NEEM
THE CORNUCOPIA TREE

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In the Philippines in 1976, Michael Benge wrote a booklet called BAYANI [Giant ipil-ipil (Leucaena leucocephala)] A Source of Ferrtilizer, Feed and Energy for the Philippines It described a new variety of an old tree The booklet was not a "Madison Avenue," slick publication, and looked as if it were produced on a photocopying machine But it was effective' Soon Benge was flooded with tens of thousands of requests for it, and within a few months Filipinos were planting that new tree over thousands of hectares

Today, that tree, better known as giant ipil-ipil or giant leucaena is well extablished in the Philippines, Indonesia, Thailand, India and other countries of the region Indeed it has been hailed as a breakthrough in tropical forestry, and in 1986, King Carl XIV Gustaf of Sweden awarded Benge the International Inventors Award [modeled after Sweden famous Nobel Prizes] for his outstanding innovation in promoting the use of this tree

In scope and presentation, this current booklet reminds me of Benge's 1976 one Perhaps he is here initiating worldwide enthusiasm for neem as he did a decade ago for leucaena I hope so Neem is potentially one of the most valuable of all semi-arid-zone trees It can grow in parched and nutrient-deficient soil and is a fast-growing source of fuelwood Moreover, it has many other commercially exploitable by-products and environmentally beneficial attributes, such as a natural, non-toxic pesticide

Noel Vietmeyer
BOSTID
National Academy of Sciences

PICTURE OF NEEM TREE

Azadirachta indica

Neem or the Margosa Tree

(the name is based on the Persian for "a noble tree")

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THE NEEM TREE
ITS POTENTIAL FOR AGRICULTURAL, INDUSTRIAL AND COMMERCIAL EXPLOITATION

INTRODUCTION

The neem tree* offers great potential for agricultural, industrial, and commercial exploitation Its most promising use is for commercial and on-farm production of pesticides, which so far have proven to be non-toxic to man Not only can it protect plants from insect damage, but it can greatly contribute to reducing post-harvest food losses, and could be substituted for many of the environmentally damaging pesticides such as DDT Neem seed extract, azadirachtin, has proven effective against 131 species of insects, 60 in the U S , of which 45 are extremely damaging to agricultural crops here These include the leafminer, which attacks vegetable and flower crops, and the gypsy moth, which causes millions of dollars of losses to the U S forest industry every year It even stops the common cockroach

Azadirachtin has also proven to be effective against desert and migratory locusts, which cause millions of dollars in crop losses in Africa and elsewhere "A single swarm of locusts has been estimated to destroy in a day enough food to feed 50,000 people for one year' (Rule, 1986)

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*Azadirachta indica A Juss (family Meliaceae) has a synonym in Melia azadirachta, which is not to be confused with Melia azadirach, commonly called the Persian Lilac in India and the Chinaberry tree elsewhere (Larson, 1986)

DRAFT

A highly biologically active fraction has been seperated from fresh neem kernels that shows remarkable antiviral activity against the Ranikhet poultry virus and has blood-sugar lowering and antimicrobial properties

A program has been recently initiated in the United States to evaluate various parts of the neem tree as anti-inflammatory and healing substances in dentistry, and to determine their toxicological properties

Almost every part of the neem tree--roots, bark, trunk, leaves, flowers, fruit and seeds--is known to have some use in countries where it grows, this is particularly true in India There, the tree is held sacred by the Hindus and its parts are used in many of their rituals and ceremonies It is believed that a few drops of heavenly nectar fell on neem Hence, on New Year's day, the Hindus eat its leaves and take a bath with water in which a few neem leaves are boiled in the hope of acquiring freedom from disease Sri Chaitanya, the father of the Vaishnava cult, is believed to have been born under a neem tree and hence his nickmane "Nimai "

Neem is a source of many other potential products, besides insect antifeedants and repellants Almost every part of the neem tree is used medicinally in India Oil is extracted from the seeds for soap, wax, lubricants, and lighting and heating fuel, and the residue is used an an organic fertilizer And neem oil is even being tested for use in cosmetics, such as nail polish (Schmutterer, 1984) Other parts of the tree are used for commercial products, including timber and cabinetry wood, tannins, a toothpaste ingredient, and livestock feed Neem bark contains 14% tannins, which compares favorably with conventional tanning chemicals (Radwanski, 1977a, NAS, 1980) Its resin is a gum substitute (Ketkar, 1976) The cotyledon and cotyledon-originated callus tissues contain abundant compounds of an important steroidal drug precursor widely used in commerce (Sarkar and Datta, 1986) Twigs of neem are used as a toothbrush, without toothpaste, and are reported to effectively prevent tooth decay (Henkes, 1986)

Neem production sustains cottage industries in India, and when grown on a large scale in developing countries such as Haiti or in Africa, where labor and land costs are low, neem could provide a base for profitable large commercial operations for industrialized nations such as the United States

The ideal tropical plant product is easy to produce and cheap to process, has few natural enemies and diseases, can be utilized in a multitude of outlets, can grow quickly and easily where it does not displace other crops, can be prepared for export locally with value added in the country of origin, especially in the village, can act as a soil ameliorant in a previously non-productive area, and can raise the income of the poor countries by providing an export crop or by substituting for expensive imports Neem is a candidate as an ideal tropical plant

The neem tree and its products offer a wide range of development alternatives, especially for semi-arid zones Processing of several neem ingredients, which could become highly competitive in price and quality with some petroleum-based synthetics, does not require special skills or sophisticated machinery It can be done by village inhabitants and thus provide employment and income in underprivileged rural communities The development of this tree will also improve the declining ecosystems of many areas, such as in Haiti and the arid (irrigated) and semi-arid (non-irrigated) regions in Africa

DESCRIPTION

Neem is a moderate to large size tree 12-20 meters (40-65 feet) high, reaching a girth of 1 8-2 5 meters (6-8 ft) It forms a round crown with a spread of 5-10 meters (16-33 ft), is a broadleaf, evergreen tree, except in periods of drought when it will drop its leaves, has a relatively straight trunk (but not long) with moderately thick bark, roots deeply, grows moderately fast, is hardy, stands pollarding (repeated lopping of branches) well, coppices rapidly, and produces root-suckers (often induced by root injury), especially in dry localities (Troup, 1921)

Neem leaves are alternate, compound, 23 to 38 cm (9 to 15 in) long leaflets 7 to 17, alternate or opposite, very shortly stalked, 6 to 7 cm (2 1/2 to 3 in) long, oblique, toothed The tree is open pollinated, and the small, white, scented, bisexual flowers are borne in azillary clusters, which are shorter than the leaves and attract bees The fruit is a smooth, ellipsodal drupe, 1 25 t0 1 8 cm (0 5 to 0 7 in) long, greenish-yellow to yellow when ripe, with a bitter-sweet pulp and one, or at times, two seed The flowers and fruit stink badly after a rain

In India, neem sheds its leaves in February-March but is never completely leafless except in dry localities where it may drop all its leaves The flowers appear in February to May with the new leaves The exact period of flowering varies from locality to locality In general, flowering takes place earlier in the southern parts of the country Neem fruits usually ripen in May to September (Troup, 1921, ICSIR, 1948), although some literature indicates neem has two distinct fruiting periods, May-June and August-September

DISTRIBUTION

Neem is thought to have originated in Burma and is common throughout the open scrub forest in the dry zone there and on the Siwalik hills, and if it is native to India, it occurs naturally only in Karnatak and in parts of the Deccan Peninsula (Troup, 1921) In its native environments, neem is generally found growing in mixed forests, associated with other broadleaf species, such as *Acacia sp* and *Dalbergia sissoo* It grows in tropical to sub-tropical regions, semi-arid to wet tropical regions, and from sea-level to over 2,000 feet It is cultivated throughout India, and in many places it has become wild [The fruit is not toxic to birds and bats, and it is reported that they are mainly responsible for the spread of wild neem] It is now found in many places outside of its native distribution to the sub-Himalayan track, including the northern part of Uttar Pradesh at 610 meters (2,000 feet) and the southern part of Kashmir at 670 meters [2,200 feet] (Ketkar, 1976)

However, according to Amed and Grainge (1985), neem is native to the Indo-Pakistan subcontinent, while others attribute its nativity to the dry forest areas of India, Pakistan, Sri Lanka, Malsysia, Indonesia, Thailand and Burma (NAS, 1980) Nevertheless, neem also found throughout Pakistan, Sri Lanka, southern Malaysia, Indonesia, Thailand, and the northern plains of Yemen and has been recently introduced into Saudi Arabia Now, the Philippines has begun widescale plantings of neem for fuelwood and pesticide production Nineteenth century immigrants carried the tree from the Indo-Pakistan region to Fiji, and it has spread to other islands in the South Pacific

East Indian immigrants introduced neem to Mauritius, and it is thought that they took it to a number of African countries It is now widely cultivated on the African continent in Ethiopia, Somalia, Kenya, Tanzania, Mozambique, Mauritania, Togo, Ivory Coast, Cameroon, Nigeria, Guinea, Ghana, Gambia, Sudan, Benin, Mali, Niger, Burkina Faso, Chad, and Senegal, particularly in rainfall-deficient regions

Neem was also introduced into several Caribbean nations by East Indian immigrants and is now propagated by Indian communities as a medicinal plant in Trinidad and Tobago, Jamaica, Suriname, Guyana and Barbados (Pliske, 1983) Neem plantings are also abundant in Guatemala, Nicaragua, Bolivia, Ecuador, Honduras, Argentina, Brazil, Cuba, Nicaragua, Dominican Republic, St Lucia, Honduras and Antigua and large numbers are now being planted in and Haiti In addition to the ongoing experimental cultivation of neem in Puerto Rico and the U S Virgin Islands in the Caribbean area, plantings in southern Florida are thriving, and the field cultivation of neem in Oklahoma, southern California, and Arizona has begun (Jacobson, 1986, Ahmed and Grainge, 1985, Radwanski and Wickens, 1981, Radwanski, 1977a, and Granvsholt, et al , 1967)

ADAPTATION

Neem grows well from sea level to over 670 meters (2,000 feet), and can be established in hot and dry regions without irrigation Neem thrives under subhumid to semi-arid conditions and can be established in areas with an annual rainfall of 450-750 mm (18-30 inches) Optimum growth is obtained in higher rainfall areas (1150 mm), 130 mm per year is sufficient for survival (NAS, 1980), but it needs 450 mm to to grow successfully It grows where maximum shade temperature may be as high as 49°C (120°F), but it does not stand excessive cold Neem is frost-tender, especially in the seedling and sapling stages, but it is grown in frost zones of the sub-Himalayan tract by protecting seedlings during the winter with screens (Radwanski, 1977a) Fire often kills it outright (Ketkar, 1976, Radwanski and Wickens, 1981) According to Gorse (1986), it is not a very sociable tree, does not grow well in pure stands (plantations in Africa often die out in 3-10 years), and is very competitive for water and soil nutrients, thus doesn't grow well on marginal soils

Neem seems to grow best in deep sandy soils that are well drained, but can grow in practically all sorts of soil, it thrives on black cotton soil in India and does not do badly even on clay It does better than most species in dry localities, on sandy, stony shallow soils with a waterless subsoil or in places where there is a hard calcareous or claypan (hardpan) not far from the surface However, neem will grow much better if this hardpan is broken up before planting Occasionally, neem will initally grow well on soils that appear to be sandy, but quickly die out when roots hit a deep layer of dense clay Neem can grow even on saline and on alkaline "usar" soils (ICOC, undated), however, neem has been reported to be susceptible to moderate salinity in the Sudan (Jackson, 1976) Thus within the species, some provenances must be more genetically tolerant to salinity than others Fishwick (undated) observes that the best neem growth is found on sites with a soil pH of between 6 2 and 7+

Neem does not tolerate waterlogged soils, and does not do well on soils with impeded drainage and on soils subject to inundation Growth is not good on poorly drained soils, because the taproot tends to rot and the trees gradually die In Nigeria, De Jussieu (1963) reported that the best neem groves grew where the water table was 1 5 to 1 75 m down, at 2 5 m, the groves were only mediocre, and at 8 m, the groves died out In his report, the method of planting the neem trees was not given, and in many places in Africa it was commonplace to establish plantings by stump cuttings, whereby the tap root was pruned When this is done, a normal length tap root will not regenerate, and the tree develops extensive lateral root systems with only pseudo-taproots developing that do not penetrate deep into the subsoil In some soils, the water table markedly rises during the rainy season, and if this rise persists, the roots of neem trees may smother

Neem does not grow well in soils with high proportions of very fine sand or silt or finely divided mica, the yellowing of leaves is often followed by death (Radwanski and Wickens, 1981) However, this may have been the result of nutrient deficiency [See section on TOXICITY, PESTS, DISEASES and LIMITATIONS] In Nigeria, where systematic tests have been conducted, it was observed that very successful neem groves could be found in soils having a high clay content (67%), while trees died out on soils with a high sand content (83%) (De Jussieu, 1963)

It has been planted on plantation scale in Nigeria since 1936 Most of the forests in the Sokoto region are of this species The introduction of neem to Sokoto was cited as the greatest boon of the century The tree grew quickly and met the local demand for firewood, poles for house construction, and fence posts, in addition to providing welcome shade in towns and villages (Senior Resident, 1948) Gorse (1986) states that neem is often the preferred species for planting in semi-arid areas because animals do not readily browse it, and when they do, mortality is low and neem recovers rapidly However, Welle (1985) reports severe stunting of neem girdled from bark feeding by goats

WOOD

The wood of neem is beautifully mottled, rather uneven and narrowly interlocked, medium to somewhat coarse textured and moderately heavy, with a specific gravity of adult wood from 0 56 to 0 85, averaging 0 68 (NAS, 1980) Because the wood has a high calorific value, it is excellent both for fuelwood and charcoal and the smoke of the burning wood is said to have a high insect-repellant effect In many ways it resembles mahogany (Switenia mahogani), but lacking the smoothness of the grain and workability under tools The sapwood is greyish white and the heartwood red when first exposed to the atmosphere and sunlight, fading to reddish brown, dull to somewhat lustrous especially on the beautiful narrow ribbon striped radial surface, but medium to somewhat coarse-textured

The timber seasons well and is durable even in exposed situations Because of its resistance to pests and does not rot easily, neem wood makes excellent door panels, sash frames, poles and fence posts and other building materials, however, it has limited value for construction, because the logs are too short This could be partially overcome through genetic improvement by selecting and reproducing trees with maximum clean bole height

The wood is not subject to much shrinkage and it is used also for making carts, agricultural implements, low quality furniture (the wood has an offensive odor) and toys Trunks and chests made of neem withstand the attacks of termites and resist woodworms, and are said to render their contents resistant to other insects (Radwanski and Wickens, 1981) Neem makes excellent fence posts because of its resistance to pests and does not rot easily Neem can also be chipped and used for composite board and paper (NAS, 1980)

The timber seasons well and is durable even in exposed situations It is suited for door panels, sash frames, poles and fence posts and other building materials, however it has limited value for construction, because the logs are too short This could be partially overcome through genetic improvement by selecting and reproducing trees with maximum clean bole height

SILVICULTURAL AND PLANTATION CHARACTERISTICS

In India, neem is generally found in mixed forests So far, little is known about the behavior of neem in plant communities and its ecological potential and limitations Neem seems to do much better on an isolated basis than in full groves, and grows beautifully along roadsides, or as isolated shade trees It also does well in mixed species plantings and in relatively well spaced rows (approximately of 3 meters apart) along contour line ditches (De Jussieu, 1963) Michel-Kim and Brandt (1981) report that experience in India and Africa indicates that neem may not be suited for monoculture This contention is supported by Gorse (1986), who states that neem is not a sociable tree and plantations often die after 3-10 years, especially on poorer sites One explanation for this variance is that neem is very demanding on both water and mineral nutrients, and on soils where nutrients are limited, thus neem will not do well in monocultural plantations on poor sites

Individual neem trees are reported to live for 200 years (Ketkar, 1976) However, Gorse (1986) contends that neem needs to be pruned or it will die-back, which can be avoided by pollarding the tree Many report neem growing well in monoculture in plantations (Gravsholt, et al , 1967, Fishwick, undated, McComb, 1967, Kemp, 1970)

Neem grows better with shade in its early stage of growth, but demands light as it matures Therefore, it has a great capacity for pushing its way through thorny scrub in its youth Welle (1985) reports neem growing exceedingly well in plantations in Haiti where Leucaena leucocephala is interplanted as a nurse crop, with trees having a better form (the elephant-foot stump type growth with a large taper is reduced) Radwanski and Wickens (1981) report that transplants are likely to be seriously injured by developing leaf spot (clorosis) as a result of insolation (grown in full sunlight), thus neem does best in its earlier years when planted with a nurse crop However once mature, neem does best in full sunlight, and does not do well as an understory

GROWTH

Neem is reported to grow relatively fast, but varies greatly depending upon its environment, site characteristics and the genetic capability of the plant material Slower growth results at higher elevations, at colder temperatures and on drier sites Radwanski (1977a) reports that 66% of the tree's total growth occurs in the first three years, during which it reaches a height of 4 to 7 m, it reaches 5 to 11 m in the following five years Seedlings show moderate development, ordinarily reaching a height of 10-20 cm (4-8 inches) by the end of the first year As a rule, trees put on a mean-annual girth increment of 2-3 cm (0 9-1 2 inches), though more rapid growth is obtained under more favorable conditions De Jussieu (1963) reports that in irrigated groves in India, 16 year old neem trees reached diameters over 40 cm, but trees grown in this way break more easily and are subject to wind damage Under mediocre conditions, the average diameter of trees in a 44 year old grove was 25 5 cm, and average height was 10 5 m In Africa, it is generally assessed that at 1 year in good soil, a grove reaches a height of about 1 5 m, at 2 years a height of 2 m, and during the 4th year trees reach a diameter of 7 to 8 cm and a height of about 4 5 m

Fishwick (undated) notes that on poor sites, there was evidence that neem stagnated after the first 5 to 6 years, and for this reason rotations were reduced to 7 years, which appeared to be more profitable Furthermore, it appears that the critical time in the development of the trees in the plantation occurs when crowns begin to touch the 3rd or 4th year with a spacing of 8 ft (2 44 m) X 8 ft, and 5th and 6th year at a spacing of 15 ft (4 57 m) X 15 ft, thus on poor sites the wider spaced trees would cost less to plant, be larger and have a greater economic value (Comparing two plantations on poor sites, the value of the trees at the wider spacing was 4 times greater)

YIELD

According to Michel-Kim and Brandt (1981), the yield of neem varies between 10 and 100 tons of biomass (dried material) per hectare per year, depending upon rainfall, site conditions and spacing, and 40 tons [12 5 m^3 solid wood/ha/yr (based on $1m^3$ = 800 kg)] can be achieved easily under the proper conditions About 50 percent of the biomass is contained in the leaves, about 25 percent in the fruit, and 25 percent in the wood

Gravsholt et al (1967) reports that the first rotation yield in Ghana was 30 to 38 cords of fuelwood per ha (approximately 13 5 to 17 m^3/ha/yr solid wood), and in Samaru in northern Nigeria, 7 5 to 67 cords (approximately 2 4 to 21 m^3/ha/yr) Commonly in West Africa, plantations are cropped on an 8-year rotation, with a spacing between trees of 8 ft X 8 ft (2 4 m X 2 4 m)

Fishwick (undated) reports that on more suitable sites in Bornu Province in Nigeria, the yield was 15 to 27 cords per ha per year (13 5 m^3 to 24 3 m^3 solid wood) on a 7 year rotation The plantation spacing was 8 ft (2 43 m) X 8 ft, and site conditions included soils comprising drift sands with a pH ranging from 5 0 to 7 5, and a mean annual rainfall varying from 380 mm to 762 mm (15 to 30 in) An average annual yield for all plantations was 7 to 15 cords/ha (6 3 m^3 to 13 5 m^3) In Nigeria, neem poles are in great demand for house construction and fence posts because they are semi-resistant to termites, poles there realize a greater price than fuelwood

McComb (1967) reports plantation yields in Samaru, Zaria, Nigeria, of 300 to 2250 ft^3 per acre for the first 8 year rotation crop (2 55 to 19 67 m^3/ha/yr solid wood), and 350 to 2250 ft^3/acre (3 to 19 67 m^3/ha/yr) for the 8 year coppice crops on the same plantations [The lower yields were for class IV sites, while the higher ones were for class I sites, and the spacing between trees was 2 4 m X 2 4 m] Interestingly, the first 8 year rotation crop on class I plantation sites showed an average incremental growth rate of 350 ft^3/yr (after the second year), while the coppice crop averaged only 250 ft^3/yr There were no significant growth rate nor yield differences on the class IV sites, and on the class I sites the volume of the coppice growth by the 3rd year was almost equal to the growth by the 5th year of the first 8 year rotation crop

Radwanski (1977c) gives the yields of the Majiya plantation near Sokoto, Nigeria, as 520 ft^3 per acre of fuelwood after 7 years (5 2 m^3/ha/yr), and after coppicing, 820 ft^3 solid volume of fuelwood and 290 ft^3 solid volume of timber per acre (total yield of 8 6 m^3/ha/yr) The plantation was planted in 1945 with "open-root" neem seedlings (assumed to mean bare-root), spaced 6 ft X 6 ft (approximately 1 8 m X 1 8 m) The average annual rainfall in this region was 31 in (787 mm) with a maximum of 47 in (1194 mm) to a minimum of 20 in (508 mm)

Welle (1985) reports that trees grown in plantations in Haiti at 4 years of age yielded an average of over 1 pole and 0 09 m^3 of fuelwood, but the volume of the pole was not given Radwanski (1977d) gives a volume of 1 05 m^3 for neem poles in one plantation in Nigeria, while McComb (1967) reports a pole volume ranging from 37 to 85% of the total wood produced

COPPICE

Fishwick (undated) reports that plantations in Nigeria were cut to a stump height of 8 cm (3 in), and coppice from such low stumps is less likely to suffer from wind damage than from higher stumps Higher stumps also have a higher incidence of dying off Gorse (1986) observed that by cutting at a stump height of 1-2 meters, the number of poles produced by coppice will increase Early growth is faster from coppice than from seedlings, reaching a height of 8 5 meters (28 feet) in 3 years after cutting However, in Nigeria, the height of 8 year old coppice was reported to have only equaled that of 8 year old trees started from seedlings In plantations there, trees reached a height of 7 meters (23 feet) in 3 years and 12 meters (40 feet) in 8 years Approximately 66 percent of height is achieved in the first 3 years after planting (Department of Forest Research, 1967) Radwanski (1977a) recommends a coppice management system every 3 years for maximum biomass yield based on the observation that 66% of the tree's growth ocours in the first 3 years However, this merits further research, since much faster growth of coppice occurs once the root system is established, and a much shorter rotation may give a maximum yield

THE CHEMICAL

Azadirachtin acts in two ways first as antifeedants and repellants, and second, when some invading insects manage to get past this barrier and reach the treated crops, either they die on the spot or their hormone balance and genetic makeup are so disturbed that they become permanently incapacitated and unable to fend for themselves and breed normally (Radwanski and Wickens, 1981, Jacobson, 1983)

