru over late summer and autumn for use as dry season feed. *Leucaena Research Reports 5,* 3-4.
Jones, RJ. (1979) The value of *Leucaena leucocephala* as a feed for ruminants in the tropics. *World Animal Review* 31, 13-23.
Jones, R.M. and Carter, E.D. (1989) Demography of pasture legumes. In: Marten, G.C., Matches, A.G., Barnes, R.F., Brougham, R.W., Clements, RJ. and Sheath, G.W. (eds), *Persistence of Forage Legumes.* American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Madison, pp. 139-158.
Jones, R.M. and Jones, RJ. (1984) The effect of *Leucaena leucocephala* on liveweight gain, thyroid size and thyroxine levels of steers in southeastern

Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry* 24, 4-9.
Kendall, J., Margolis, H. and Capo, M. (1989) Relative cold hardiness of three populations of *Leucaena leucocephala* from northeastern Mexico. *Leucaena Research Reports* 10, 19-21.
Lesleighter, L.C. and Shelton, H.M. (1986) Adoption of the shrub legume *Leucaena leucocephala* in Central and Southeast Queensland. *Tropical Grasslands* 20, 97106.
Lowry, B. (1987) The leucaena story - a biological solution to a toxicity problem - an account of one man's belief *Australian Science Magazine* 4, 53-58.
NAS (1977) *Leucaena - Promising Forage and Tree Crop for the Tropics.* National Academy Press, Washington DC, 115 pp.
Ruaysoongnern, S. (1989) A study of seedling growth of *Leucaena leucocephala* (Lam.) de Wit cv. Cunningham with special reference to its nitrogen and phosphorus nutrition in acid soils. PhD thesis, The University of Queensland.
Ruaysoongnern, S., Shelton, H.M. and Edwards, D.G. (1985) Effect of pot size on growth of *Leucaena leucocephala cv.* Cunningham. *Leucaena Research Reports* 6, 11-13.
Sivasupiramaniam, S., Akkasaeng, R. and Shelton, H.M. (1986) Effects of nitrogen and lime on the growth of *Leucaena leucocephala cv.* Cunningham on a red-yellow soil in southeastern Queensland. *Australian Journal of Experimental Agriculture* 26, 23-30.
Smith, F.W., Van den Berg, P.J., Gonzalez, A., Andrew, C.S. and Pieters, W.H.J. (1992) Foliar symptoms of nutrient disorders in the tropical shrub legume *Leucaena leucocephala.* Division of Tropical Crops and Pastures Technical Paper No. 43, CSIRO, Australia.
Sorensson, C.T., Shelton, H.M. and Austin, M.T. (1994) Seedling vigour of *Leucaena leucocephala, L. diversifolia, L. pallida* and their hybrids. *Tropical Grasslands.* (In press).
Swasdiphanich, S. (1992) Environmental influences on forage yields of shrub legumes. PhD thesis, The University of Queens land.
White, C.T. (1937) Annual Report of the Department of Agriculture and Stock for the Year 1937. Government Printer, Brisbane, pp. 110-114.

Information on other species has been drawn form Agroforestree Database; ICRAF, Kenya