There is, however, a fairly rapid photo-degradation by sunlight of azadirachtin after field application Vikwood Ltd of Sheboygan, Wisconsin has developed a shelf-stable pesticide through collaborative efforts of the USDA in Beltsville, Maryland The first product manufactured is MARGOSAN-O^{TM} which was patened for its stabilization enhancement as well as the processing method in December, 1985 The product is claimed to be effective at least one year under normal shelf-life conditions (Larson, 1986) It is thought that this chemical cannot be economically synthesized because its structure is so complex Azadirachtin can be extracted from neem seeds in pure form (Jacobson, 1983)

Systemic Action -- Investigations by Gill, Lewis and Chadha (undated, 1971, 1972, 1977) revealed systemic uptake and translocation of azadirachtin and other neem seed extracts in plants Systemic uptake of azadirachtin was demonstrated in bean plants, wheat, barley, rice, sugar cane, grass, tomatoes, cotton, chrysanthemum and small spindle trees Persistence of 1000 ppm of seed dust to dry soil weight lasted over four weeks and at 1% for over 10 weeks Even when washed under a simulated rain of 20 in (50 cm), the soil retained sufficient activity to protect bean transplants The transplants transferred from treated to clean soil remained protected for two weeks against the desert locust (*Schistocera gregaria*)

PESTICIDE

Efforts to increase food crop production are frustrated by many problems, pest damage ranks among the most serious Over 20,000 species of field and storage pests destroy approximately one-third of the world's food production annually, valued at over $100 billion (McEwen, 1978)

In developing countries, inadequate product knowledge, supply uncertainties, and high prices cause inefficient pesticide use and also create additional socioeconomic problems between the "haves" and the "have-nots" (Herdt, 1979) Alternative strategies, especially those which are effective and low-cost, are thus needed Azadirachtin, extracted from neem seed, may play an inportant role in this respect (Brady, 1982)

Unlike most of the present pesticides on the market, azadirachtin is not known to pollute the environment, and is nontoxic to man and most plants and animals The Environmental Protection Agency recently approved the use of an azadirachtin pesticide (to be marketed under the trade name Margosan O™ on non-food crops, and approval for use on food crops is expected in the near future (Larson, 1986, Jacobson 1983, 1985)

Larson (1986) reports that Margosan O™ is a shelf-stable pesticide that is non-toxic to humans, domestic animals, birds and honeybees Low concentrations of active extracts from seed kernels, active against spider mites, were found to be nontoxic against their predators--P persimills, and the spider, C mildel (Mansour, et al , 1986)

Although all parts of the tree are repellant to insects, azadirachtin, extracted from the seed, is outstanding as a repellant and feeding deterrent for a broad spectrum of economic agricultural and household insects The pesticidal qualities of azadirachtin is well documented in the Proceedings of the First and Second International Neem Conferences (GTZ, 1981 and 1984) The biologically active constituent, azadirachtin, is found in small amounts in aqueous and in larger amounts in organic extracts of neem leaf, fruit, and bark, but mainly in the seed Minor pesticidal components are the terpeniods salannin and meliantriol

Kinds of Pests -- Azadirachtin reportedly controls over 131 species (60 in the U S) of insects, mites, and nematodes--including such economically important pests as the desert and migratory locusts, rice and maize borers, pulse beetle and rice weevil, rootknot and reneform nematodes, and citrus red mite Modes of control include antifeedant, growth regulatory, repellant, through hormonal disruption, or pesticidal action, and in larval as well as adult stages of these pests (ICOC, undated, Grainge, et al , 1984, GTZ, 1981, Radwanski, 1977a, Ketkar, 1976, Warthen, 1979)

Azadirachtin deters at least 45 species of crop pests in the United States from feeding, inhibits the growth and development of others, and render others sterile Such insects include the Gypsy moth that plagues the forest industry, leafminer that is one of the most serious pests facing U S and foreign commercial flower producers, Colorado potato beetles, Japanese beetles, scale insects, cotton bollworms and coakroachs The Environmental Protection Agency has approved the use of an azadirachtin pesticide (to be marketed under the trade name Margosan O) for use on non-food crops, and approval for use on food crops is expected in the near future (Jacobson, 1983, 1985)

Locusts and Grasshoppers -- The earliest report in scientific literature on neem as an insect repellant is perhaps that of Mann and Burns (1927) who observed that during the 1926/27 locust cycle in India, no feeding by the adult was observed on neem leaves Further research in India showed neem's effectiveness as an antifeedant for locusts (Pradhan et al , 1963, Lavie et al , 1967, Pradhan and Jotwani, 1968, Butterworth and Morgan, 1971, Attri, 1975, Batra, 1979) The first opportunity to test laboratory findings under field conditions was in 1962 at the Indian Agricultural Research Institute (IARI, 1962) during an invasion of desert locust when large areas of different crops were given a protective spray of neem seed suspension No feeding was observed on the sprayed crops, while crops adjecent to the sprayed area were totally consumed, and the spray caused no damage to the plants Adult desert locusts were observed not to feed on leaves sprayed with a neem seed suspension [at a level of concentration as low as 1gr in 1 litre of water--0 001%]

The sulphur containing liquid fraction of neem seed cake has also shown to be effectice as a antifeedant against migratory locusts (Radwanski, 1977c) 1000 ppm of ground neem seed dust to dry soil weight lasted over four weeks and at 1% for over 10 weeks

In Israel, azadirachtin injections into the 5th (last) instar of migratory locusts prevented molt and resulted in overaged nymphs that died after 70 days Males were unable to copulate (Ascher, 1986)

In the Federal Republic of Germany, molting of migratory locusts was delayed and inhibited by minute doses of azadirachtin, and injections into females during the first four days after eclosion retarded or completely inhibited oocyte maturation (Rembold, et al , 1986)

In Nigeria, passive extracts of neem were found to be effective as an antifeedant against the variegated grasshopper, Zonocerus variegatus (L), and when combined with the passive extract of Piper guineese, this produced a significant, high mortality in the test insects (Olaifa and Akingbohungbe, 1986)

Leafminer -- The USDA in a "commercial greenhouse experiment" compared the efficacy of neem seed extract, azadirachtin, used as a soil drench, to a combination of insecticides used by growers and to an experimental, highly potent insecticide, cyromazine (Trigard) The insect examined was a leafminer, Lirimyza trifolii, which attacks vegetable and flower crops, and is one of the most serious pests facing commercial flower crop producers in the U S and abroad The experiment was conducted in an infested commercial greenhouse and USDA found that under these real-world conditions 0 4% azadirachtin caused more mortality than did the most common insecticides used by the growers, and caused as much mortality as did cyromazine (Larew, 1986)

Gypsy Moth -- Skatulla and Meisner (1975) demonstrated that larvae of the gypsy moth (Lymantria dispar) are highly sensitive to different concentrations of an aqueous extract of neem kernel incorporated in an artificial diet All larvae died within 18-21 days, and a 100% mortality was obtained after 30 days of feeding Moreover, after feeding on neem-treated diet the molting process of larve was inhibited The affected larvae were unable to liberate themselves from the old larval skin and head capsules, and died Similar results were obtained when leaves of Quercus robur were sprayed under field conditions with a 0 5% aqueous extract of neem seed All larvae of the gypsy moth when fed on 0 5%-neem-seed-suspension-treated leaves died after 15 days (compared with only 4% on the control leaves)

Rice Insect Pests -- Neem seed derivatives are promising for use against rice pests, such as sucking insects--the green leafhopper, Nephotettix virescens (Distant), the brown planthopper Nilaparvata lugens (Stal), the whitebacked planthopper Sogatella furcifera (Horvath), and the rice bug (Leptocorisa oratorius (F), and foilage feeders--the rice leaffolder Cnaphalocrocis medinalis (Guenee), the ear-cutting caterpillar Mythimna separata ((Wlk), and the rice armyworm Spodoptera mauritia acronynctoides (Boisd) Insects were found to feed far less, grow poorly, and lay fewer eggs in rice plants treated with the oil, cake, extracts or purified fractions, such as azadirachtin, and their formulations (Saxena, 1986)

Cockroaches -- Margosan O™, a commercial preparation of neem seed extract, was tested for its effects as a toxicant, growth inhibitor, or repellent against six species of cockroaches--Blattadorientalis L , Blattella germanica (L), Byrstria fumigata Guerin-Meneville, Gromphadorhina portentosa (Schaum), Periplaneta americana (L), and Supella longipalpa (F) (Orthoptera Blaberidae, Blattidae, and Blattellidae) Last-instar nymphs of these species fed Lab-Chow pellets inpregnated with neem extract at a rate of 0 5 ml/pellet showed increased mortality and retarded development All 1st-instar nymphs of B orientalis, B germanica and S longipalpa died after consuming treated Lab-Chow pellets Topical application of 2 ul of Margosan-O to the abdomens of last-instar B orientalis nymphs, as well as injection of 0 5 ul, resulted in reduction of growth and increased mortality Pint cardboard cartons treated with 1 5 ml extract repelled adult P americana (Adler and Uebel, 1985)

CHEMICAL CONTENT OF THE SEED

The azadirachtin content of the seed may depends upon one or a number of variables, and it is difficult to determine which one(s) All neem germplasm originates in the Burma-India area, therefore, the differences in azadirachtin content may be determined genetically and may be environmentally triggered or influenced, perhaps by heat and/or water stress, high humidity, high or low levels of rainfall, or soil nutrient content Azadirachtin content may also vary greatly depending upon the age of the tree, when the seed is picked, how it is dried, stored, shipped, exposed to light, heat or cold, etc Some think azadirachtin content of seed from trees 5 or more years of age is higher than that from younger trees The only way this can be determined is by scientifically noting the environment where the trees are growing (altitude, soil type, latitude, rainfall and pattern, e g , was the tree water-stressed before fruiting?), determining the age of the tree, collecting all seed at the same age or stage after fruiting (green, ripe but still on the tree, fallen to the ground), and cleaning, drying, storing, handling and analyzing the seed in the same manner

Jacobson (1986) analyzed seed from some varieties from India that contained only 1-3% of the chemical, while seed from Africa tested at 5-6%, and some as high as 9% Also collections of neem seeds (reared from Togo-bred seeds) in June and September have shown that the seeds from older trees contain larger quantities of pesticidal compounds, especially azadirachtin Ermel et al (1986) analyzed seed from 66 sources The highest contents were measured in samples from Nicaragua and Indonesia, showing 4 8 and 4 85% azadirachtin, respectively High contents were also measured in kernels from Togo, India, Burma and Mauritius 3 3-3 9%, whereas samples from Sudan and Niger gave lower yields, 1 9% and 1 5% The incubation of kernels under increasing temperatures and high air moisture resulted in time-dependent decrease of the azadirachtin contents The exposition of extracts toward sunlight and ultraviolet radiation also decreased the azadirachtin contents remarkably Singh (1986) notes that an attempt to correlate the antifeedant efficacy with extract yield and oil content and these three factors with environment often failed However, it was observed that seeds from neem trees growing in dry areas near the desert possessed much higher biological activity than those from trees growing in coastal areas

COMMERCIAL ECONOMIC FEASIBILITY

Establishing neem plantations and extracting azadirachtin from the seed in a developing country, such as Haiti, and producing this pesticide commercially in an industrialized country, such as the United States, seem to be economically feasible and attractive Vikwood Ltd expresses the amount of azadirachtin in the seed in micrograms per gram, and they tested seed from various areas and obtained a range varying from a low of 0 05 mg/g in some Caribbean seed to a high of 6 2 mg/g in some African seed Indian seed from several sources did not exceed 0 2 mg/g (Larson, 1986) USDA analyzed seed from some varieties from India that contained only 1-3% of the chemical, while seed from Africa tested at 5-6%, and some may be as high as 9% (Jacobson, 1985) Neem originated in the Burma-India area, therefore, the high azadirachtin content of the African seed would either be a genetic variance (perhaps environmentally triggered), age of the tree and/or time of picking, a result of handling (cleaning, drying, storing or shipping) of the seed, or perhaps a combination of all of them

Commercial operations may demand a more sophisticated and costly extraction method than that being used in cottage industries in India Azadirachtin should be extracted from the whole seed with alcohol, which would yield more of the chemical

The profitability depends upon several factors including the percentage of azadirachtin that the seeds yield, the number of fruits that each tree yields, the number of trees that a hectare of land can support (influenced by moisture and soil fertility, type and depth), the costs of plantation establishment, management and maintenence, and the cost of processing this chemical

To maximize profitability, planting stock used for plantation establishment must be selected from the best genetic material from plus trees that produce a maximum number of fruits of optimal size, weight and azadirachtin content (see section on Research Needs)

Production can also be enhanced by fertilizing neem plantations and by irrigating them (preferrably by drip irrigation) on nutrient stressed soils Neem production is retarded by nutrient deficiencies (see section on Toxicity, Pests, Diseases and Limitations), and through drip irrigation, water needs are minimized and amounts can easily be controlled if it is found that azadirachtin production can be increased by stressing trees at fruiting time (see section on Research Needs)

To demonstrate potential profitability of pesticide production from neem trees and to emphasize the importance of using the best possible genetic material, the following low-high variables are used (1) numbers of trees per hectare, 225-400, (2) azadirachtin content, 2-9%, (3) fruit yield, 25-50 kg per tree, and wholesale price of azadirachtin, $80-160 per kg (these are arbitrary figures and do not reflect the price of azadirachtin) (For cost comparison According to the August 11, 1986, Chemical Marketing Reporter, 20% purified pyrethrum was selling for approximately $82 50 per kg ($37 50/lb) It is assumed that plantations would begin producing after 5 years, reaching full production at 10 years Although speculative, an estimated yield of 25 kg per tree at year 5, graduating to 50 kg per tree at year 10, is one variable considered

GROSS PROFIT PER HECTARE PER YEAR

	At 225 trees/ha	At 400 trees/ha X 178%
225 X 02 X 25 X 80 =	$ 9,000	$ 16,020
225 X 09 X 25 X 80 =	40,500	72,090
225 X 02 X 50 X 80 =	18,000	32,040
225 X 09 X 50 X 80 =	81,000	144,180
225 X 02 X 25 X 160 =	18,000	32,040
225 X 09 X 25 X 160 =	81,000	144,180
225 X 02 X 50 X 160 =	36,000	64,080
225 X 09 X 50 X 160 =	162,000	288,360

Investors interested in neem pesticide production wouldn't have to to wait to establish plantations in a developing country Countries such as Haiti already have a large number of neem trees planted along roads for aesthetics and shade and in plantations for wood and pole production A commercial operation could begin by purchasing fruits, seed or kernels for azadirachtin production from farmers and the landless as is done in India

The cost of establishing, managing and maintaining plantations can partially be offset by planting a higher density of trees initially On good soils with adequate moisture in Haiti, neem plantations were established at a spacing of 2 5 X 2 5 meters (1,600 trees/ha) for wood production, and at 4 years of age, each tree yielded 1 pole and 023 m^3 of firewood In Haiti, neem poles sell for U S $1 00 ea and firewood for $8 00/$m^3$ (Welle, 1985) If plantations established for azadirachtin production were first closely spaced at 2 5 X 2 5 meters, and then at year 4 thinned to 5 X 5 meters (400 trees/ha), a gross profit of $1,420 could be realized from the wood thinnings, based on the Haiti yield estimates and prices

A PESTICIDE FOR DEVELOPING COUNTRIES

In less developed countries, the inadequate knowledge of a product, uncertainties of its supply and high prices often lead to the inefficient use of its product (Herdt, 1978) Furthermore, the sophisticated technology and high investment needed for the research, development and manufacture of synthetic pesticides preclude their producton in many less developed countries Clearly, this increases the vulnerablilty of those countries to disruption in their supplies of pesticides due to natural or man-made causes (Ahmed and Grainge, 1985)

According to Ahmed and Grainge (1985), approximately 60-150 kg of neem leaves would be ample to protect 2-3 metric tons of grain in storage [About 50-200 kg of neem cake would be needed to protect one hectare of paddy in the field] Thus, 2-3 neem trees may be sufficient to provide material to protect one hectare of a crop in the field and its harvest in storage Srivastava and Bhanotar (1983) estimates that 19 mt of neem leaves per hectare (7 ton/acre) will protect a wheat crop from termite attack

The Tongolese Republic's Ministry of Rural Development (undated, a & b) has published two appropriate technology pamphlets on "The Preservation of Beans (Cowpeas) with Neem Oil," and "Treatment of Cabbage and Gboma Against Pests with Neem Seed Extract" that merit close examination for use in other developing countries as a media to poplarize this technology

Grain Storage -- The use of various portions of neem has proven to be effective in protecting a number of stored grains against insect damage In India, both neem leaves and whole, chopped or ground seeds (kernels), often added to stored grain to prevent insect damage If the neem is not seperated from the grain before cooking, a bitterness is imparted to the cooked grain However, Jotwani and Sircar (1967) conducted organoleptic tests on grains that had been treated with neem and stored for 12 months (2 5 parts ground neem kernels to 100 parts grain), and after washing and cooking the grain, no taste or smell of neem could be detected by any of the tasters Also, germination tests on the stored grain did not show any impairment due to treatment

Leaves -- Traditionally, for stored grain pest control, Indo-Pakistani farmers simply mix 2-5 kg dried neem leaves per 100 kg grain, or they soak empty sacks overnight in water containing 2-10 kg neem leaves per 100 liters of water and then dry these sacks before filling them with grain Some farmers also apply ground neem leaf paste to the inside of their earthen containers used for grain storage (Ahmed, 1984)

In India, Pruthi (1937) reported that neem leaves mixed with grain or simply kept over the stored grain in 5 to 7 cm layer gave protection from damage by storage pests Reports by Lall and Hameed (1969) and Singh and Sitaramaiah (1969) revealed the possibility of controlling nematodes by green manuring with neem leaves, which resulted in 50% reduction of root-knot nematode (infection with <u>Meloidogyne javanica</u>) Leaves are also placed among woolens in India for protection against moths (Henkes, 1986)

Neem oil -- As a grain storage pesticide, the Khadi and Village Industries Commission (KVIC) in India recommends a neem oil application of 800 grams of oil to 100 kg of seed or grain (after washing) giving a cost benifit (cost of oil weighed against savings in grain) of 5 times for grain and 12 times for seed (Thery, 1978)

Powdered neem kernels -- A ratio of up to 2 5 parts of powdered neem kernels to 100 parts of seed [wheat, mung beans, gram, peas, cowpeas, sorgum, lentil, dal and pigeon peas] proved effective against insect pests [viz , grubs of the khapra beetle, Trogoderma granarium Everts, adults of the lesser grain borer, Rhyzopertha dominica Fab , rice weevil, Sitophilus oryzae Linn , bean bruchid, Callosobruchus maculatus, the pulse beetle, Callosobruchus maculatus] for 8-12 months (Jotwani and Sincar, 1965, Jotwani and Sircar, 1967, Deshpande, 1967, Yadav, 1973, Ivbijaro, 1983, Can et al , undated)

Neem seed (kernel) extracts -- In Pakistan, neem seed extracts were found to protect stored grains from insect attacks of three species Tribolium castaneum Hbst , Trogoderma granarium Everst , and Rhyzopertha dominica F The tests revealed that the extracts inhibited feeding and repelled the insects, indicating that neem seed (kernel) extracts can protect stored grains from insect attack if applied to bags or earthen pots (Ghulam and Malik, 1973) The cost of treatment gives a benefit of 5 times in the case of bags and 12 times in the case of pots

Field Crops -- Mane (1968) determined that the antifeeding efficacy changes at different stages of growth of neem Suspensions from over-mature fruits collected from the ground under neem trees were found to be more effective as an antifeedant to suspensions from yellow and green fruits (The kernels from green fruits were smaller in size, had whitish pulp, were shrivelled and light brown The second stage consisted of mature fruits which were yellow to brown in colour with very little pulp, while the third stage comprised fruits which had dropped after maturity and were dark brown with practivally no pulp, in some cases only the seed was left This indicates that kernels should be taken from the fruits which have fallen off the tree after maturity Another report states that the kernels should be hard (IARI, 1983), and Srivastava and Bhanotar (1983) say that neem seeds can be obtained from natural fallen fruits, gathered easily under a neem tree during fruiting season, and after breaking the ripen neem fruits, the kernels are taken out and sun-fried Dried kernels are then ground to powder Literature indicates that the biological activity in neem progressively decreases when the kernels are stored for prolong periods

Neem kernel (seed) suspensions -- When locust swarms invaded Delhi in 1962, standing crops at the Indian Agricultural Research Institute experiment satation were sprayed with a 0 1% neem kernel suspension at the rate of 300-600 liters per hectare depending upon the crop and growth stage and the spray caused no damage to the plants No feeding was observed although the locust settled on the treated crops In contrast, adjacent untreated crops were severly destroyed (Jotwani and Srivastava, 1981)

In another experiment in Gujarat, India, a solution comprised of a ratio of 10 grams of ground kernels to 10 litres of water was prepared and sprayed on sun hemp

(Crotalaria juncea) and tobacco There, the hairy caterpillar (Amsacta moorei But) is a serious pest Plants in the unsprayed control were completely defoliated, with stems eaten out, but the treated plants were not consumed at all and all the caterpillars died after 36 hours (Radwanski, 1977c)

Water suspensions of crushed neem kernel were also used successfully against several insect pests in Nigeria and Gambia According to Rednap (1979), in Nigeria, these simple treatments--which can be safely prepared and applied by any farmer according to his needs--were found to compare favorably with the following commercial insecticides DDT, Endosulphan, DDT/BHC mixture and Carbaryl, and in Gambia they proved to be more effective in some cases than the highly toxic malathion In developing countries, neem kernel suspensions could to a large extent replace conventional insecticides, particularly on food crops and vegetables in remote villages where modern agricultural technology is either too expensive or not available

Pradhan et al (1962, 1963) recommended spraying of 0 1% dried neem kernel suspension (ten mg in one litre of water) for the protection of crops against the desert locust, and also described a simple method of preparing neem kernel suspensions which can be applied by using ordinary sprayers The kernels are obtained after removing the hard shells of the seed should be crushed in a grinder or household stone crusher (mortar and pestle), so as to give as fine a product as possible To obtain the recommended concentration of 0 1% of the suspension, nine grams of crushed kernels should be taken in a cloth bag of muslin, the bag should be dipped in a bucket of water (nine litres capacity) and rubbed with slight pressure for about three to five minutes, when a light milky suspension will be formed Some residue will be left, which if in sufficient quantity, can be recrushed and the process repeated The suspension can be sprayed with any of the conventional sprayers so as to ensure a thorough coverage of the foilage One spray is likely to keep the crop save for a period of about two weeks, unless it is washed out by a fairly heavy shower of rain Spraying at two week intervals will ensure continuous safety of the crop (or soon after heavy rain) Spray the crop when either the locust swarm invasion is imminent or the hoppers are expected to invade the crop, or immediately when the crop has been invaded by hoppers or adults

Neem kernels were crushed into a pulp in a electric blender, and the paste formed was diluted with water and strained through muslin cloth This produces a fairly stable suspension Adult desert locusts were observed not to feed on leaves sprayed with a neem kernel suspension [at a level of concentration as low as lgr in 1 litre of water--0 001%]

The choice of these alternatives depends on the availability of neem seed, spray arrangment, availability of sprayers, etc , and on the risk that the farmer is prepared to take When applied at the rate of 1,200 litres (approximately 240 gallons) per hectare, only 1 1 kg of kernel per hectare is needed The cost of the neem kernel would be negligible in most areas where neem is planted, and seed could be gathered beneath trees However, the potency of the spray would be affected by the age of the seed at the time of making and applying the spray to areas invaded by locusts In the Rajasthan region of India, the flowering and fruiting of neem coincides with the locust swarm invasion of the Thar Desert area according to Srivastava and Bhanotar (1983)

Neem cake -- In India, neem cake is used to control a variety of pests Farmers incorporate 1-2 tons of neem cake per hectare into the soil to protect eggplant from borers, and tomato from nematodes and leaf spot disease Two tons of neem cake per hectare is used as a fertilizer for sugarcane, and fields thus treated usually show no sign of sugarcane borer damage (Ahmed and Koppel, 1985)

Mixed with urea, neem cake has been reported to be an excellent nematocyde (Larson, 1986) Conclusive evidence presented in India shows that neem oil cakes (applied at the rate of about 1,800 kg/ha) are effective on a field scale in controlling root-knot nematode [*Meloidogyne javanica*] (Singh and Sitaramaiah, 1966, 1969, Sharma et al , 1970)

Since 1978 entomologists at the International Rice Research Institute (IRRI) in the Philippines have tested neem as a source of inexpensive "natural" insecticide that causes no environmental damage Neem cake mixed with urea has significantly increased yields of the insect-susceptible line of IR 1917-17 rice in both wet and dry seasons at the IRRI farm by reducing the incidence of ragged stunt, grassy stunt, and tungro virus diseases The reduction was probably due to the antifeedant effect on plant hoppers, the main virus vectors (IRRI, 1982a) Ahmed and Grainge (1985) state that approximately 50-200 kg of neem cake would be needed to protect one hectare of paddy in the field [Thus, 2-3 neem trees may be sufficient to provide material to protect one hectare of a crop in the field and its harvest in storage]

Applied to experimental rice fields, neem cake has reduced nitrogen losses in experiments in India and at IRRI, apparently by inhibiting the nitrification bacteria that form nitrate from ammonia Nitrate is easily lost into the atmosphere Expirmentation by Sharma and Prasad (1980) in India showed that for rice production, neem cake-coated urea is as effective as sulphur-coated urea in respect of grain yield as well as nitrogen uptake, and increased the recovery of Nitrogen Neem cake-coated urea was superior to lac-coated urea and sulphur-coated urea in respect to residual N effects (IARI, 1983)

Populations of ostracods -- crustaceans that feed actively on nitrogen-fixing blue-green algae -- have also been reduced by applying neem cake, thus encouraging algal growth and subsequent nitrogen fixation (IRRI, 1982a)

Neem oil -- In tests at IRRI, 5 applications of a 25 percent neem oil emulsion sprayed with an ultra low volume applicator at 4 liters/ha gave adequate insect protection to a rice crop The cost of the neem oil was about $5/ha Sometimes the oil is applied to the hair in order to kill vermin (Radwanski, 1977a)

MISCELLANEOUS USES

Neem parts and compounds are used in various other ways to control and repell pests, and for medicinal purposes

Veterinary -- A highly biologically active fraction has been seperated from fresh neem kernels that shows remarkable antiviral activity against the Ranikhet poultry virus and has blood-sugar lowering and antimicrobial properties (Sankaram, 1986)

In Nigeria, the Fulani use a poultice of the leaves to treat cattle wounds and sores (Radwanski and Wickens, 1981) and the leaves are reported to have a therapeutic or antihelminthic effect against worms in livestock In Sri Lanka, the oil is used as a fly repellent for cattle (Ganesalingam, 1986)

Insect repellant -- Leaves are also used to protect clothes, books, papers, etc from the ravages of insects, but they are inferior to camphor for this purpose and have to be renewed frequently (Radwanski, 1977c) Neem leaves are also placed in baskets in which various fruits are transported from the farmland to urban markets in many parts of India and Pakistan for protection from fruit flies and other pests (Ahmed, 1984)

Michel-Kim and Brandt (1981) report that the smoke of burning neem leaves keeps mosquitoes and other insects away, however, it was not mentioned whether this is a function of azadirachtin in the smoke or the smoke itself

Companion seeding -- Neem seed has also been sown together with other seeds to protect the latter from insect damage In Berar, India, neem seed was direct seeded along with seed of *Acacia arabica* in linner sowings using a mixture 75% of *A arabica* seed and 25% neem seed The seeds of *A arabica* when sown alone was found to be subject to frequent insect attacks The *A arabica* seed when mixed with neem seed was virtually unharmed by insects (Radwanski, 1977a) In south India, neem leaves are incorporated with the soil in pits dug for planting coconut (Ahmed, 1984)

<u>Earthworms</u> -- Ground neem leaves and seed kernels have shown to be benificial to earthworms (Lumbricidae), decreasing mortality and increasing weight (Roessner and Zebitz, 1986)

<u>Medicinal and Prophylactic</u> -- Neem has been used in Hindu medicine practice in India and elsewhere, mentioned in the earliest Sanskrit medical writings, and has been proven to possess antidiabetic, antibacterial and antiviral properties (Dutt, 1910, Maegau, 1952 and Luscombe and Taha, 1974) The root bark, stem bark and young fruit are used in Indian folk medicine as tonic and antiperiodic, the seeds, oil and leaves as antiseptic, insecticide and local stimulant, flowers as stimulant tonic and stomachic, gum as demulcent tonic, and a toddy is made and used as refrigerant, nutrient and alternative tonic Simply sitting under a neem tree is deemed healthy due to the cleansing vapors

Compounds derived from various parts of the neem tree are used to treat fevers, thirst, nausea, vomiting, some forms of skin diseases (including leprosy eczema, and ringworms), heat rash, boils, chicken pox, external ulcers, tuberculosis, scrofula, diabetes, wounds, stomach worms and ulcers, jaundice, hepatitis, prurigo, urticaria, urinary diseases, piles, warts, and scorpion and snake bites Twigs are used as tooth cleaners and for general oral hygiene (Mitra, 1963, Radwanski, 1977b) Neem oil reportedly has these medicinal effects antibacterial, antihelminthic, antipyretic, contraceptive, antiulcer, antiviral, antidiabetic, anti-inflammatory, antimalarial and cardicac active (Jacobson, 1986, Radwanski and Wickens, 1981) Chaurasia and Jain (1978) found neem oil to be active against all of ten bacteria tested

A program has been recently initiated in the United States to evaluate various parts of the neem tree as anti-inflammatory and healing substances in dentistry, and to determine their toxicological properties (Jacobson, 1986) Recent tests in West Germany haveshown a bark extract to be of value in preventing and healing gum inflammation And a West German firm has patented neem bark extracts for use as active ingredients in toothpastes and tooth powders (Doria, 1981)

In Nigerian traditional medicine, Neem oil is a popular remedy for the treatment of Malaria Iwu et al (1986) found that neem oil created a radox perturbation in the blooe unacceptable for the normal development of the malaria causing plasmodia Althouth this state may be an effective malaria treatment, it could be potentially harmful to the patient

Components of neem oil are reported to have contraceptive effects Sinha and Rair (1985) found neem oil to completely immobilize human sperm within 30 seconds of contact And in tests performed on numerous animals and 20 human volunteers, pre-intercourse intraviginally-applied neem oil completely prevented pregnancy, with no observed irritaton or side effects

OTHER NEEM PRODUCTS

Neem Oil -- In India, oil from neem seed (kernels) is chiefly used for the manufacture of soap (approximately 60%), but it is also used as fuel for lamps and for heat, as a lubricant for machinery (including the wheels on oxcarts), as a fly repellant for cattle, for controlling headlice and for other pesticidal uses Neem oil contains over 35% saturated fats and virtually no polyunsaturated acids, which makes it suitable for soap manufacture (Ketkar and Ketkar, 1984) With better refinement, its products probably could be used for the manufacture of a high-quality antiseptic soap, wax and lubricants, and for use as a pesticide Neem oil also contains some important aromatic compounds and steroidal substances

The oil is a non-drying oil, brownish-yellow in color, which has an unpleasant odor and an acrid, bitter taste The oil contains about 2 percent of active compounds that have promising potential in the manufacture of pesticidal and pharmaceutical preparations The nature, constituents and quality of neem oil are subject to considerable variation due to the soil and climatic conditions and other factors such as methods of harvesting, storage, processing/extraction and other factors (Ahsan and Hahn, 1938) The chemical composition and physical characteristics of neem oil can be found in papers by Mitra (1963) and Coursey (1964)

Neem oil extraction -- In India, neem seeds (kernels) are pressed in mechanical expellers to obtain the oil The high oil content of the seed allows the oil to be easily extracted by on a cottage industry level ("appropriate technology"), and no specialized, capital-intensive equipment is necessary Minor extactions and refinements of the oil performed with alchol and/or water can also be performed at the village level Reports on the amount of oil in the seed vary from as low as 17% to over 59% According to Larson (1986), there is no evidence at this time that the azadirachtin level rises linearly with the percentage of the oil since the Azadirachtin does not tend to follow the oil in the extraction process using ethanol According to Radwanski (1977b), the kernels constitute about 45 percent of the fruit and yield about 45-49 percent oil (25% of the whole fruit), proper handling of the seed and more refined methods of extraction yield higher levels of oil The yield of oil from the Ceylonese seed kernels is reported to be the highest at 59 25% Larson (1986) states there is no evidence at this time that the azadirachtin level rises linearly with the percentage of the oil since the azadirachtin does not tend to follow the oil in the extraction process using ethanol Mitra (1963) and Ketkar (1976) estimates neem seed to contain about 20% oil, which contains about 2% active ingredients with manufacturing potential for producing pharmaceutical and insect-repellent preparations Singh (1986) notes that kernels from trees growing in humid areas or areas with more rainfall yielded more oil than those from other places Again, the amount of oil in the kernel is probably inherited and may be environmentally influenced

Farmers can use a simple animal-drawn oil crusher ("ghanee") to obtain oil for themselves from neem or to make neem cake In larger, village level operations, electrically-operated oil expellers may be employed A number of both types exist in India's rural areas (Ketkar and Ketkar, 1984), and many electrically-operated expellers are run on a cooperative basis Ahmed and Grainge (1985) cites one cooperative in India that has two electric expellers with a total crushing capacity of 10 tons of depulped neem seed per day (it is unclear if this is fresh or dried seed) The machinery (expellers, boiler, filter press, shaft pulley, decorticator and neem cutter) is manufactured locally The cost of the machinery is about $12,000 (U S), and the superstructure $20,000, while a working capital of about $30,000 is needed The operation of the plant is relatively simple, the work-force consisting of one mechanic and 12 unskilled workers Smaller, one-expeller units can also be operated economically Because the neem-crushing season lasts for about 3-4 months of the year, it is necessay to find other ways the facility can be used to make the operation more economical, such as crushing other oil seeds

In India, farmers are paid approximately $0 10 per kilo for depulped and dried seed, $0 08 per kilo for depulped and undried seed, and $0 04 per kg for fruit with pulp The oil content of the depulped seed is 12 percent, and that of the fruit 7-8 percent Neem oil currently sells for $1 20-130 per kilo from the factory, and neem cake (a by-product), for $0 10 per kilo (Ahmed and Grainge, 1985)

The fruit yield of neem trees vary greatly, depending upon the environment and their genetic capacity, and the seed comprises about 45% of the fruit [However, the literature is unclear if this is by bulk or weight, and if by weight, whether it is dried or undried] Using an average yield of 20 kg of fruit per tree (assuming this is dry weight), one tree would produce 9 kg of dry seed, and it would take 66,667 neem trees to support a processing plant with a 10 mt/day capacity for 3 months at 5 working days per week At a plantation spacing of 3 m X 3 m (1,000 trees/ha), it would take approximately 66 hectares of trees to support the plant, and at a spacing of 2 5 m X 2 5 m (1,500 trees/ha), 44 ha It must be remembered, neem is a very demanding tree for space, moisture and minerals

Seeds should be dupulped soon after collection This may be done by soaking them in streams, tanks or canals using baskets or special frames so that the pulp is washed out into the water while the seed is retained in the basket or frame It takes 4-5 days of soaking before the pulp seperates easily Were sufficient water supply is not available, depulping may be done by mixing the fruit with mud or ashed, trampling under foot, drying, loosening the adhering soil or ashes and winnowing (Mirta, 1963)

In some areas of India, neem fruits are dried without depulping, which is not desirable because fermentation soon sets in which affects the quality of the kernel Well-dried seeds can be stored for up to 4 to 6 months in well-ventilated sheds But if the deeds have not been depulped or dried properly, deterioration soon sets in Well-dried, ripe seeds can be heaped up to a height of about 3 to 3 5 meters [10 to 12 ft] (Mirta (1963)

Neem oil has an unpleasant garlic-like smell, and the problems of deodorization, refining and purification in large scale industrial production have yet to be solved However, the treatment of the oil with alcohol separates most of the odoriferous fraction It is in this fraction that many active principals with medicinal and insecticidal properties are concentrated These can be isolated and used in the manufacture of pharmaceutical preparations and of pesticides, thus giving rise to various local industrial activities based on these compounds

Aqueous extractions of neem oil have been used successfully against locusts and other insect pests (Radwanski and Wickens, 1981) Rao and Rao (1979) found hot water extraction to be superior to cold, and the hot water extractions killed 100% of the brown plant hoppers tested

Neem Seed Cake -- Neem seed cake is the solid residue remaining after extraction of the oil - representing 80 percent by weight of the whole seed

Fertilizer -- The use of neem seed cake organic manure for cash and food crops in India attracted the attention of agriculturalists because of its insect-repellant and insecticidal properties, particularly in the case of termites and nematodes (Mitra, 1963) and its relatively high content of nitrogen, allowing for partial substitution of nitrogenous fertilizers (Tilac, 1975) Compared to farmyard manure and other organic materials, neem seed cake has a much higher nutrient value (Radwanski, 1977a)

Chemical Analysis of Organic Materials in Neem Cake
(Radwanski and Wickens, 1981)

Organic Matter	% Moisture	% of the fresh matter				
		N	P	K	Ca	Mg
Neem seed cake	--	3 56	0 83	1 67	0 77	0 75
Farmyard manure	76	0 50	0 11	0 54	0 42	0 11
Cattle slurry	93	0 31	0 07	0 32	0 11	0 04
Pig slurry	97	0 20	0 10	0 20	--	--
Sewage sludge	55	0 83	0 22	0 40	0 07	--

In a series of experiments conducted in India, the application of urea mixed with neem cake has rendered this fertilizer more efficient and allowed for considerable economy in its use a savings of 25 to 50 percent urea nitrogen, giving a cost benifit (cost of neem cake weighed against savings of urea) of 12 times (Ketkar, 1976, Thery, 1978) And Lal et al (1982) also reported a higher rice yield by combining urea with neem seed cake powder IRRI (1982b) notes that by applying margosa (neem seed cake) mixed with urea helps inhibit nitrification, reducing nitrogen loss through NO_3 leaching and denitrification Margosa application may hold promise for rice fields (paddys) where water cannot be drained to allow topdressing In such situations, fertilizer is applied as a single basal application Urea blended with margosa gave 0 6 t/ha extra grain yield over single application, saving about 20% nitrogen at little extra cost in fields where topdressing cound not be used because of poor drainage In Senegal, Can et al (undated) reports a rice yield increase of 28% by combining 10% neem cake with urea Neem cake used regularly in flower and vegetable gardens results in healthy and vigorous growth of the plants and their increasing resistance to fungal and pest attacks (Tilak, 1975)

Livestock feed -- Chemical processing of neem cake results in the formation of a protien-rich, granular meal that can be used as a cattle feed Vijjan et al (1982) report a higher growth rate in sheep resulted by incorporating 20% neem cake into their diet

CHEMICAL ANALYSIS OF NEEM CAKE FOR LIVESTOCK FEED
(Ketkar, 1976)

percent (averaged)	COMPOSITION with oil	w/o oil
Moisture %	12 0	4 65
Drymatter %	89 7	94 2
Carbohydrate % (N F E)	36 31	46 2
Crude Protein %	22 64	16 05
Crude Fiber %	24 33	26 18
Fats (ether extract) %	5 02	8 6
Ash (mineral) %	11 5	5 3
Silicon or Insoluble Ash	4 95	0 88
Calcium %	0 77	0 69
Phosphorus %	0 69	10 44

Methane gas generation -- The pericarp represents about 50 percent by weight of the whole neem fruit and this will give large quantities of pulp after depulping of the fruit prior to oil extraction from the seed Neem fruit pulp is reputed to constitute a promising subtrate in methane gas generation and it may also serve as a carbohydrate-rich base for other industrial fermentations (Mitra, 1963) In Banjul, The Gambia, the Gambian Council of Churches has set up a biogas (methane) plant, using neem pulp for energy production in a rural agricultural community (Jacobson, 1980)

Leaves -- Ketkar (1976) reports that a 7 5 to 8 meter tree on an average gives about 350 kg of leaves However, it is unclear if this is from normal leaf drop, from pollarding the tree, or total amount of leaves stripped from a tree standing or when cut

The bitter leaves of neem are used also as a pot herb, being made into soup and curry with other vegetables The slightly aromatic and bitter taste they impart to curries is much relished by some people

Fertilizer -- In some parts of India, the main objective of growing neem is for its green leaves, which are puddled in paddy land prior to transplanting rice and left to decompose, thus forming an excellent manure No other fertilizers were needed to obtain good crops of rice (COSC, 1956-57) In some areas of Sri Lanka, neem leaf mulch is regularly applied to tobacco and other crops (Radwanski, 1981) The leaves of neem have also been used as mulch in tobacco cultivation in Sri Lanka (Macmillian, 1962), and, in Gambia, tomato plants were observed to have matured several weeks earlier and had more and longer branches when mulched with neem leaves (Redknap, 1979)

High costs and limited availability of chemical fertilizers may favor a more extensive use of neem leaf mulch by poor farmers in developing countries who have access to large plantings of neem trees In poor countries such as Haiti, where fuelwood is scarce and large areas are in need of reforestation, large scale mixed plantings of neem and other multi-purpose trees could halt the accelerated depletion of the natural resource base, reduce flooding, increase sustained sources of potable water and help solve the fuelwood shortage, while at the same time help increase food crop production

Forage -- Neem leaves contain 25 percent protein and have a low fiber content, but they contain bitter ingredients Domestic animals may browse neem if other forage is not available, but it is rarely destroyed By and large, neem is ignored by cattle, sheep and even goats, which makes it easy to establish However, it is recognized as a suitable fodder for camels (Radwanski, 1977a) Shaw (1985) reports that in areas of India, both cattle and goats now readily browse neem, an adjustment to the paucity of more palatable forage According to Fodder Trees of India (Singh, 1982), neem is regarded as a good fodder tree and is very heavily lopped to feed goats and sometimes cattle The leaves contain insecticidal compounds, but when these are extracted, the leaves can be used as a high-quality animal fodder

CHEMICAL DATA OF NEEM FOLIAGE FROM NIGERIA (Radwanski, 1969)

COMPOSITION	LEAVES	LEAF STALKS	PODS
Moisture %	17 30	15 30	15 90
Calcium %	1 67	0 83	0 34
Magnesium %	0 71	0 27	0 40
Phosphorus %	0 91	0 13	0 24
pH	8 20	8 10	7 90

NEEM SEED

Neem begins to bear fruit in three to five years (Jacobson, 1980) The period of collection of neem fruits naturally varies from place to place, depending upon the regional climatic conditions In India, collection may begin as early as May and extend through September, however, there seems to be two distinct fruiting periods, May-June and August-September The fruits are collected from the trees when fully ripe or are gathered from beneath trees

Yield -- Neem produces fruits in 3-5 years and becomes fully productive in 10 Ketkar (1976) gives a yield of about 50 kg (110 lbs) per tree per year, Ahmed and Grainge (1985) 30-50 kg (66 6-110 lbs), and Radwanski (1977b) lists 11 4-34 kg (25-75 lbs), averaging about 20 5 kg (45 lbs) About 2-3,000 fruits weigh one kilogram, the de-pulped fruit yields about 1,800 seeds per kilogram (De Jussieu, 1963), and 9-10 dry seeds weigh one gram (Singh, 1982) The ratio of seed to pulp is approximately 1 2, and fruit pulp and kernels account for 47 5% and 10 1%, respectively, of the fruit's weight (Ketkar, 1979) For reproduction seed preparation, the fruits are rubbed and washed to remove the flesh from around the seeds After washing, the seeds are dried in shade and preferably stored in dry, airtight containers

Viability -- Neem seeds remain viable for only a few weeks, 1-2 months is probably normal Therefore, they have to be sown quickly But when mature seeds are depulped and adequately cooled and dried, they can be stored for longer periods Reportedly, germination rates rapidly decline during storage Care is necessary in the collection of seeds when they are fresh to obtain a high germination percentage They should be collected when thoroughly ripe and sown as soon after collection as possible

Germination -- Seeds germinate in about 2 weeks after sowing Fresh neem seed germinates quite readily and scarification is generally not needed Research at the Royal Botanic Gardens in Great Britian indicates that germination is improved if the inner shell is removed to expose the embryo before planting (Radwanski and Wickens, 1981), and Smith (1981) reports the same But Singh (1982) recommends that the seeds be cut across with a sharp blade and the cotyledons examined If the cotyledons are green the seeds are sound, but if they have turned yellow or brown, they will not germinate

In more efficient containerized nurseries, it is desirable to produce a sprouted seed in every container because less space is required and it reduces per seedling labor costs Experiments were conducted by Operation Double Harvest in Haiti in an attempt to pregerminate neem seeds for transfer to containers, however, the research showed that 47% of pre-germinated seed had a major tap root deformity (crooked or looped), while the roots of only 7% of dry sown seed were deformed (Larson, 1985)

Fagoonee (1983) found that germination is best when seeds that have fallen from trees during the preceding week are soaked in water for about 3 days, depulped and cleaned, then sown directly into the nursery in damp soil The soaking breaks the dormancy by neutralizing the germination inhibiting chemicals found in the shell of the seed

But Ezumah (1986) concluded that Neem seeds do not require a period of after-ripening Seed origin, year and time of production have no significant effect on germination and longevity Sun-drying does not adversely affect viability and appears preferable to air-drying to bring seed moisture content to 10% or less before storage The method of seed cleaning also 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 Cold storage adversely affects the viability of neem seed, seeds stored at room temperature (26^{o}-$28^{o}C$) retained some viability for 16 weeks, while viability lasted for only 12 weeks at cold storage (6^{o}-$7^{o}C$)

PROPAGATION TECHNIQUES

Most commonly, neem seedlings are propagated in the nursery and seedlings transplanted to the field, although direct sowing has been successful in some areas if rainfall is adequate (Troup, 1921, Welle, 1985)

Although neem needs light, young seedlings can suffer from strong solar radiation, thus a light shade is desirable during the first season of growth Sudden exposure of seedlings without first hardening off will result in a high rate of mortality Seedlings naturally regenerated under old stands often die when the trees are cut and the canopy is opened (Fishwick, undated)

Nurseries -- In the nursery, seedlings are either grown in containers (plastic bags or root-trainers) or in seedbeds Germination starts in about eight days and continues up to about three weeks

Bags and other containers -- Seeds are sown directly into the container filled with potting soil and are ready for transplanting in 12 weeks (CATIE, 1986) In Haiti, seedlings are grown in containerized nurseries and transplanted in 3-5 months, depending upon the rainfall pattern (Welle, 1985)

Seedbeds -- If the nursery is irrigated, seeds can be harvested early, in April, and planted in the nursery The seed should be lightly covered with earth and sparingly watered, the soil kept loose to prevent caking Singh (1982) recommends a spacing of 5 cm in-row and 20 cm inter-row, planting the seed at a depth of no less than 1 cm to minimize rodent damage Fishwick (undated) states that seeds should be sown thickly in lines 30 cm apart, selectively thinned when the seedlings are about 8 cm high (3 in) to a spacing of 8 cm, and selectively thinned again in 4 to 5 months with only the best stock remaining at a spacing of about 23 cm (9 in)

Method and Transplant Time -- Recommendations of what form, age and height of neem for transplanting vary

Seedlings -- If seeds are planted early in April, seedlings should be ready for transplanting by July (4 months), reaching a height of 15 to 20 cm De Jussieu (1963) and Troup (1921) report that neem fruits from April thru July, and seeds are planted in seedbeds in an partially shaded nursery as soon as possible after harvest, around the middle of July when the rains begin, and are ready for transplant by the next rainy season, after reaching a height of about 0 80 to 1 m Radwanski (1977a) and TAREC (1986) indicate that seedlings are ready for transplant in about 12 weeks when they are 7 5 to 10 cm high (3-4 in), with a taproot approximately 15 cm long (6 in) Mirta (1963) recommends transplanting when seedlings reach 7 5 to 10 cm (3 to 4 in) high According to Singh (1982), seedlings transplanted younger than one year have a poor survival rate, this does not hold true according to experience in Haiti, where the survival rate of 3-5 month container grown neem transplants is 85% (Welle, 1985)

Root balls -- Seedlings that have not been planted during the first year are kept until the following season and sometimes until they are 2 years old Year old seedlings are carefully uprooted from the nursery leaving a ball of soil around the roots, and are transplanted as soon as possible Planting is done in July-August in pits dug in April-May, which allows weathering of the soil, and if rain immediately follows, good survival rate is ensured In dry areas, about 90% of the leaves are removed, reducing evapotranspiration, and decreasing transplant shock The areas in the vicinity of the trees must be kept weed free (Singh, 1982)

Stumps -- In India, stumps are usually prepared from 2 year old seedlings, although in irrigated nurseries, year old seedlings may attain the desired size for stump preparation The seedlings should be uprooted with care to avoid splitting or breaking the taproot Stumps are prepared with 22 cm roots and 5 cm shoot portions and wrapped (bare-rooted) in moist gunney sacks and kept in the shade until transplanted Just before planting in 30 cm^3 pits, desiccated root and shoot tips are pruned (Singh, 1982) In Nigeria, Fishwick (undated) found that seedlings cut to a stump height of 0 3 m (1 ft) were better than taller ones because they were easier to handle and provided sufficient buds for sprouting, and were not damaged by wind, which whipped taller ones, loosened the soil and exposed the roots Roots were trimmed to 30 cm (12 in), with most of the new growth produced by the callus that forms at the point where the roots are trimmed Survival was increased when the seedlings were cut in the seed bed rather than at the time of lifting because shock was reduced by not cutting, lifting and transplanting at the same time, and a callus tissue would form on the shoot wound before lifting In Africa, Gorse (1986) cut canes to a height of 1 5 meters and removed all leaves before transplant, and in this way the bark is already hardened and not as susceptible to damage by animals

Tissue culture-- The use of tissue culture and cuttings to produce neem for reforestation has been deemed unrealistic in most cases because of the high cost of a production facility, and the relative ease of producing seedlings (Sommer and Caldas, 1981) Also, it is questionable whether tissue-cultured plantlets and cuttings will develop full taproots However, it could be economically justified to screen and reproduce plants of unique germplasm (such as a tree with an unusually high azadirachtin content) in this manner for seed orchard establishment in more moist areas, which would not be affected by limited taproot development

Neem has been successfully tissue cultured from leaflet callus tissue and from stem tissue by growing it in modified Murashige and Skoog media, producing roots in 40% of the cultures and developing into complete plantlets in a supplemented medium (Sanyal et al , 1981, Jaiswal and Narayan, 1984, Narayan and Jaiswal, 1985) In further tissue culture research, Schultz (1983) was not able to achieve root initiation as reported by Sanyal et al (1981), which supported research by Rangaswamy and Promila (1972) describing the differentiation of 'growth centres' in Azadirachta callus and the eventual shoot bud formation with rarely any rooting Again, it is questionable whether a normal length tap root will develop from tissue-cultured plantlets, which would exclude their planting in water stressed areas

Cuttings -- Neem can also be propagated by cuttings, which require a production period of six months to one year (TAREC, 1986), but again the development of a normal taproot would be doubtful Air layered branches treated with IBA or NAA in lenolin paste at 0 1% develop roots satisfactorily (Shanmugavelu, 1967) In Nigeria, Fishwick (undated) records that in Maiduguri a number of neem shoot cuttings were treated with a rooting hormone (Seradex B) and then placed in pots A number took, but did not survive after being transplanted In Sokoto, the work was repeated, but cuttings were covered with polythene bags, and a number survived after being transplanted It was found that a significantly higher proportion of the cuttings took root when they were taken and prepared at the start of the rainy season

Direct Seeding --In the literature, the term direct seeding (sowing) is used in two ways direct seeding in the nursery and direct seeding in the field In India and Nigeria, direct sowing is reported to have proven more successful for reforestation than transplanting, however, this is when areas to be sown are well prepared (similar to land preparation for sowing food crops) Direct seeding on hard and inhospitable soils has not been very successful But establishment and growth can be greatly enhanced when seeds are sown in bore holes that have been dug in these hard soils and filled with a fertile potting mix Research has shown that hole size on difficult sites can significantly enhance establishment and growth of transplanted seedings Although drilling bore holes with a post-hole auger and filling them with a potting mix may to some seem expensive, the cost is comparable to nursery raising and transplanting seedlings

When direct-seeded, neem establishes an extensive root system before aerial growth becomes rapid (NAS, 1980) Site preparation and transplanting are the two biggest costs of reforestation, and direct seeding can markedly reduce transplanting costs De Jussieu (1963) reports that aerial seeding has been tried but yielded poor results, since the chances of survival for the seeds is much lower than direct seeding on prepared land Gorse (1986) recommends the use of a groundnut planter and weeder for direct seeding neem and for weeding, and covering the seed beds with a 10-15 cm mulch of groundnut hulls

Welle (1985) reports that direct seeding has proven to be a viable method of establishment in Haiti Seedlings raised in nursery beds are ready for transplanting during the first rains when they are 7 5 to 10 cm (3 to 4 inches) high Sometimes seedlings are retained in nursery beds and transplanted during the second rainy season (ICOC, undated)

Methods of direct seeding vary (Radawanski, 1977a, Singh, 1982, ICOC, undated) and include

In India (a) The soil is worked to a depth of about 15 cm and the seeds are sown at a depth of 1 5 cm Sowing is done either in patches or lines, in the former they are spaced about 3 X 3 m, and spacing between lines is about 3 m A seed rate of about 3-4 kg per hectare Weeding is necessary and seedlings are thinned at the end of the first season, leaving two seedlings per patch or two seedlings per meter length of the line (b) Seed was sown at high and dry sites that had been plowed twice No watering was done, but the seedlings were kept free of weeds In less than three years, the plants were 7-8 feet high, the growth being equal to or better than that of transplants that had been carefully watered and tended Trees in similar plantings at another site measured up to

12 feet in 3 years (c) Direct seeding into mounds of earth 12 feet by 4 feet by 1 5 feet on sites receiving 24 inches (600 mm) of rain annually produced plants that reached a maximum height of 4 5 feet in one year (d) Neem was sown in combination with the cultivation of sesame, cotton and the lesser hemp in an area with an annual rainfall of less than 500 mm (20 in) The sown lines were 0 3 m (1 ft) apart, three lines of field crops to one line of trees, so that the latter were 1 2 m (4 ft) apart Sowing of both field crops and trees was done after site preparation by plowing and harrowing The lines of trees were weeded twice during the first rains The trees reached a height of 5 m (16 ft) and girth of 43 cm (17 in) in three years (e) Direct sowing into plowed furrows in black cotton-soil produced trees with a maximum height of 1 5 m (5 ft) after 1 year (f) Success has been achieved by dibbling neem seed under Euphorbia bushes

In Nigeria, Fishwick (undated) reports successful direct seeding at the bases of the native cover, with a survival rate of about 40 trees per hectare It was observed that although the rate of growth is generally slower than on cultivated sites, it had merits of simplicity and cheapness to enrich degraded forest area

In northern Nigeria, neem interplanted on farms among groundnuts, beans, and millet showed markedly superior growth When the crop was harvested, a healthy stand of neem seedlings was left behind (NAS, 1980)

Natural Reproduction -- Under natural conditions, the fruit (seed) ordinarily drops to the ground during the rainy season, and germination takes place in one to two weeks Neem reproduces naturally with tolerable freedom, especially around trees growing in moist, sandy soils Naturally regenerated seedlings have been used for reforestation, but they do not compare in vigor with good nursery stock Their root systems are poorly developed, they are very sensitive to sunlight, and they lack buds (Fishwick, undated) In Haiti, a number of volunteer seedlings were dug up from under a tree, 22% were highly deformed, and only 39% could be rated as having well shaped tap roots (Larson, 1985) Neem establishes well under bushes and scrub (Troup, 1921), though initial growth is usually slower (NAS, 1980) Bats and birds are reported to spread neem by eating the fruit and depositing the seed elsewhere, and spontaneous individual trees and stands of neem trees are reported to have been established in this manner in several countries in Africa, in India and in Haiti Some feel that bats spread more seeds than birds, and larger numbers of volunteer seedlings can be found under trees where they roost (De Jussieu, 1963, Gorse, 1986, Brouard, 1987)

SURVIVAL AND DISADVANTAGES OF PLANTING TECHNIQUES

There are disadvantages to planting neem seedlings early, without hardening-off and with inadequate tap root and root system development, for survival would be low especially in water stressed soils There are also distinct disadvantages to planting overage seedlings First, it is very costly to keep and care for seedlings in the nursery for one to two years And the added weight of seedlings with a soil root ball drastically increases transportation costs and reduces the number of seedlings that can be delivered to the planting site, especially if they are hand carried Another problem when seedlings are transplanted bare-rooted, they suffer severe transplant shock, roots dry out, root hairs and beneficial mycorrhizae die, survival rate is decreased, and growth rate is retarded

The rate of seedling survival is influenced by a number of other factors besides age of seedlings and methods of transplanting Genetics play an important role, and seeds should be gathered from plus trees of the desired phenotype Also the size of the seed influences survival and early plant growth, larger seeds produce a much stronger seedling (maternal influence) Seedlings with a well developed root system (such as those promoted by "root trainers," and through fertilization, and those which have been inoculated with mycorrizae) can withstand drought much better and have the capacity for a more immediate and larger uptake of moisture and minerals, thus will have a higher survival rate

In compacted and eroded soils, survival can be influenced by the size of the hole in which the seedling is planted A larger hole allows for increased water infiltration because of the uncompacted soil, and it also allows better development of the root system In nutrient-poor soils, it should be possible to gain a higher rate of establishment by boring or augering a hole into the ground about 10 cm (approximately 4 in) in diameter by 15-23 cm (approximately 6-9 in) deep, replacing the displaced soil with a good nutrient-rich nursery mix, and seeding directly into the hole This would greatly reduce reforestation costs, doing away with the expensive nursery operation

The loosening of soil to prevent caking (in some soils), which promotes soil-aeration and increases moisture percolation, is found to be most beneficial Research indicates that on undisturbed soil, less than 25% of the rain falling on it is absorbed, but up to 60% when frequently hoed,mulching plus hoeing increased the absorption up to 90% (Fishwick, undated) In either case, direct sowing has been found to give better results than transplanting nursery-raised plants (Troup, 1921)

Also, neem is intolerant of grass competition and needs thorough weeding, especially in dry areas, to obtain good growth (NAS, 1980)

<u>Weeds</u> -- Thorough weeding without watering is found to gain results almost, if not quite, equal to those attained by irrigation and weeding Because weeds compete for moisture and nutrients, early growth of seedlings is much retarded, and regular weeding and cultivation stimulates neem growth and vigor Research carried out in Dehra Dun, India, has shown that seedlings that were weeded reached a height of 0 6-1 4 meters (2-4 5 feet) by the end of the second season, but only 0 5-1 meters (1 66-3 25 feet) if not weeded Later, the seedlings that were not weeded were killed by weed suppression and frost (Troup, 1921) Experiments in Nigeria have shown that some tillage during and at the end of the wet season has a remarkable effect on the growth, health and survival of neem in the first year when interplanted among groundnuts, beans and millets (Mackay, 1952)

Fishwick (undated) concludes that once established and rooting below the upper zone of competition, the presence of weeds and grasses does not seem to affect the tree growth, although it should be noted that perennial grass roots have been observed at depths of over 3 meters (10 ft)

Spacing -- Neem seems to be very nutrient-demanding, and has been known to send out lateral surface roots reaching over 18 meters In Nigeria, a spacing of 1 8 m X 1 8 m is recommended (De Jussieu, 1963)

Root Formation -- Roots that have been pruned (as suggested in the stump planting method) may not regenerate into a long, normal taproot (rather they develop several shorter pseudo taproots, which are not as long as a normal one) Fishwick (undated) found--by digging--that a 2-year old tree planted from a stump possessed 7 taproots each with a 1 27 cm (1/2 in) diameter at a depth of 12 ft (full depth of penetration was not recorded) [Actually, these were probably psuedo taproots, since trees normally have only a single deep taproot if grown from a seed] Without a normal taproot, the plant would be limited in its ability to penetrate into low water tables and reach nutrients in lower soil horizons During drought, when water tables drop considerably, the trees may die Similar difficulties would be encountered when trees are established from cuttings, for they do not generate normal taproots This might explain the die-off of the neem plantations (established by stump cuttings and from seedlings with the taproot pruned) in Maiduguri, Nigeria, reported by Fishwick (undated) and elsewhere by others (Labelle, 1985, Gorse, 1986)

AGROFORESTRY POTENTIAL

Radwanski and Wickens (1981) report, "Neem cannot be grown among agricultural crops since it will not tolerate the presence of any other species in its immediate vicinity, and if not controlled, may become aggressive by invading neighboring crops " But Makay (1952) reported that even though neem seedlings had been hidden under a 10 foot crop of millet, they were still healthy after the millet was harvested Others state that neem can be planted in combination with fruit cultures and crops for feeding cattle (e g , Pennisetum pedicellatum, as suggested by Misra, 1960) Recommendations have been made for combinations of neem with sesame, cotton and hemp (Howaldt, 1980), with peanuts, beans, sorghum (Radwanski, 1969, 1970, 1977a), with Acacia arabica (Syn A_ nilotica) and cotton (Troup, 1921), and with Khaya senegalensis (Giffard, 1979)

In Nigeria, a form of taungya was used for neem plantation establishment and farmers cultivated groundnuts, beans and millet between the trees, but the forest department planted the trees These plantations were superior in survival and quality to plantations established by other means, and the cost was much lower In areas where neem plantations were cleared, groundnuts were cultivated and yielded 3 times the average for other fields (Fishwick, undated) Neem did surprisingly well under millet Although hidden under a 3 meter (10 foot) high crop in August and September, growth of seedlings did not appear to have been retarded and when the millet was harvested in October, a healthy stand of neem was left behind (Mackay, 1952)

It is known that the compounds found in neem are not only effective against insect pests and beneficial in the efficient use of nitrogen, but they also affect some fungi and bacteria Thus, the tree may have a significant influence on the balance within the microfauna, fungi, and bacteria communities Because plants depend upon a certain microfauna and a special complex of bacteria and fungi, it is possible that where neem changes the composition significantly, problems may arise The effect of neem may be both positive and negative, and research is needed to prove or disprove these factors (Michel-Kim and Brandt, 1980)

Perhaps neem 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 to other crops or vice versa Or the reason may be that since neem fruits produce a systemic, somewhat repugnant chemical, food crops may take up this chemical from fruits falling on the ground once the tree begins bearing fruit (usually at 5 years) Food crops might then have a bitter taste, hence the reference that neem isn't a good species for agroforestry Research is surely needed to prove or disprove neem's incompatibility as an intercrop and agroforestry species

The answer may be to plant neem in mixed forests in combination with pasture Michel-Kim and Brandt (1981) suggest that up to 20 percent of the area could be planted to neem, and village plantings could constitute up to 15% Neem would also be a good species for use in a sequential agroforestry system as illustrated in Radwanski's and Wickens' paper (1981) Another excellent of use of neem in agroforestry systems is for windbreaks In the Majjia Valley in Niger, over

500 km of windbreaks (a form of agroforestry) comprising double rows of neem trees have been planted to protect millet crops and to supply wood to local villagers This has resulted in a 20% grain yield increase for local farmers and the windbreaks are lopped and provide needed fuel and construction wood to villagers (Long, 1986, Bogentteau-verlinden, 1980)

Perhaps one of neem's best agroforestry potentials is where it is grown it for its various useful products (leaves, neem cake, etc) but not intercropped with food crops, and in a cut-and-carry system, applied to food crops as a fertilizer and pesticide

Michael-Kim and Brandt (1980) estimate the yield of neem between 10 and 100 tons of dried biomass per hectare per year, depending upon the micro-environment, and 40 tons should be easily achieved About 50% of the biomass is contained in the leaves, 25% in the fruit, and 25% in the wood (it is assumed that this is sustained yield)

SOIL IMPROVEMENT

Neem leaves and twigs have been successfully used as mulch and fertilizer in Ceylon, India and Burma (see section on Leaves) Neem seed cake (the residue left after extracting oil from the fruits) is reportedly an excellent fertilizer, many times richer in plant nutrients than manure (see section on Neem Seed Cake) Neem has been successfully used to reclaim semi-arid wastelands, particularly in India (NAS, 1980)

Neem is a non-leguminous tree and there is no symbiotic nitrogen fixation in the soil However, free-living, nitrogen-fixing bacteria are known to be C heterotrophic and thus dependent on the supply of organic carbon for their energy (Mengel and Kirkby, 1978) It is possible therefore that a substantial increase of the organic carbon content in the neem soil may create conditions favorable for the proliferation of those bacteria and a consequent increase in the supply of plant-available nitrogen Termites active in the decomposition of dead wood may constitute another source of nitrogen They have been found to possess nitrogen-fixing bacteria in their hindguts and their activities may also result in an increased nitrogen supply under neem (Benneman, 1973, Breznak et al , 1973) By tunneling, termites also increase water percolation into the soil

Nye and Greenland (1960) have shown that the content of organic matter in the soil is often considerably increased bny fallow periods in which woody species increase, and that nitrogen and other nutrients increase at the same time Neem's extensive root system can extract nutrients from deep subsoils and enrich surface soils through litter, thus increasing soil fertility and at the same time adding valuable organic matter

In northwest Nigeria, significantly higher total cations, cation-exchange capacity, base saturation, and pH were observed in soils under neem than in similar soils in bush-fallow (Radwanski and Wickens, 1981) In a case study on red acid sands of desert origin, 2 phases of the same soil series, one under neem and the other under bare fallow farmland, were examined Ten topsoil samples (0-7 5 cm and 7 5-15 cm) from each phase were analyzed and the results showed some striking differences The average pH value of red sands without neem was 5 4 in the first and second layer, and the average pH in the corresponding layers under neem was 6 8 A substantial increase in the soil pH values under neem was due to the accumulation and decomposition of leaf litter and is a surface phenomenon The pH of neem leaves was 8 2 The content of organic carbon had risen from 0 12 percent under fallow to 0 57 percent under neem, and the total nitrogen content increased from 0 013 percent in the top layer of the fallow soil to 0 047 percent in the corresponding layer of the neem phase (Radwanski, 1969, FAO, 1968)

However, the phosphorus content in the fallow phase (201 and 190 parts per million) was higher than in the neem soil (131 and 106 parts per million) Phosphorus content of neem leaves appears to be relatively low and it is possible that this element is stored in other parts of the plant, such as fruits, bark and roots The most striking difference was between the total cations, base saturation and exchange capacity, particularly in the top 3 inch layer There is no doubt that observed increases under neem were largely due to the accumulation of the bivalent cations calcium and magnesium (Thery, 1978) The total cations increased from an average of 0 39 milli-equivalents/100 grams soil in the fallow to 2 40 milli-equivalents under neem, the cation exchange capacity from 1 70-2 25 milli-equivalents and the base saturation from 20-98 percent

The leached and degraded sandy soils of the type described here are not uncommon in dry savanna regions of west Africa and the proven capacity of neem to improve their productivity renders this tree eminently suitable for inclusion in forest fallows and also for planting on soils unsuitable for farming In the latter case, neem can be established without displacing other crops (Radwanski and Wickens, 1981)

SOAP MAKING AS A COTTAGE INDUSTRY

Radwanski and Wickens (1981) feels that making soap from neem oil is presently the most feasible industrial development for neem in the developing countries Neem oil could replace edible oil employed in soap making, thereby freeing the later for dietary use Soap produced from neem oil also has beneficial medicinal properties In India, the major use of neem oil is for making soap There, soap making is often a traditional household activity, and its expansion, based on simple techniques with locally available neem oil, will create sound village industries Paul (undated) in the Directory of Mass Employment details the neem soap making process in India

Processing -- In India, neem fruit are sundried and stored until December or even later, when they are decorticated and the kernel pressed However, drying neem fruit without depulping is not desirable because fermentation soon sets in, which affects the quality of the kernel The fruits should be depulped soon after collection This may be done by washing them in streams, tanks or canals using bamboo baskets or special frames so that pulp is washed out into the water while the seed (kernels) is retained in the basket or frame Where sufficient water is not available, depulping may be done by mixing the fruit with mud or ashes, trampling underfoot, drying, loosening the adhering soil or ashes and winnowing

The seeds contain a lot of moisture and deteriorate rapidly during storage, and if dried improperly will char as a result of the heat produced by auto-oxidation, thus reducing the yield of oil Therefore, it is important to clean and dry the seeds as thoroughly as possible before storage (ICOC, undated)

Neem fruit in India is collected by farmers and the landless poor who collect them from trees growing in their home lots, along roadsides, or in the wild and are paid the following approximate prices brought to centers US $0 10/kg for depulped and dried seed, $0 08/kg for depulped and undried seed, and $0 04/kg for undepulped fruit Ketkar and Ketkar, 1984) Fruits are collected from trees growing wild or along roadsides

For depulping, neem fruit is soaked for 4-5 days in water and then trampled upon or rubbed vigorously This separates the skin, which is used for organic fertilizer The seed thus depulped is then dried, and the Indian Central Oilseeds Committee (undated) reports that in this form it can be stored in well-ventilated storage sheds for up to a year without losing its pest-control effectiveness However, Larson (1986) observes a marked deterioration of the azadirachtin level occuring in a short time even when the seed is stored in veltilated sheds on shallow trays, and feels that storing well dried seed will retain a higher level of the chemical when stored in a cool dark area

In India, a simple animal-drawn oil crusher ("ghanee") India) can be used by farmers themselves for processing neem kernels to obtaining neem oil and neem cake, and village-level industries may employ simple electrically-operated oil expellers A number of both types of facilities exist in India's rural areas (Ketkar and Ketkar, 1984)

Many electrically operated expellers are run on a cooperative basis These have been established at costs ranging between US $5,000-30,000, with capacities of crushing 5-10 tons depulped neem seed per day The machinery needed (expeller, boiler, filter press, shaft pulley, decorticator, and neem cutter) are locally fabricated and plant operation is relatively simple--needing only a mechanic and 3-15 unskilled workers (Ahmed, 1984)

Dried neem seed contains approximately 10% oil and 12% cake (Ahmed and Grainge, 1985) Neem oil currently sells in India for $1 20-1 75/kg from the factory, and neem cake, for $0 10/kg (Ahmed, 1984) Larson (1986) reports a price of $1 75/kg for oil in India It may be possible to couple charcoal production with seed drying for oil or neem cake production, utilizing the hot air given off in carbonization, however, this would cause a drastic deterioration of the azadirachtin level, rendering the product nearly useless for use as a pesticide

TOXICITY, PESTS, DISEASES AND LIMITATIONS

Neem is said to have few pests and its naturally occurring pesticide is nontoxic to man and animals But there is evidence that this may not be so

Toxicity -- Radwanski and Wickins (1981) state that one of the most significant attributes of neem oil as an insecticide is that it is effective and reportedly non-toxic to man or animals, and nonpolluting to the environment However, a syndrome similar to Reye's syndrome has appeared in children given large doses of neem oil (Sinniah, et al , 1982, Sinniah et al , 1985), although infrequent, this manifistation has been fatal Because Reye's syndrome and the neem oil-induced Reye's-like syndrome are poorly understood, neem extracts should be tested more thoroughly before being used for medicinal purposes Also, neem extracts have been found to be toxic to guinea pigs and rabbits (Deshpande, 1983), and the insectivorous fish Gambusia spp , and tadpoles died at 0 04% concentration of neem extracts (Jotwani and Srivastava, 1981) Welle (1985) observed that neem seeds falling into fish ponds in Haiti proved fatal to Talapia fry This indicates the need for systematic follow-up toxicological studies

Pereira and Wohlgemuth (1982) report that neem seeds carry Aspergillus flavus, which in certain conditions produces aflatoxins, this is a particular concern in waste piles at preparation sites

Allelopathy -- There is some concern that neem compounds may be allelopathic, but no hard evidence supports this contention (also see section on AGROFORESTRY POTENTIAL)

Pests -- Roberts (1965) lists 14 insect species and one parasitic plant as recorded pests of neem in Nigeria, although few are serious, and most plantations of neem are reported to be insect free, evidently due to the trees repellant compounds Insects will eat off the radicle of germinating seeds if not covered well with soil Occasional insect infestations by species of Microtermes and plant parasitism by Lorantium have been observed in Nigeria, but the attacked trees almost invariably recover, though their rate of growth and branch development may be considerably retarded (Radwanski and Wickens, 1981)

In India, the larvae of Enarmonia koenigana Fabr feed on rolled leaves and bore into tender shoots, and the larvae of Cleora cornaria Meyrick and Odites atmopa defoliate the leaves (Bhasin et al , 1958) Warthen (1979) lists 9 other insect pests that attack neem Calepiterimerus azadirachta, Araecerus fasiculatus, Cryptocephalus ovulus, Holotrichia consanguinea, H insularis, H serrata, Pulvinaria maxima, Laspeyresia aurantianna, and Orthacris simulans CAB-IIBC (1987) reports that Aonidiella orientallis has become a pest of neem in some parts of Africa (e g , the Lake Chad Basin Niger, Chad, Nigeria and Cameroon)

Termites have been known to damage trees, attacking them at the level of the collet, sometimes extending to the trunk and to the cyme, but generally not killing them (De Jussieu, 1963) Fishwick (undated) reports that termites attack weak, sickly trees but at times they also attack and kill young, vigorous trees Neem commpic shoots have also been attacked and killed, but the roots of the stump were not damaged and produced fresh coppice shoots

Gosh (1984) reports that the neem scale, Palvinaria maxima, is a serious pest in central and south India. It feeds on sap, covers the tender shoots and stem in numbers and sometimes damages a young tree considerably A tree in an advanced stage of infestation is recognized by the thick coating of white, mealy patches formed on the foliage, shoots and bark Another scale insect, Aspidiotus orientalis, thickly covers the shoots and stems of seedlings of about 0 6-2 5 cm in diameter, appearing on the new shoots and spreading to the leaves In severe infestations, the growth is retarded, leaves are shed, the stems die back and young trees may be killed Also, *Aspidiotus pseudoceriferus* feeds on the sap And the nymphs of *Helopeltis antonii* feed on sap by puncturing the soft plant tissue which blackens and dries The wounds cause deformation of leaf and shoot, or the whole shoot may dry up and die back

Diseases -- Recorded pathogens attacking neem are *Ganoderma lucidum*, causing root rot, *Corticium salmonicolor*, causing stem and twig blight, *Cercospora subsessilis*, causing leaf spots, *Oidium* sp , causing powdery mildew, and *Pseudomonas azadirachtae*, causing leaf spot and blight (Bakshi, 1976, Desai et al , 1966) Sankaran et al (1986) reports additional diseases attacking seedlings in nurseries in India *Rhizoctonia solani*, causing web blight, *Sclerotium rolfsii*, causing stem rot, *Colletotrichum capsici* and *C subsessilis*, causing leaf spot, and *Fusarium solani*, causing wilt Stem rot, leaf blight, web blight and wilt being reported for the first time caused up to 30% mortality of 2 to 3 month-old seedlings

Singh and Chohan (1984) observed a severe canker disease of twigs and shot-holes in leaves of neem and identified a fungus, *Phoma jolyana*, as the cause De Jussieu (1963) reports that cankerous lesions can also sometimes be found on tree in fissures coming up from the collet along the stem The wood becomes brown around the cankers and this coloration can penetrate to the heartwood Gorse (1986) observed that canker prevailed on the sunset side of the tree This disease seems to correlate with a sudden absorption of water after a long drought, but through exploration of the genetic potential of neem, genetic resistance might be found

Parasites -- Mistletoes that parasitize neem include *Dendrophthoe falcata* and *Tapinanthus* sp (Browne, 1968)

Nutrient Diffeciencies -- Research by Zech (1984) determined that zinc (Zn) and potassium (K) deficiencies reduce neem growth evidenced by chlorosis of leaf tips and leaf margins, particularly on the older leaves The first symptom of Zn deficiency is yellow coloration of the intercostal areas leading to complete breakdown of the chlorophyll, and the shoots exude much resin with shedding of the older leaves With K deficiency, leaf tip and marginal chlorosis and necrosis are evidenced

Other Problems -- Neem seedlings are killed by frost and fire, and large trees are frequently snapped off during high winds However, trees seemingly killed by fire will coppice and regrow if cut soon after the burn Regeneration beneath stands of neem is sensitive to sudden exposure to direct sunlight, and clear felling in plantations normally results in the death of this regeneration if seedlings are under 8 cm (3 in) in height (Fishwick, undated)

In some localities rats and porcupines girdle neem seedlings and trees, gnawing the bark from around the base and killing them In areas with high rodent densities, they devour the fruits greedily and consume most of them after they fall to the ground Goats and camels have been known to severely browse young plants and kill them (Singh, 1982)

Because of the potential of pest outbreaks, neem should not be raised in pure stands, and it is recommended that neem should be mixed with leguminous trees like Leucaena leucocephala, Albizzia lebbeck or Acacia nilotica, which reduce the risks of infestation by these pests These trees would also complement the non-nitrogenous neem tree Welle (1985) reports that neem interplanted with Leucaena leucocephala in Haiti showed better growth than neem in monoculture

RESEARCH NEEDS

Radwanski and Wickens (1981) recommends further field work in neem's native habitat and where introduced to study the range of variation due to genetic and environmental factors Provenance trials and autoecological studies are also needed as well as an evaluation of present silvicultural practices and marketing research Additional research needs include

- Market analysis to determine the feasibility, marketability and profitability of the production of azadirachtin pesticides

- Economic analysis of the cost of an azadirachtin production facility

- Field and/or laboratory analyses of the azadirachtin content of seeds from various neem plantings in the Caribbean, Asia and Africa This has to be done in a scientific manner to ensure proper seed handling to minimize deterioration of the azadirachtin content

- Research to find if the azadirachtin content in the leaves of a single tree has any correlation of the azadirachtin content in the seed Radwanski (1977b) reports a yield of oil of over 59% from Ceylonese seed kernels, which might indicate a higher percent of azadirachtin from the entire fruit

- Identification of mother trees with fruit high in azadirachtin content (first in the Caribbean, then Asia and Africa) This should be coupled with an assessment of site conditions to see if environmental conditions are influencing factors

- Genetic improvement of these trees by selection for trees that

(1) yield maximum numbers of heavy fruits containing the highest possible percentage of azadirachtin There is a great variability in the number and weights of fruits on different trees, and the many ecotypes of neem have different concentrations of azadirachtin

Optimum fruit yield is essential if neem is to be grown for fruit production for the various products and by-products--such as oil for soap and pesticide extracts and neem cake for fertilizer--and is to be a viable and profitable cottage industry Standardization is essential to mass production

(2) have straight trunks with maximum clean bole height for construction lumber and poles in order to remit maximum income to farmers in developing countries

These factors may be genetic as well as environmentally influenced Biotechnologies, such as tissue culture, can greatly reduce the time frame for this development process

Genetic selection for optimum branching from a stump close to the ground for pole production is also needed, as is research to determine the best time of the year to coppice neem Often in the developing countries, neem poles bring the highest price for wood

- Additional research is required into the methods of pressing and extracting the oil from the neem fruit and seed, the methods of purification, deodorization and refining, analysis and tests for quality, and experiments in the manufacture of soaps, lubricants, waxes and other products

- Selection of provenances better suited for dry areas

- Mycorrhizal association with neem, if there is association or not, both on trees growing in the Burma-India area where the tree is indigenous, and areas where the tree is exotic. If there are associations, the various strains should be tested to see if the Burma-India strains give higher performance than strains which form an association with the tree when planted in exotic areas Research should include whether this association increases tree establishment and growth on marginal sites and if drought tolerance in semi-arid areas can be increased If no associations are formed in the exotic areas, trees should be inoculated with mycorrhizae and compared with uninoculated ones to judge performance differences

- Additional research is needed to extend the activity of azadirachtin Sunlight degrades neem extract sprayed on plants within a week The systemic effect of azadirachtin incorporated into the soil, however, lasts more than a month Vikewood Ltd reports that by retaining of a portion of the oil, coupled with a UV screen, has shown to give good activity at longer than 21 days This synergism is covered under a U S Patent held by Vikwood Ltd for MARGOSAN-O™ (Larson, 1986)

- Research is needed to develop methods to extend the period of the viability of neem seeds for replanting

- Additional research on the best height and time of year to pollard neem for leaf and/or wood production Neem is often planted as a windbreak, for shade and for roadside planting, and valuable by-products of wood and leaves could come from these plantings

  Pollarding and coppicing often results in aditional branching of the tree, over that which might occur from normal bole development Research is needed to determine how this might affect the fruiting of the tree, and if additional fruit production might result

- Since neem trees are rarely browsed because of the bitter ingredients in the leaves, it may be possible to mix neem extracts in a solution of water and soak the soil around the roots of seedlings readily eaten by livestock (such as Leucaena leucocephala) during dry periods for uptake by the plant as a natural repellant The neem extract absorbed by the plant would be transposed to and deposited in the leaves As the tree matured and old leaves are shed, the repellant effect would diminish since the plant manufactures no natural repellants This protection period could be regulated by the application of additional solutions Neem extracts have a systemic action when applied to some crops, which means that once absorbed by the plant tissue, they offer more durable protection even after heavy rain

One of the most difficult reforestation problems is how to protect young trees from being eaten by livestock and wildlife A survival rate as low as 20 percent has been estimated for many areas in Africa

CONCLUSION

Neem can be effectively grown in many unproductive and eroded soils unsuited for agricultural production Large scale planting of neem on such sites should be integrated with local farming and grazing practices A modified farming system using neem, local and exotic fast-growing trees and shrubs as a fallow crop (modified bush fallow or shifting cultivation system) would result in a marked improvement in declining ecosystems of many developing countries and in the restoration and maintenance of soil fertility It would also supply large quantities of basic materials for rural industries and provide a series of products highly competitive in price and quality with petroleum based synthetics, but does not require specialized skill or sophisticated machinery It can be done by village inhabitants and thus provide employment and income in underprivileged rural communities And it would alleviate the often conflicting interests of farming, foresty, grazing and industry Radwanski and Wickens (1981) illustrates one such system in their paper

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SECTION I

Development of the Neem Tree for Private Enterprise

Neem (Azadirachta indica juss) has potential as a pesticide for both commercial exploitation and on-farm use A neem seed extract, azadirachtin, has proven effective against 131 species of insects, 45 of which are extremely damaging to agricultural crops in the U S , and is reported to be non-toxic to man Among some of the most damaging is the Colorado potato beetle, which has resistance to most agricultural pesticides, initial research indicates that the neem-derived pesticde can effectively control this beetle

A biotech firm, Native Plants, Inc , has developed a small neem industry in Haiti Neem fruit (seed) is collected in the rural area and processed by a Haitian-owned firm in Port-au-Prince There the oil is expelled from the seed and the active chemical, azadirachtin, is extracted from the oil and exported to the U S for the manufacture of the pesticide Native Plants hopes to have EPA approval of its pesticide for use on non-food crops early next year

Native Plants is one of three U S companies pursuing commercial exploitation of neem as source of pesticide A second firm, W R Grace & Co , already has a neem-derived pesticide on the market, cleared by EPA for use on non-food crops One of the many uses of neem-derived pesticides is the control of insects in greenhouse-grown flowers and other ornamental plants A third firm, Rohm and Haas Co , is developing a neem-derived pesticide and is interested in setting up an operation similar to Native Plant's in Africa

Neem oil, a by-product of the process, has potential for use in the soap industry in Haiti   In India, where the neem tree is native, neem soap is widely used for its purported anti-fungal and anti-bacterial properties   Neem seed cake, a nutritious second by-product of the extraction process, is used in India as a feed for livestock, much like peanut, cotton seed or soybean cake   It is also used as a soil amelioriator, and according to scientists in India, neem cake has a much higher nutrient value than farmyard manure and other organic mulch   They also report that neem cake effectively controls both nematodes and termites when incorporated into the soil   Research at the International Rice Research Institute (IRRI) in the Philippines indicates that by mixing neem seed cake with urea and incorporating it into the soil, nitrification is inhibited, thus reducing nitrogen loss through leaching and denitrification

Agroforester Mike Benge, with the Office of Forestry, Environment and Natural Resources, Bureau for Science and Development, Agency for International Development, has been working with private industry for the past several years in developing neem as a source of a commercial and on-farm pesticide   A manual he wrote has served as a guide for the development of this multi-purpose tree, and he has been working with all three firms in securing sources of neem seeds in the developing countries   Benge is also working with a Minnesota-based PVO, Agency to Facilitate the Growth of Rural Organizations (AFGRO), to develop a manual on exploiting the neem tree as a source of pesticides The manual will explore the economics, processing requirements and feasibility of the use of neem as a source of pesticide as a small-scale industry for rural income generation The manual is projected to be completed in early 1992 and will be available in both English and French For further information contact Mike Benge, S&T/FENR Agro-forestry, Rm 515E SA-18, Agency for International Development, Washington, DC 20523-1812, telephone (703) 875-4063

SECTION II

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SOME SIMPLE METHODS OF APPLICATION OF NEEM *(AZADIRACHTA INDICA)* PRODUCTS FOR PEST CONTROL BY AFRICAN FARMERS

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Abstract - Insecticidal neem *(Azadirachta indica)* seed products can easily be obtained and applied by African farmers in various simple ways

Water extracts are most important and very effective against a wide range of insect pests in the field They often compete favourably with synthetic pesticides About 25 g of neem seed kernels are needed per litre of water, in case of heavy pest pressure the treatments have to be repeated in intervals of 7 - 10 days Neem oil is a long-lasting and very useful pesticide against bruchids in cowpea seeds in the store Its pesticidal effect lasts more than six months Neem seed powder, mixed with sawdust to avoid phytotoxicity, is a powerful pesticide against stemborers of maize and sorghum This powder is applied to the funnels of young plants Neem seed cake, a by-product of oil production, reduces nematode populations in plant roots and improves growth and yield of vegetables The active principles in this cake are taken up and translocated in treated plants

There are good prospects for the use of simple and cheap neem products by African farmers An Africa-wide neem research and application programme is recommended

Key Words Neem, *Azadirachta indica*, aqueous extracts, neem oil, neem seed powder, neem seed cake

INTRODUCTION

The increasing problems of pest resistance, environmental pollution and rising costs of new synthetic compounds are among those forcing developing countries especially to look for other less expensive but equally effective ways to control pests In this context, one of the most important tasks is to help the peasant farmers who are in a difficult, often desperate, situation merely trying to produce enough food for their large families

Before the development of effective synthetic pesticides during and after the Second World War, simple pest control practices were applied in many countries. Some of these used parts of indigenous plants For instance, to repell pests from stored products leaves and/or other plant parts were stored with the products Some success was attributed to these methods in the past Today they form the basis for the renaissance of pest control through plants and plant products, and because of the considerable improvement of scientific knowledge, they can be practised much more effectively

The neem tree, *Azadirachta indica*, is at present the most promising plant, and its main active principle, the tetranortriterpenoid (limonoid) azadirachtin, the most promising natural compound for insect control by botanicals

DISTRIBUTION OF NEEM IN AFRICA

Azadirachta indica, originating in South and Southeast Asia has a wide distribution on the African continent Introduced by Indian immigrants and foresters, it grows in the area from Senegal and Mauretania in the west to the Sudan, Ethiopia and Somalia in the east and from Cameroon and Zaire in the south to Tanzania and northern Mozambique Its tolerance of poor soils and the drought-resistance it displays have considerably favoured its fast spread from east to west

Neem is most important as a provider of fuel (fire-wood), but is also very much appreciated as a shade tree, especially in many villages and towns in West Africa In addition, neem is an important medicinal plant in many parts of this vast continent and elsewhere, especially in India Young leaves and flowers of *Azadirachta indica* var *siamensis* are consumed in parts of Asia, such as Burma and Thailand, as a vegetable ('edible neem') (Sombatsiri and Tigvattanont, 1984)

IMPORTANCE OF DIFFERENT PARTS OF NEEM FOR PEST CONTROL

Although many parts of the neem tree contain insecticidal compounds, ripe seeds (seed kernels) are the most important source for insecticides Their content of azadirachtin, the dominating active principle, may reach 6 - 7 g/kg (Morgan, 1981, Ermel *et al* , 1984, 1987) There are also some effective terpenoids in the leaves, but it is more difficult and expensive to extract these

MODE OF ACTION OF NEEM PESTICIDES

The active principles of neem are antifeedants, antiovipositants, growth-disturbing, fecundity-reducing, egg-sterilizing and insect-fitness-affecting compounds Although the physiological mode of action is not yet fully understood it can be stated that the hormonal system of insects is strongly disturbed The titre of the two important hormones, ecdyson and juvenile hormone, is reduced during critical periods of the insect's life cycle (Rembold *et al* , 1984) In a broad sense, therefore, neem has an antihormonal effect Neem ingredients are also chitin-synthesis inhibitors (Cassier *et al* , 1987)

SIMPLE METHODS FOR PEST CONTROL USING NEEM SEED KERNEL PRODUCTS

Aqueous extracts

Water extracts of ground or pounded neem seeds/seed kernels are effective to very effective against many freely feeding and some mining pests, such as larvae of Lepidoptera (main target pests), Coleoptera and mining flies (Agromyzidae) If whole neem seeds (seed kernels plus their hard shell) are used, about 50 g (for seed kernels alone only 15 - 25 g) per litre of water are needed The neem seed powder and the water required are put together in a bucket for extraction The extraction process should last at least five hours The extract is then filtered through a piece of cloth, resulting in a liquid ready for spraying, which adheres well to plants

In field experiments of our institute coworkers in Africa, Asia and Latin America the following insect pests have been controlled by application of water extracts -

Plutella xylostella and *Hellula undalis* on cabbage (Africa) (Table 1),
Heliothis armigera and *H assulta* on tobacco (Asia) (Table 2),
Sylepta derogata on okra (Africa),
Anomis flava on cotton (Asia),
Spodoptera frugiperda on maize (Latin America),
Zonocerus variegatus and other grasshoppers on gboma (Africa) (Table 3),
Henosepilachna elaterii on cucurbits (Africa),
Jacobiella fascialis and other pests on eggplant (Africa) (Table 4)

Table 1 Mean feeding damage by *Plutella xylostella* (average of three evaluations) and number of plants with dead hearts caused by *Hellula undalis* (final evaluation) on cabbage treated with neem kernel powder (NKP) aqueous extract in Togo, West Africa (Means of 30 plants/plot, plot size 1 25 x 8 00 m all plots fully randomized) (After Dreyer, 1986)

Treatment	Feeding damage	Number of dead hearts
Control	2 1 a[y]	7 3 a
NKP, 25 g/l	0 c	0 b
NKP, 50 g/l	0 c	0 b
Dipel, 600 g/ha	1 0 b	1 0 b

Damage categories 0 = no feeding damage, 1 = outer leaves slightly damaged, 2 = considerable damage, 3 = plant heavily damaged

[y] Within columns, means followed by a common letter are not significantly different at $P = 0\ 01$

Table 2 Effect of neem extract and conventional insecticide treatments on tobacco yield in the Philippines (After Kirsch, 1986)

Treatment: Insecticide concn applied	Spray interval, in days	Yield (kg/ha)
Control	7	1254 a[z]
Tamaron 600 EC, 0 09% a i	7	1436 ab
BAY SIR 14591 250 EC, 0 10% a i	7	1334 ab
AZT-VR-K EC, 0 15%	7	1480 ab
AZT-VR-K EC, 0 20%	7	1474 ab
ANSKE, 25 g NSK/l	7	1549 b
ANSKE, 50 g NSK/l	7	1405 ab
AZT-VR-K EC, 15%	10	1360 ab
ANSKE, 25 g NSK/l	10	1401 ab

[z] Means followed by a common letter are not significantly different at *P* = 0 05 (Duncan's Multiple Range Test)

AZT-VR-K = Enriched, formulated neem seed extract
ANSKE = Aqueous neem seed kernel extract
BAY SIR 14591 = Benzoylphenyl urea (chitin synthesis inhibitor)

Table 3 Yield of gboma after application of neem kernel powder (NKP) aqueous extract in Togo, West Africa. (Plot size 1 25 x 3 50 m, all plots fully randomized.) (After Dreyer, 1986)

Dosage (g NKP/l)	8 V	8 VI	10 VII	16 VIII
		Yield (kg/plot)		
Control	1 0 a[y]	1 2 a	2 8 a	3 4 a
12 5	1 3 a	3 6 b	7 1 b	7 7 b
25	1 9 a	4 1 b	7 1 b	8 9 b
50	1 4 a	3 6 b	6 5 b	7 8 b

Cumulative means

[y]Within columns, means followed by a common letter are not significantly different at *P* = 0 01

Table 4 Yield of eggplants treated with neem kernel powder (NKP) aqueous extract or neem oil in Togo , West Africa (Plot size 1 80 x 2 70 m, all plots fully randomized)

Treatment	Cumulative yield (kg/6 plants)			
	14 VI	29 VI	14 VII	28 VII
Control	0 a	0 1 b	2.1 c	8 0 b
NKP, 25 g/l	0 2 a	2 0 a	7 7 b	16 3 a
NKP, 50 g/l	0 3 a	2 8 a	10 2 a	17 8 a
Neem oil, ULV, 5 l/ha	0 a	0 6 b	4 9 bc	12 6 ab
Neem oil, ULV, 10 l/ha	0 a	0 7 b	5 8 b	13 8 a

-Within columns, means followed by a common letter are not significantly different at *P* = 0 01

Altogether for more than 100 species of insect pests proved to be sensitive to neem products in laboratory and field trials.

In case of a continuous invasion of pests, several sprayings in intervals of 7 - 10 days have to be applied.

Use of neem oil in storage pest control

Neem oil can also be obtained by kneading ground or pounded neem seed kernels The addition of some water facilitates the process In order to protect the seeds of cowpea *(Vigna unguiculata)* against the bruchid *Callosobruchus maculatus* during storage in West Africa, about 4 ml of neem oil are needed per kilogramme of seeds (Zehrer, 1984 Tanzubil, 1987) The oil has to be thoroughly mixed with the seeds

The neem oil treatment of cowpea seeds is effective for six months or longer, making neem oil more successful than all synthetic pesticides used in storage pest control, including synthetic pyrethroids Normally, West African farmers store their cowpeas only for a few months, during which the protective properties of the neem oil are at their greatest Negative effects, such as bitterness and rancidity were not considered major problems

Neem oil as ULV formulation and suspension with water (3 - 5%) may also be applied for pest control in vegetables and other crops These products are usually somewhat less effective than water extracts but may be useful in controlling aphids and spider mites which are less sensitive to aqueous extracts

Use of neem seed powder for stemborer control

Neem seed powder can be produced with either whole seeds or seed kernels alone The seeds are first ground in a mill or pounded, using locally available tools Sawdust is then added in a volume ratio of 1 1 to neutralize the neem oil, as it may otherwise be phytotoxic to young leaves (Dreyer, 1987)

The neem seed powder sawdust mixture is put in the funnels of maize or sorghum by hand One tablespoon is sufficient This method can be applied to young plants until appearance of the male inflorescence (maize) or the panicle (sorghum) Millet (pennisetum) may also be protected against stemborers by funnel treatment

Very good control of stemborers, comparable to that by synthetic pesticides, such as carbofuran and endosulfan, were obtained with neem seed powder-sawdust mixtures in West-Africa against *Sesamia calamistis* (Dreyer, 1987) and East-Africa against *Busseola fusca*, both on maize Similar results were recorded in India against *Chilo partellus* (Sankaram *et al* , 1987), which also occurs as a serious maize and sorghum pest in some parts of tropical Africa

Neem seed powder may also be used for storage pest control but some problems may arise if the grain to be protected has a high moisture content This may lead to development of moulds and the production of mycotoxins More research is needed in this field to overcome these problems

Use of neem seed cake against nematodes

Where neem oil is produced in large quantities, for instance for soap production, neem seed cake is a valuable by-product It contains some nitrogen as well as the insecticide azadirachtin and other terpenoids

The populations of nematodes (*Meloidogyne* spp , *Pratylenchus* spp) (Roßner and Zebitz, 1987, S Ahmed and Koppel, 1987) are reduced by incorporating neem cake into infested soil This leads to less nematode damage to vegetables and considerable improvement in growth and yield, for instance in tomatoes The insecticidal compounds may be taken up by plant roots and translocated to other parts of the plant where insect pests are negatively affected This has been observed in homopterous rice insects (plant- and leafhoppers) (v d Heyde *et al* , 1984)

Prospects for the use of neem products by African farmers

African farmers have to be taught that they can grow their own effective pesticides, this is a special chance for them to become more self-sufficient It has never been so easy and cheap to extract effective insecticidal plant products and apply them These practices cannot be called backward as the products being applied operate via very sophisticated modes of action Furthermore, neem products are non-toxic to man and domestic animals and have no effects or only

marginal ones on the natural enemies of pests, such as spiders, predaceous mites, ants, earwigs and egg-parasites (Mansour, 1987, Hellpap, 1986, Joshi *et al.*, 1982) These are very important features for African farmers and their environment. I believe the use of neem products in many African countries could be bright, provided entomologists, extension-workers and farmers, especially woman, work closely together. There are already encouraging activities in this field in the Sudan, in Nigeria, Ghana, Tanzania and Kenya, but these should spread to all other countries where neem trees can be grown I am convinced that an African-wide neem research and application programme within the framework of IPM could result in a widespread use of simple neem products by many peasant farmers Perhaps such a programme can be initiated during this conference here in Dakar

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SECTION III

Togolese Republic
Union Peace Solidarity
Ministry of Rural Development

Deutsche Gesellschaft fur
Technische Zusammenarbeit (GTZ) GmbH

Technical Leaflet
Plant Protection

Edited by the
Plant Protection Directorate
B P 1263 Tél 21-37-73 Lomé-Cacaveli

Treatment of Cabbage and Gboma against Pests with Neem Seed Extract

Preliminary Remarks

The neem tree originates from South-east Asia and was introduced to Africa at the beginning of the century because of its rapid growth and drought resistance Today it is found throughout West Africa outside the rain forest zone In towns and villages it provides both shade and firewood and in and regions it is used for afforestation

In its countries of origin neem has a large variety of uses It is used in traditional medicine and for the production of insecticides, and the oil from the seeds is utilized as fuel for lamps or for making soap

Neem seeds can be made into a water extract which acts as an insecticide Such an extract is easy to produce and involves no financial expenditure In principle, it can be used for various crops as long as the user is aware that it is not equally effective against all pests The extract is successful against caterpillars (larvae of moths) and grasshoppers A large number of leaf-eating beetles as well as leafhoppers and whiteflies can also be controlled with this neem water extract

Neem extract does not have a direct poisonous effect on the insects but acts more as a repellent to grasshoppers, leafhoppers, whiteflies etc i e these pests are deterred from feeding on plants that have been treated with the extract or even from colonizing them In high concentrations the extract acts as a repellent to caterpillars and the larvae of several types of beetles In low concentrations it also inhibits development, i e the larvae of insects that eat treated plant material cannot develop further, stop feeding and die off

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Major Cabbage and Gboma Pests

The major pests on cabbage (white cabbage and cauliflower) and gboma (local solanaceae also known as "local spinach") in Togo are either the larvae of moths or, depending on the region and season, grasshoppers These pests are easily controlled with neem extract

Cabbage (*Brassica oleracea*)

The caterpillars of two species of moths do significant damage to cabbage One of these is the cabbage or diamondback moth (*Plutella xylostella*) It lays its eggs on the cabbage leaves When they hatch, the larvae feed on the young plants and especially on the young leaves, later, when white cabbage begins to form a head, they feed inside the head (for symptoms see illustration) The caterpillars are light green and grow up to 10–12 mm They also chew holes in cauliflower leaves, the flower remains small and when the leaves are tied up they no longer provide enough shade so that the flower turns brown In addition, the black trass of the caterpillars soils the cauliflower head

The second major cabbage pest is the leaf-mining moth (*Hellula undalis*) The moth lays its eggs on the leaves of the heart of young cabbage plants The larvae burrow into the stalks of the leaves, feed on the contents and destroy the heart of the plant

The infested plant then either dies or develops several side shoots A head or a flower is not formed

A third less frequent cabbage pest, namely the cotton worm (*Spodoptera littoralis*) must also be mentioned briefly It is also a caterpillar and can therefore easily be controlled with neem extract It is dark in colour, grows to a length of up to 5 cm and feeds on leaves and, in the case of white cabbage, on the heart It is less important than the first two pests mentioned above

Gboma (*Solanum aethiopicum*)

Gboma is not generally badly infested by pests However at the end of the dry season and at the beginning of the rainy season it can be infested by caterpillars of two types of moths and by grasshoppers By far the most important pest is a small leaf-eating caterpillar (*Scobipalpa ergasima*) It eats away the green plant tissue inside the leaves leaving only the epidermis i e the upper and lower outer surface of the leaves The leaves get irregular transparent patches The caterpillar is often seen between the upper and lower epidermis In later stages it spins the tips of the leaves together to hide itself The caterpillar grows to a length of about 10 mm is green and has a black-capped head

The caterpillar of the second species (*Selepa docilis*) also feeds on the leaves but eats the entire plant tissue, in particularly severe cases of infestation only the ribs of the leaves remain The caterpillar is green at first and later turns grey-green with a yellow stripe on its back It is very hairy and grows to a length of up to 13 mm

Cabbage plant infested with *Plutella xylostella*

Cabbage heart infested with *Hellula undalis*

Gboma leaves with symptoms caused by *Scrobipalpa ergasima*

The variegated grasshopper *Zonocerus variegatus*

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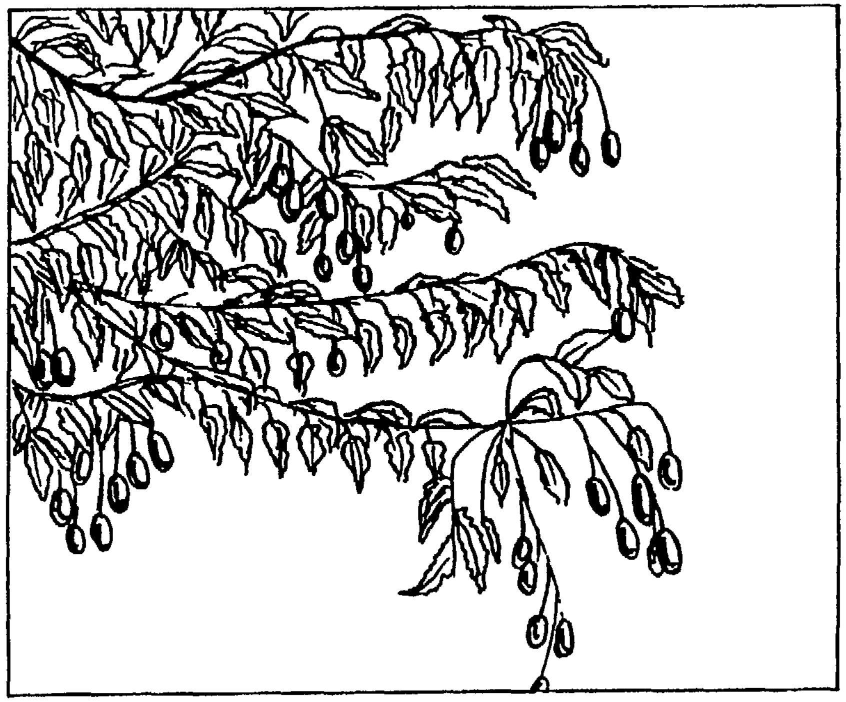
Locusts and Grasshoppers

Locusts and grasshoppers are polyphagous pests which infest cabbage and gboma as well as a large number of other crops thus, they are discussed separately here There are various species of grasshopper in Togo mostly of little significance One of them, however, *Zonocerus variegatus* is of great importance As a nymph this insect is black and yellow; later, as an adult, it is green with yellowish-green anterior wings and a yellow, black and red head

It appears at different times in the different regions of Togo In the Région Maritime, the Région Centrale and the Région de la Kara it is found in the second half of the dry season, while in the Région des Savanes it appears in the rainy season and in the Région des Plateaux throughout the entire year

The locusts and grasshoppers feed on the leaves and in cases of serious infestation they completely strip them



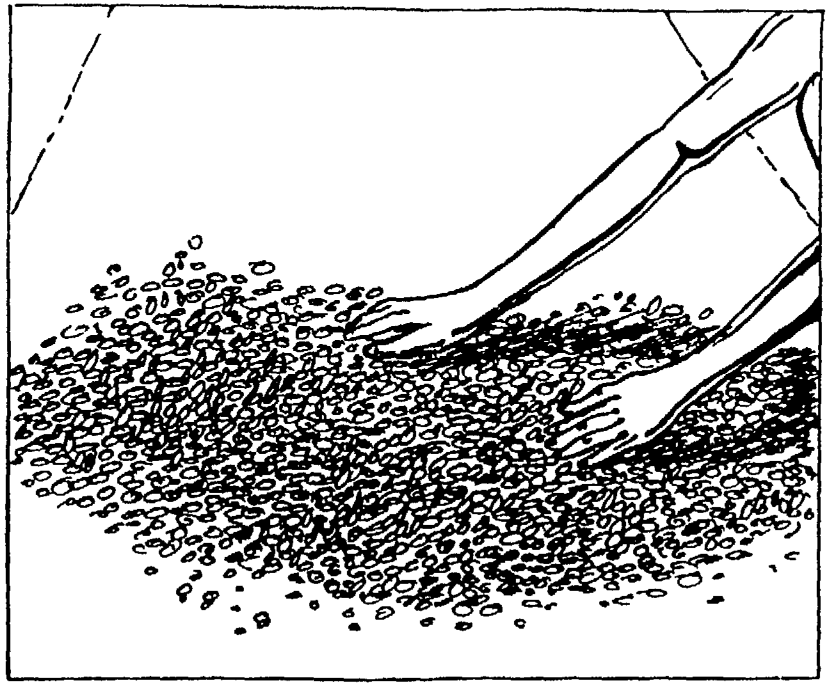
Branch of a neem tree with fruit

Harvest and Storage of Neem Seeds

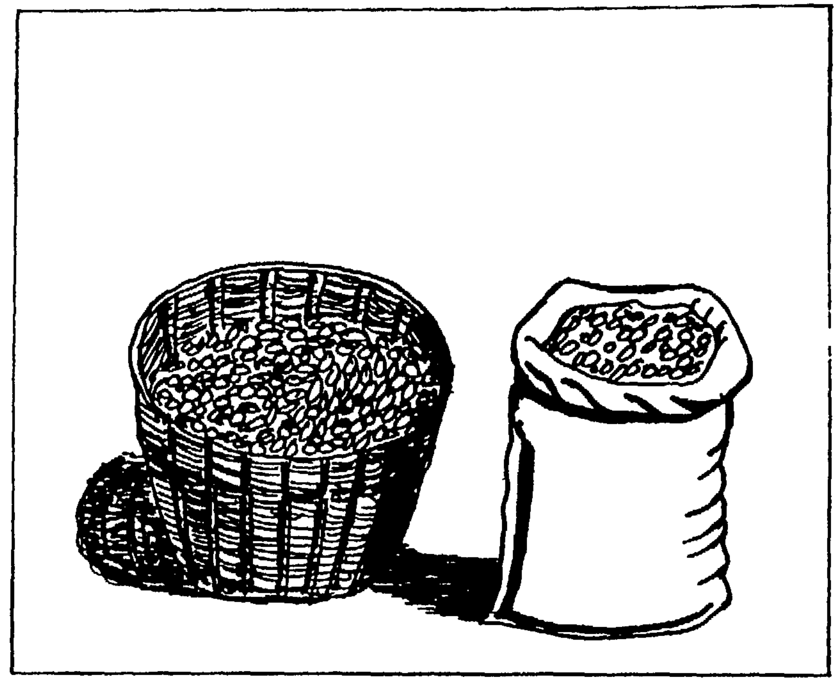
In Togo neem fruit ripens twice a year, in February/March and in July/August The fruit does not have to be picked to obtain the kernels Bats and birds eat the sweet flesh of the fruit and spit the kernels out

Thus, seeds lying on the ground around the trees just have to be collected

It is advisable to wash the seeds before drying them



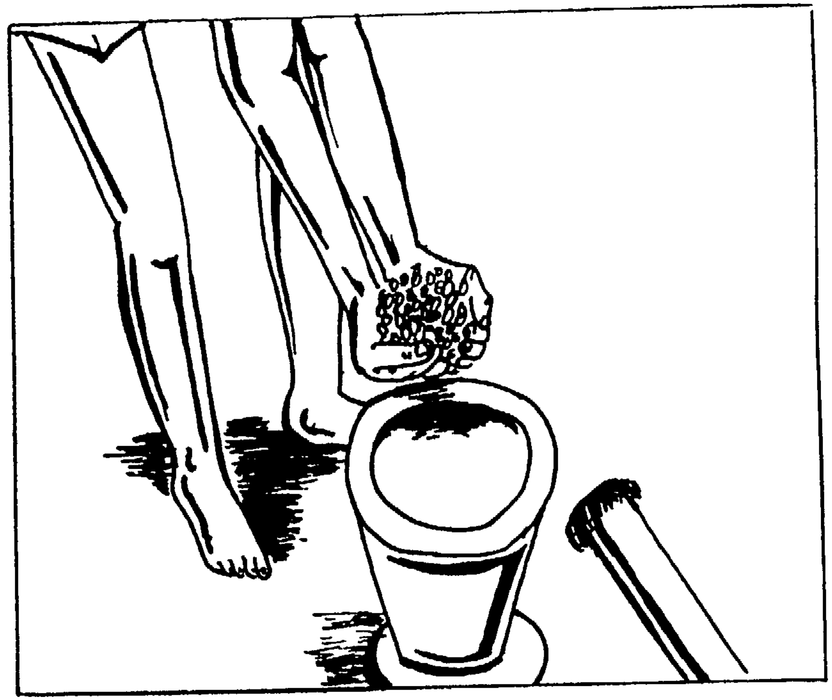
As neem seeds easily go mouldy they have to be dry when stored It is best to leave the seeds to dry in the sun for a few days



Neem seeds should be stored only in airy containers, for example, in a jute sack or basket, and never in plastic bags or sacks

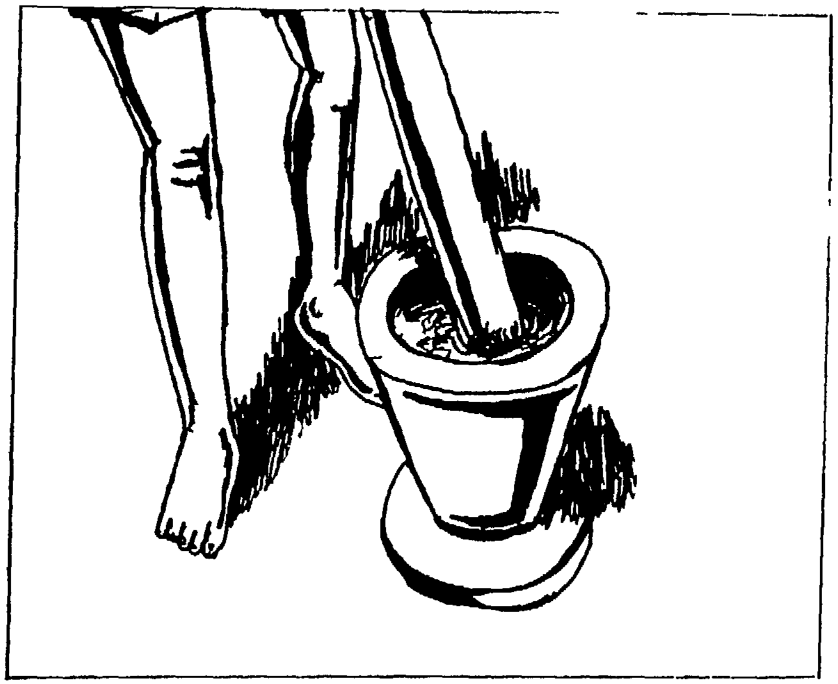
Production of Neem Water Extract

In order to prepare a neem water extract from neem kernels three times two handfuls of kernels (about 500 g) are needed per bucket of water (about 10 l) In addition, a mortar is required to crush the kernels

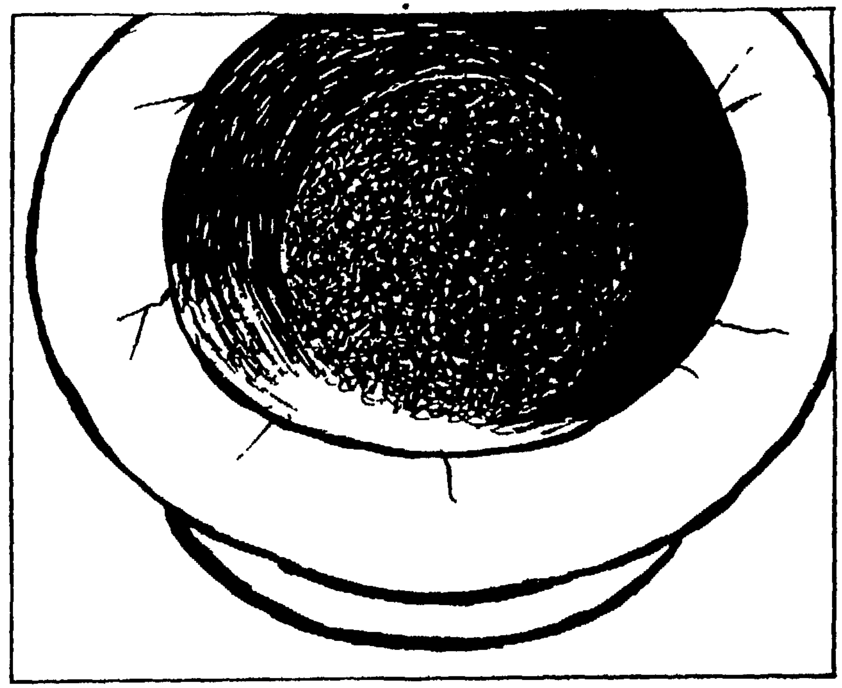


First the neem seeds are pounded carefully in the mortar so that the shell splits open without the kernels being damaged It is best to take only a small quantity at a time (two handfuls)

Then the rotten kernels, which have lost their brown colour have to be removed



After that the kernels are put back into the mortar and pounded



until they become a coarse powder The pounded seeds are then put in a vessel and the rest of the seeds are crushed in the same way Instead of a mortar, grind stones can be used to crush the seeds

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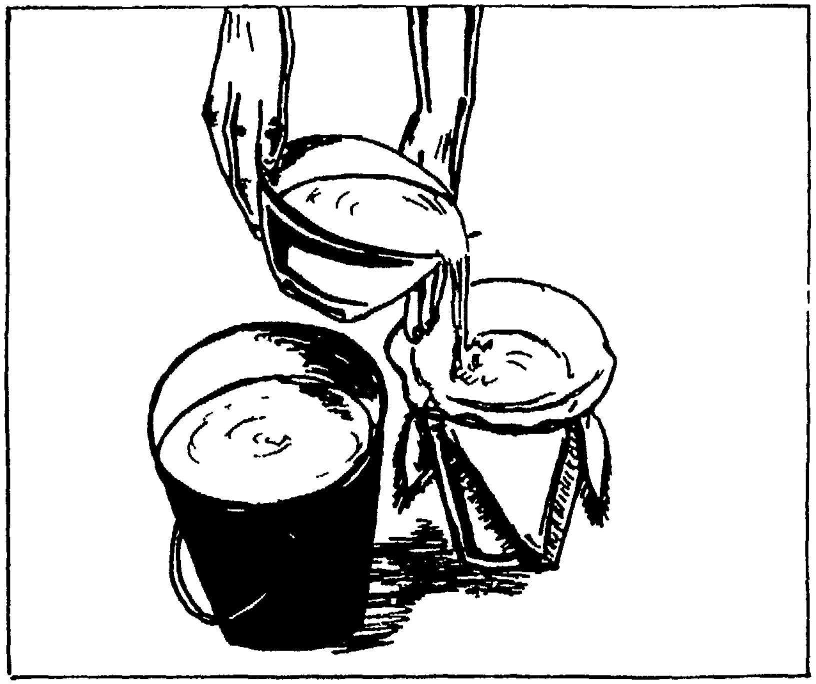
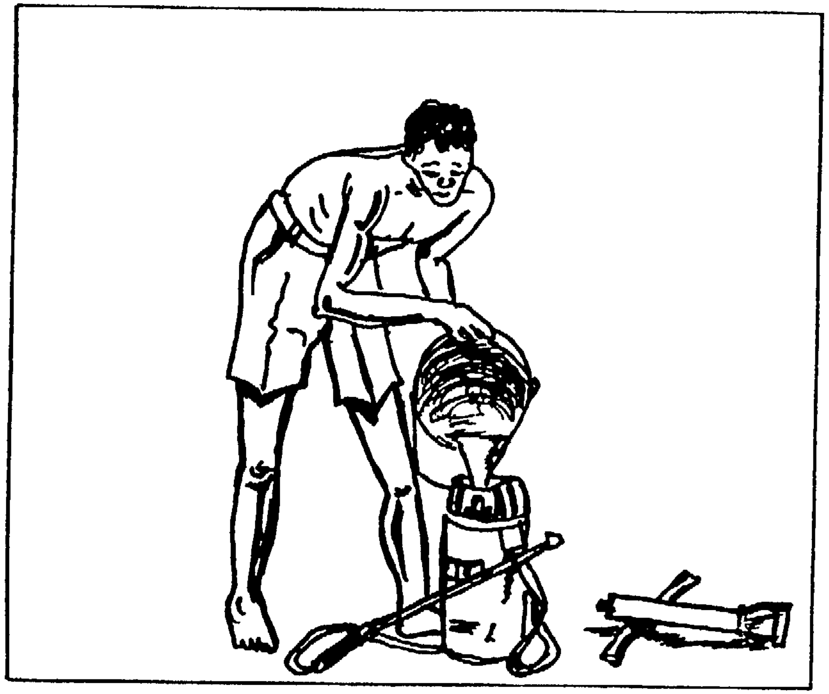
The powder is then added to water and stirred vigorously This mixture should be left to stand for a few hours It is most practical to prepare the extract the evening before the day of treatment, and to let it stand overnight



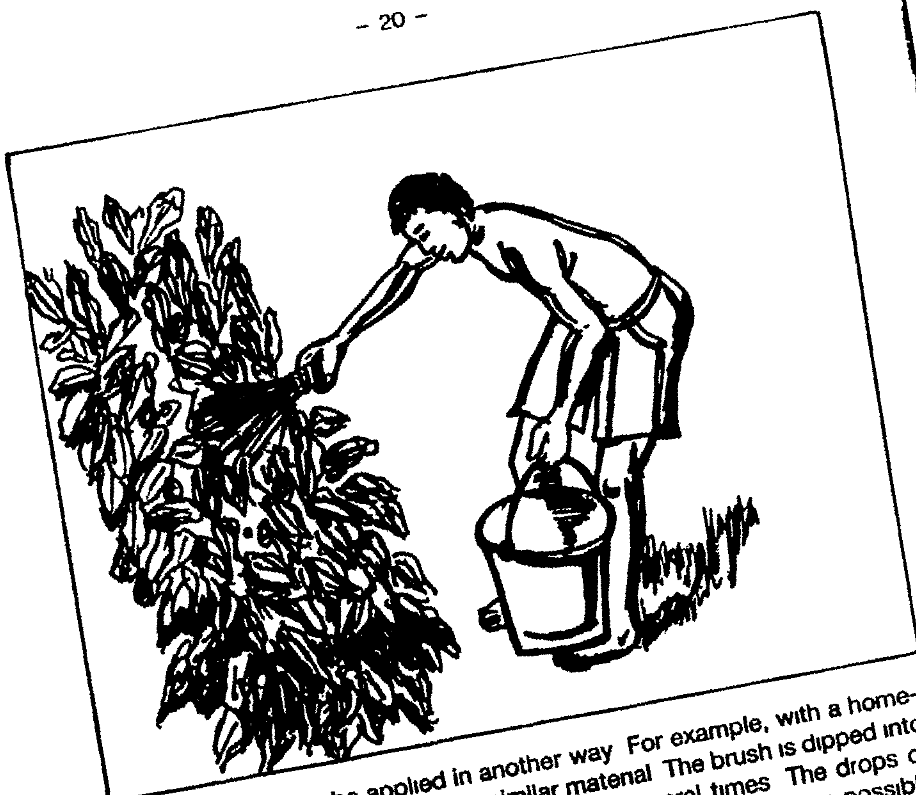
If the extract has to be applied with a sprayer, it has to be filtered before treatment in order to prevent the crushed kernels from blocking the nozzle of the sprayer A cloth or fine gauze serves as a filter Now the extract is ready



It is poured into the sprayer

and applied

If a sprayer is not available, however,



the extract can be applied in another way For example, with a home-made brush made of fine straw or similar material The brush is dipped into the extract and then passed over the plants several times The drops of extract resulting from this action have to be spread as evenly as possible over all the leaves Application continues until all the plants are wet

Further Tips

When watering crops it is recommended not to pour the water directly over the plants but onto the ground, otherwise some of the extract is washed off the leaves

As already mentioned, the extract does not have a direct poisonous effect on the pests but either acts as a repellent or inhibits further development depending on the type of insect and the concentration of the extract Thus the effect of the extract is not apparent on all pests at the same time In the case of insects that are repelled by the extract, i e grasshoppers, the effect can be seen immediately, after spraying they stop feeding In the case of caterpillars, however, it can take 2–3 days before they die off, therefore, some patience is needed

The effect of the extract lasts for a few days and then gradually decreases Treatment intervals depend on the crop and the pest In cases of severe grasshopper infestation treatment should be carried out every 4–5 days In cases of slight infestation, and with other pests, i e caterpillars, weekly treatment suffices Cabbage should at any rate be sprayed prophylactically as infestations of this crop are usually severe and damage is frequently not apparent until it is too late to do anything about it

Gboma does not require prophylactic treatment, but only needs spraying when pests actually occur Water extracts made of clean neem kernels are not poisonous for humans and domestic animals, thus, treated vegetables can be eaten without any reservations, even if they have been treated only shortly beforehand In addition, the water extract has no negative effects on the plants Cabbage leaves look darker after treatment, but this is of no significance to the growth or quality of the vegetable

SECTION IV

Togolese Republic
Union - Peace - Solidarity
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Technical Leaflet Plant Protection

Deutsche Gesellschaft fur
Technische Zusammenarbeit (GTZ) GmbH

Edited by the
Plant Protection Directorate
B P 1263 Tél 21-37-73 Lomé-Cacaveli

The Preservation of Beans (Cowpeas) with Neem Oil

Preliminary Remarks

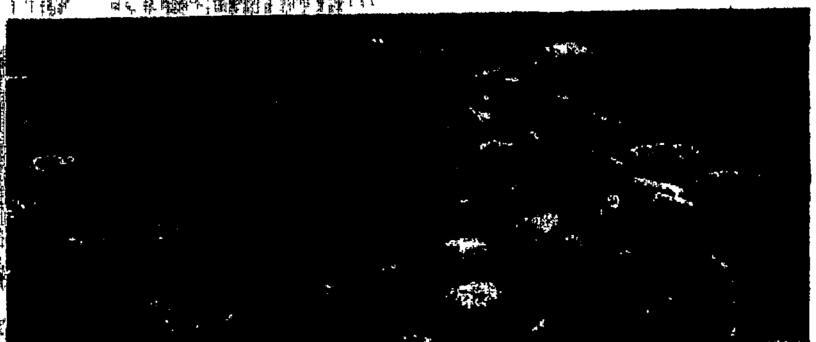
The neem tree originates from south-east Asia and was introduced to Africa at the beginning of the century because of its rapid growth and drought resistance. Today it is found throughout West Africa outside the rain forest zone. In towns and villages it provides both shade and firewood and in arid regions it is used for afforestation.

In its countries of origin neem has a large variety of uses. It is used in traditional medicine and for the production of insecticides, and the oil from the seeds is utilized as fuel for lamps or for making soap. In addition, neem oil can be used as a natural protective agent for stored beans. This special use is now to be presented.

Bruchidae constitute a major problem when storing beans (cowpeas). These beetles burrow into the beans and eat the contents. The infestation can be so severe that practically every bean is hollowed out and becomes inedible (see illustration).

Neem oil acts as an extremely effective and cheap protective agent for stored beans. When the oil is mixed with the beans they are free of bruchid infestation for at least six months, regardless of whether the beans were infested before treatment or not.

Neem oil is easy to produce and does not give rise to any costs. The oil is not poisonous for humans if the kernels used for its production were not rotten and the treatment in no way inhibits the germination capacity of the beans.



Harvesting and Storing of Neem Seeds

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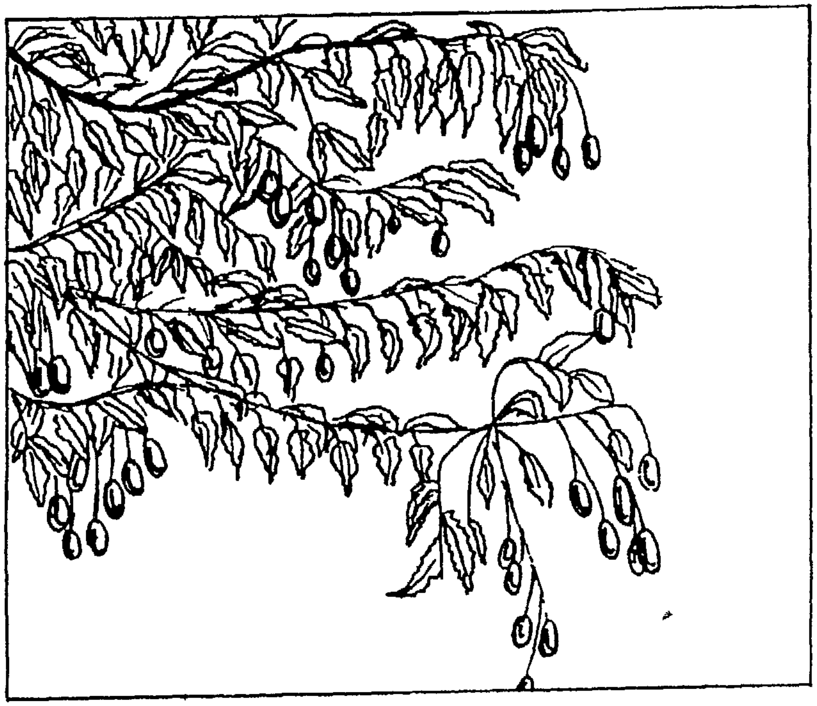
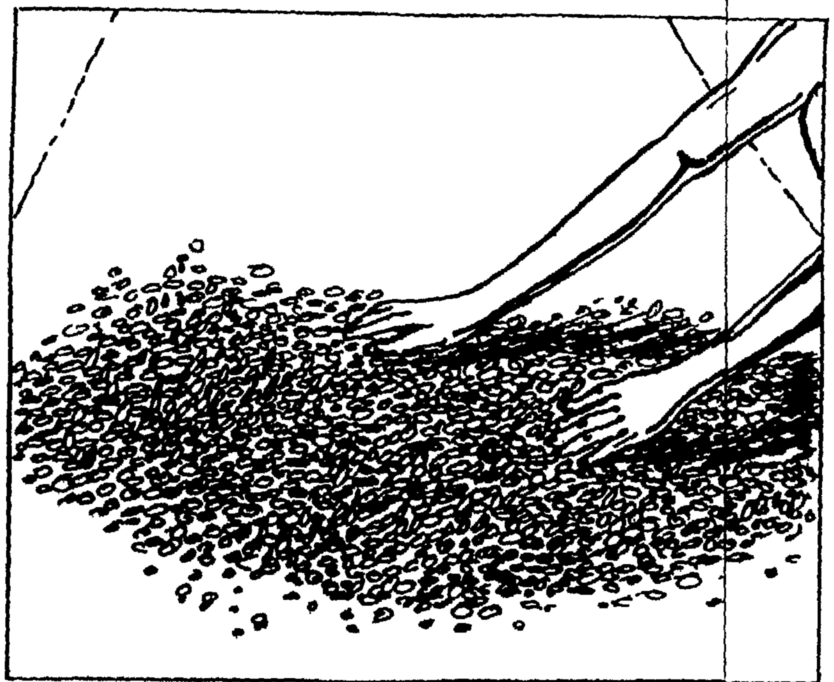
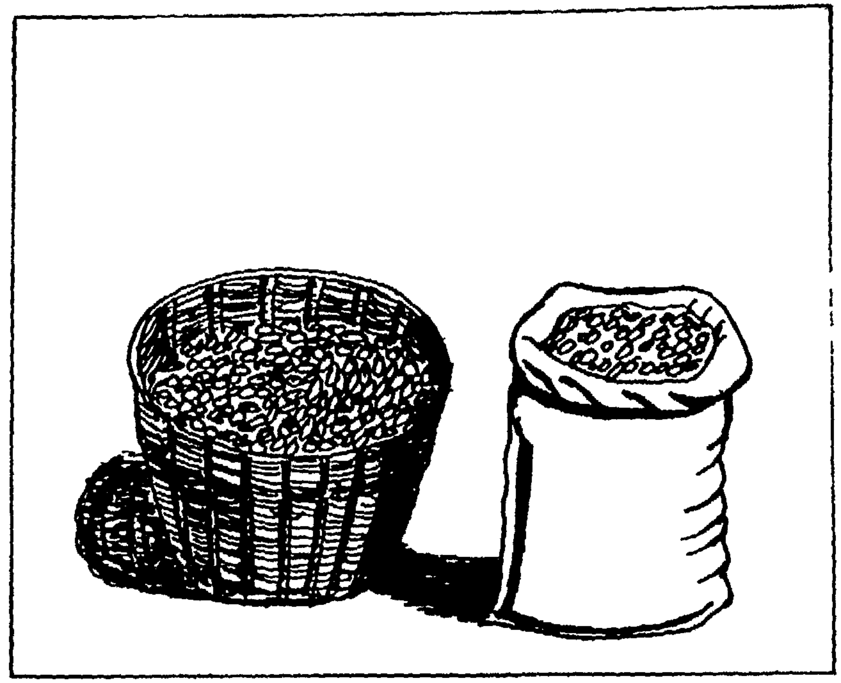


Branch of a neem tree with fruit (see title page)



When making neem oil it is important to ensure that the seeds are dry As neem seeds easily go mouldy they have to be dry when stored, too It is best to leave the seeds to dry in the sun for a few days



Neem seeds should be stored only in airy containers, for example, in a jute sack or basket, and never in plastic bags or sacks

Thus, the seeds lying on the ground around the trees just have to be collected

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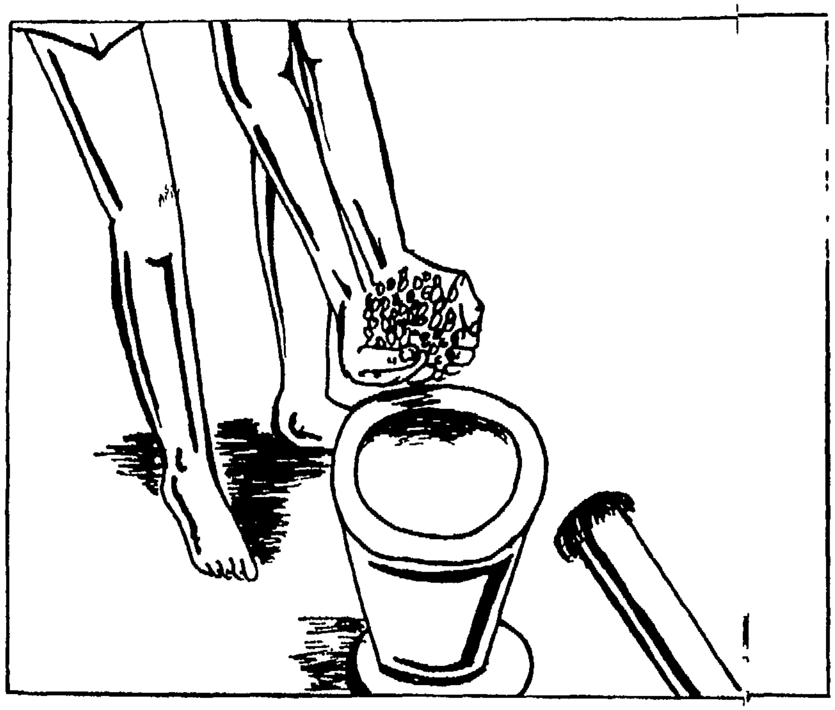
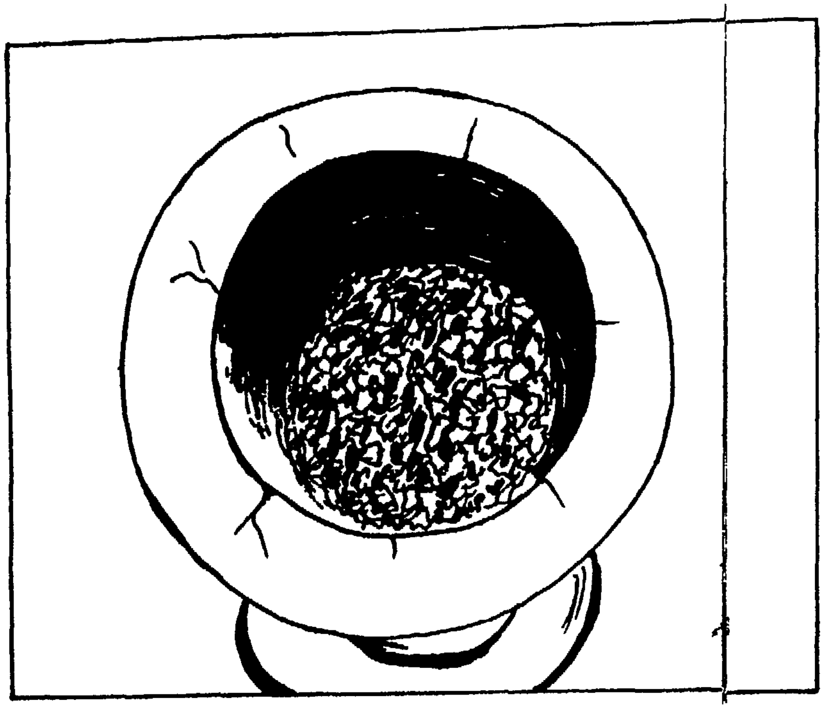


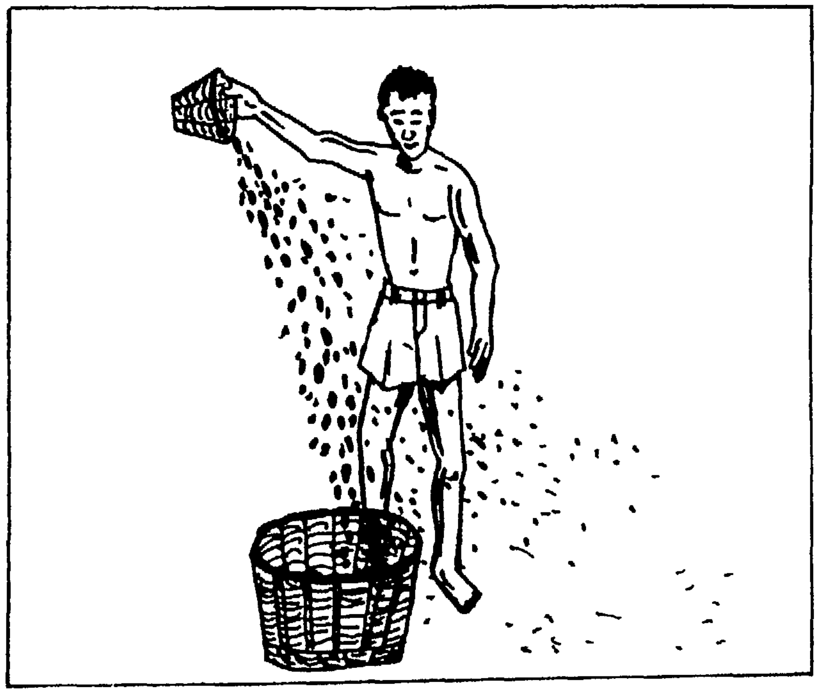
Production of Neem Oil

For oil extraction, the neem seeds must first of all be well dried, as already mentioned Then the seeds are shelled There are different ways of doing this For example, by cracking the shells with stones or even by hand However the easiest way is to put the seeds in a large mortar (such as is used for making "foufou") and to pound them gently until the shells split open About two handfuls of neem seeds suffice at a time

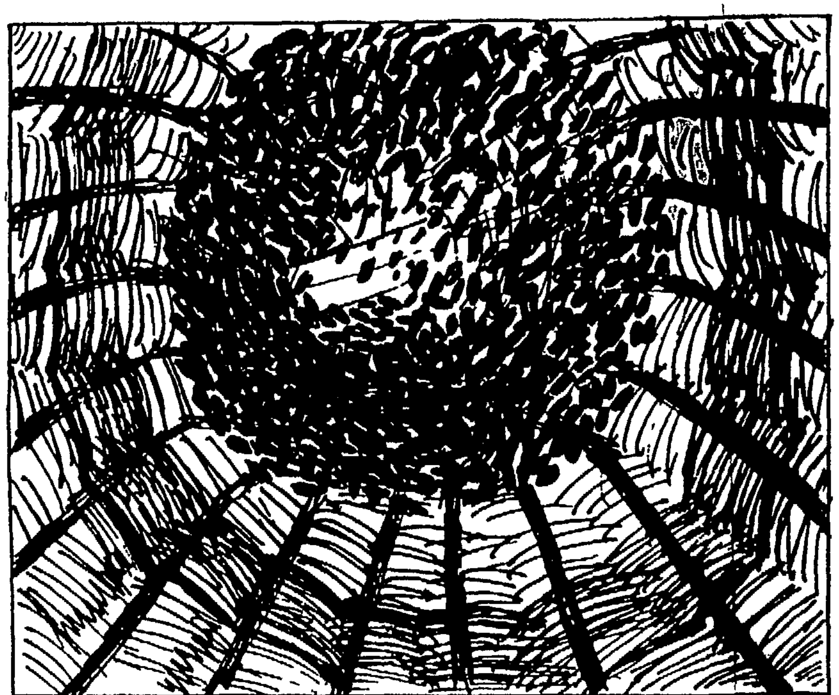
The seeds have to be pounded carefully so that the shells split open without the kernels being crushed



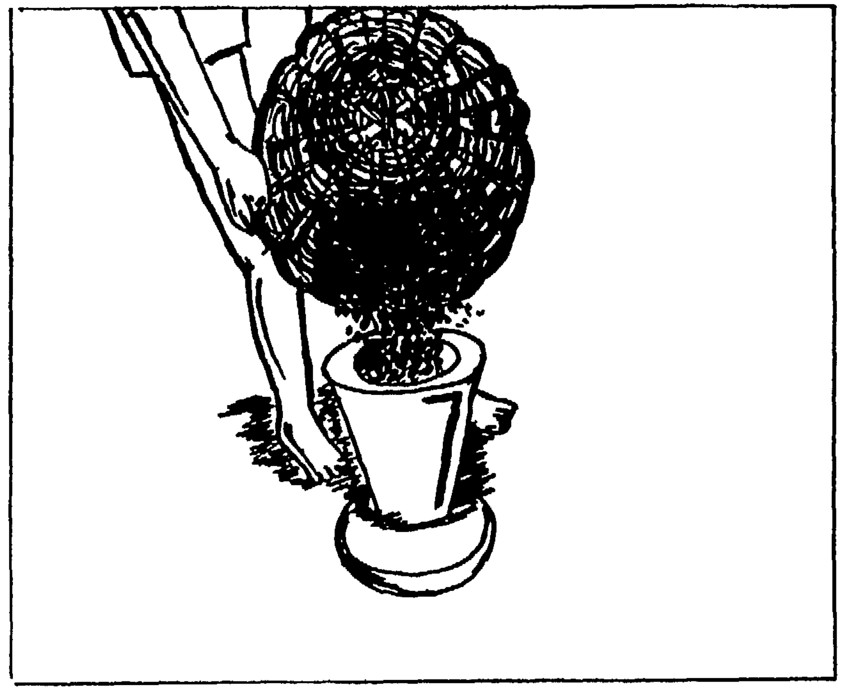
The seeds are pounded until they have all split open and there is a mixture of kernels and shells in the mortar



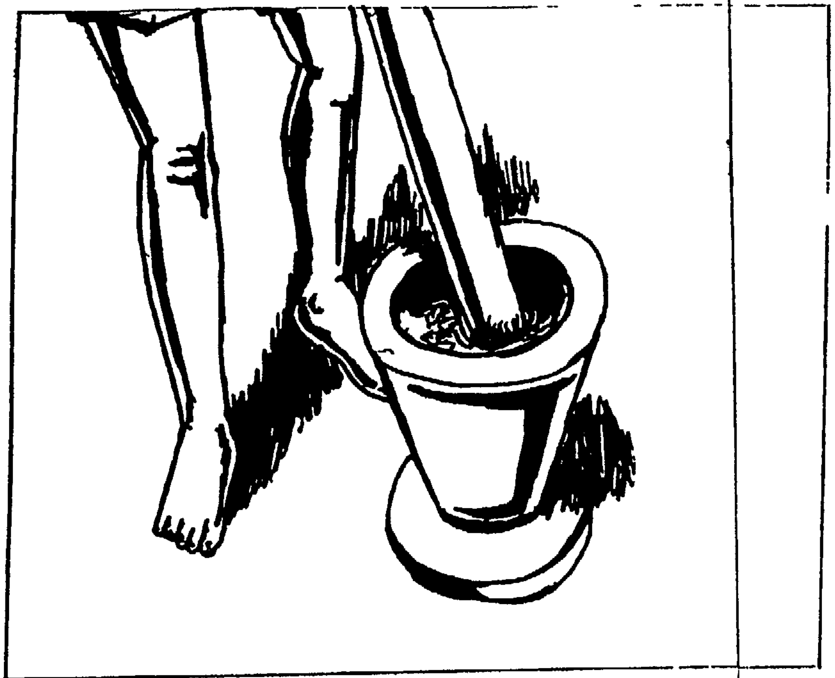
This mixture is then winnowed to remove the shells



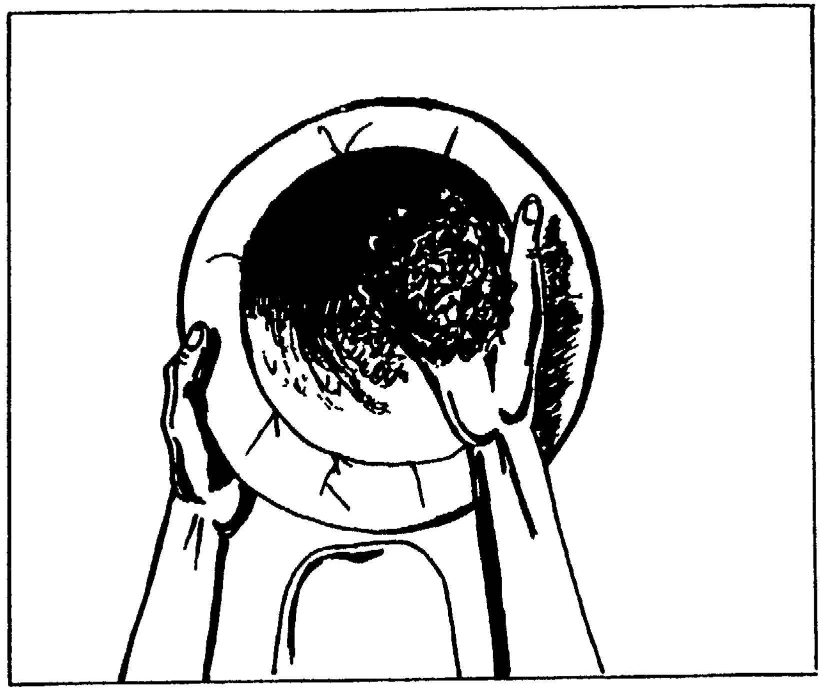
Now only the brownish kernels from the seeds are left Rotten seeds, which have lost their brown colour, have to be removed in any case as they may contain toxic chemicals produced by fungi



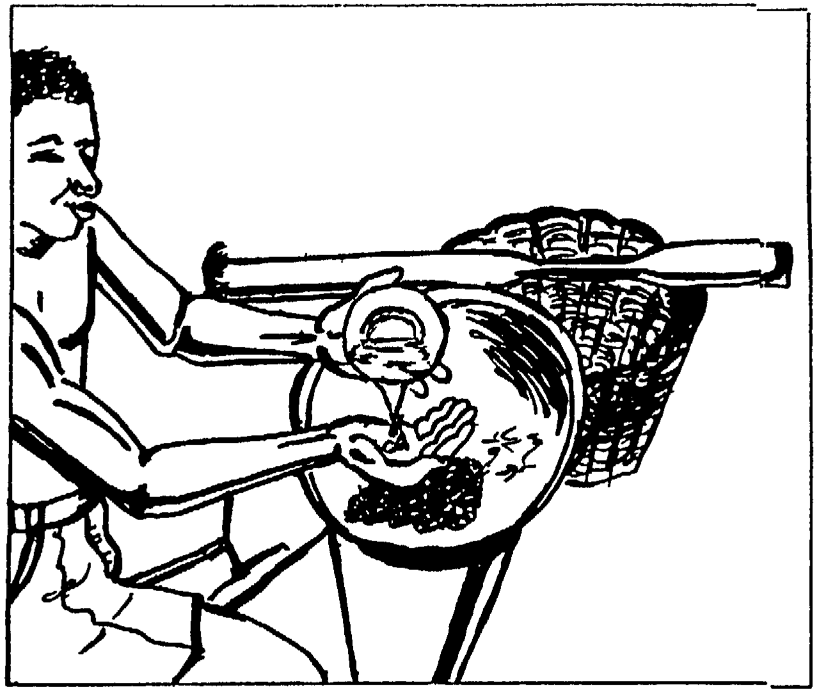
The brown kernels are put back into the mortar



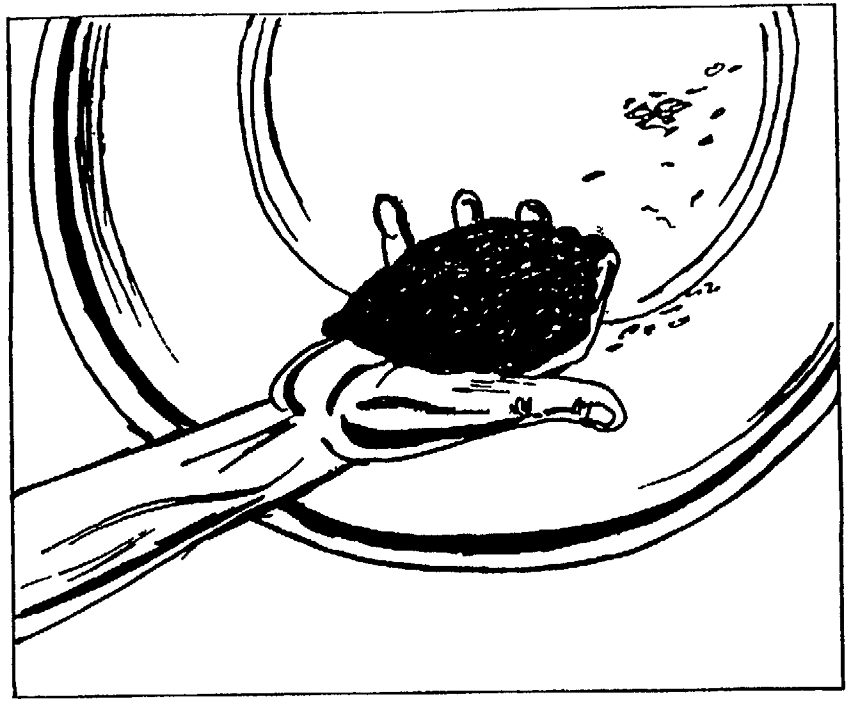
and pulverized



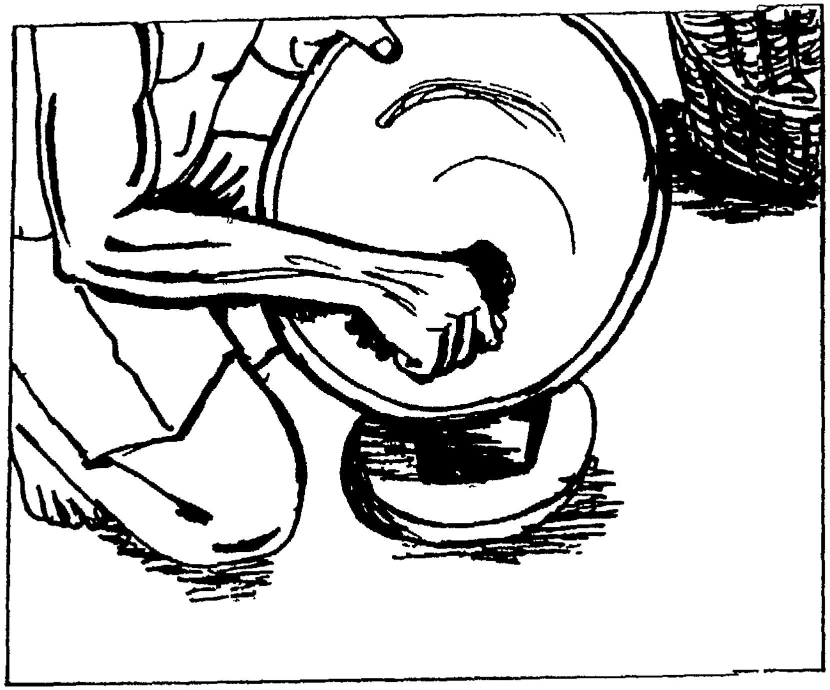
This is to be done until the kernels have converted into a brown and slightly sticky powder



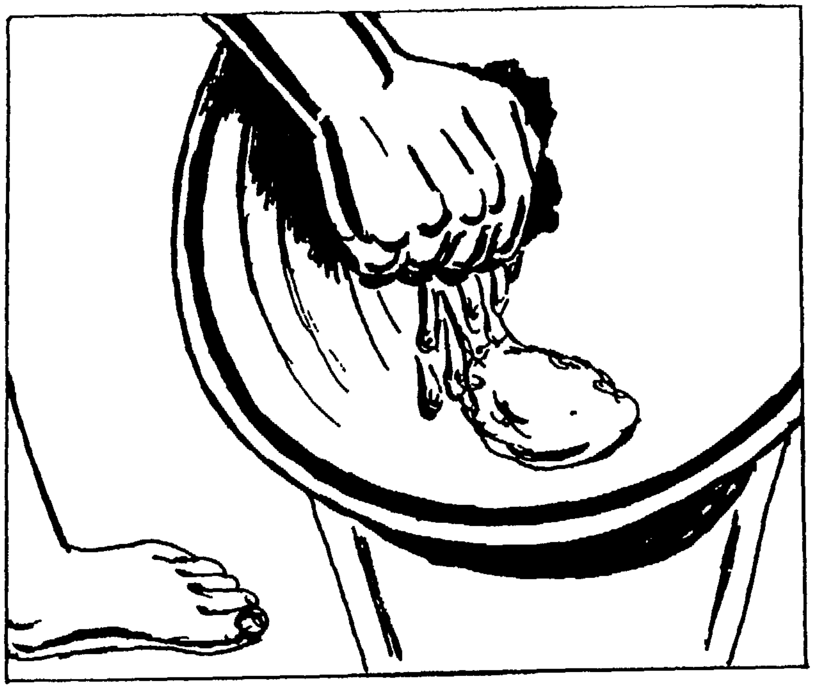
The powder has to be kneaded in order to squeeze out the oil To do so a little water has to be added to the powder



However, care must be taken not to add too much water, but just enough to make a kneadable paste



Now the paste is kneaded This is best done in a bowl so that no extracted oil is lost



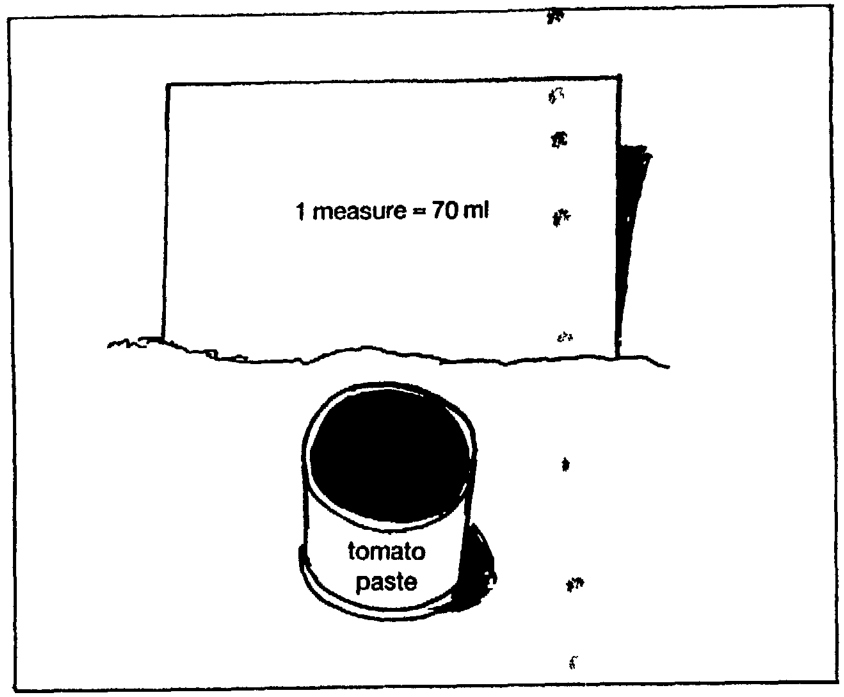
After kneading for a while the oil begins to ooze out Now the paste can be squeezed tightly and more oil will come out Then the paste is kneaded and squeezed alternately until no more oil comes out In this way about 100–150 ml oil can be extracted from a kg of neem seeds
The oil is very bitter

Note Neem oil can be produced in other ways, for example in the traditional way in which groundnut oil is made, heating does not damage the oil Since only small quantities of oil are usually required, the method described is probably the simplest one

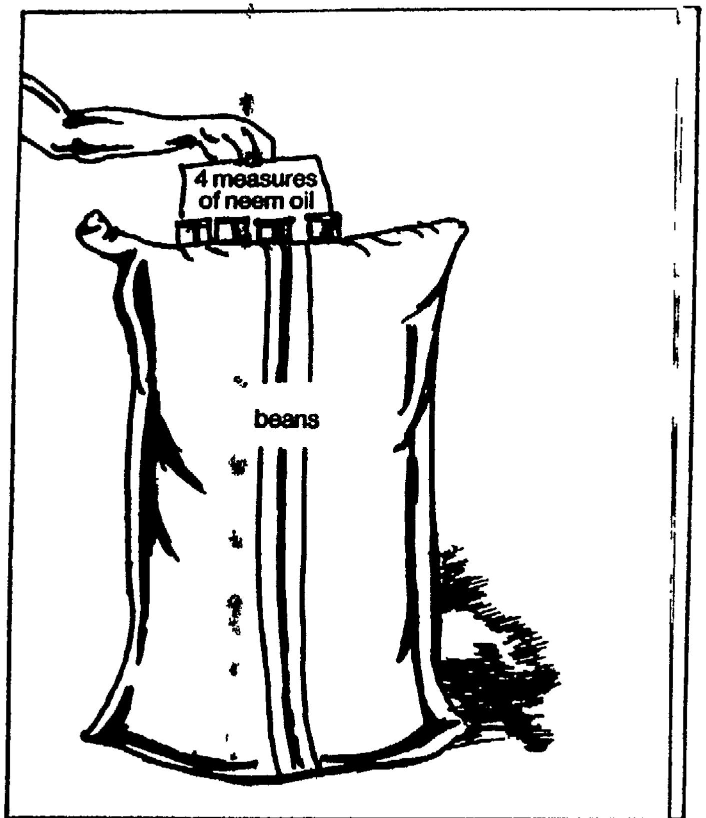
Treatment of Beans with Neem Oil

2–3 ml of neem oil
per kg of beans

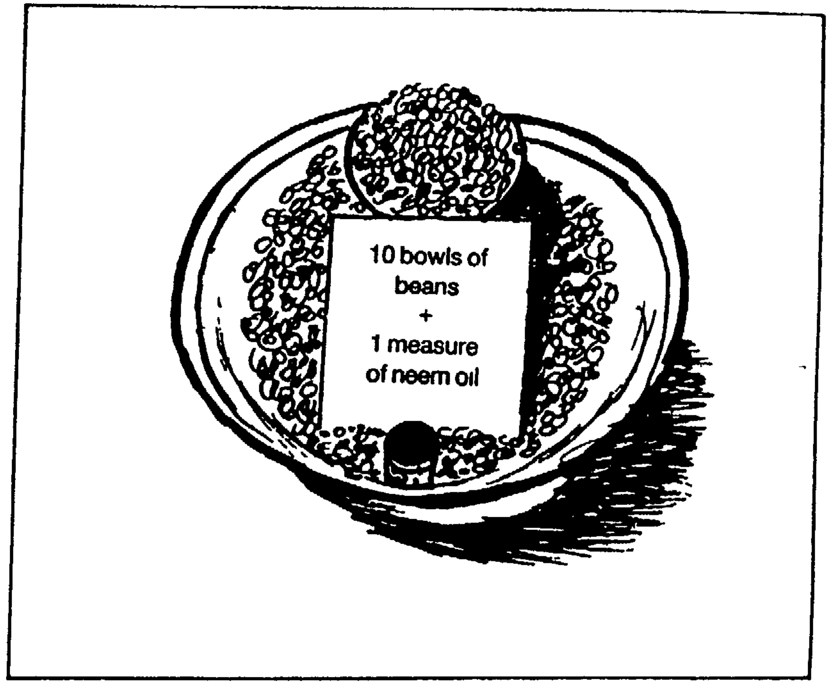
Beans must be threshed before they are treated with neem oil 2–3 mll oil are required per kg of beans Thus, for a 100 kg sack about 250 ml of oil would be needed It is better to use too much oil rather than too little



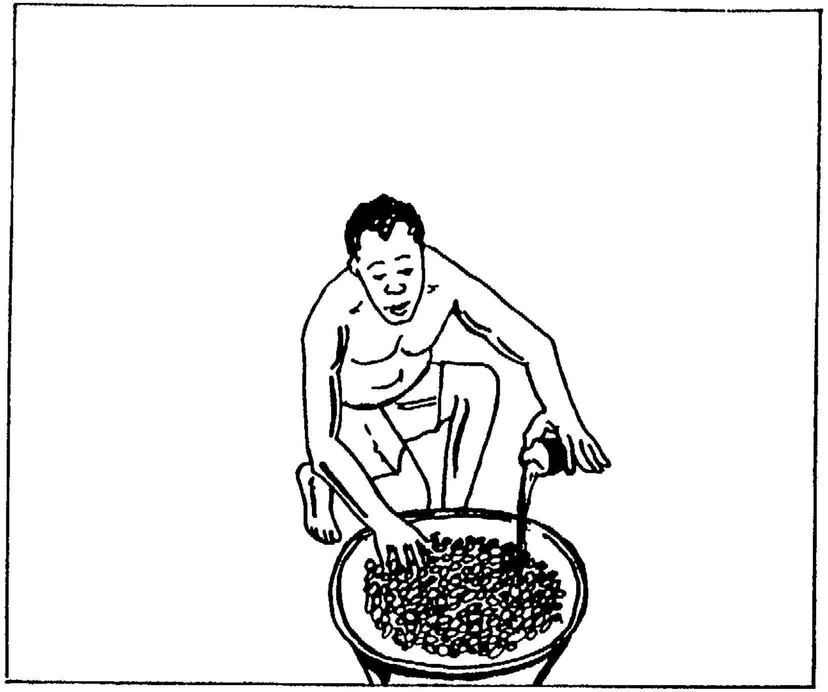
As it is usually difficult to find measures for ml, substitute measures have to be used We have chosen an empty tin of tomato paste (small size) as an example Tins of this kind are easy to find, as tomato paste is used everywhere in Togo for making sauces A small tin of this kind holds 70 ml



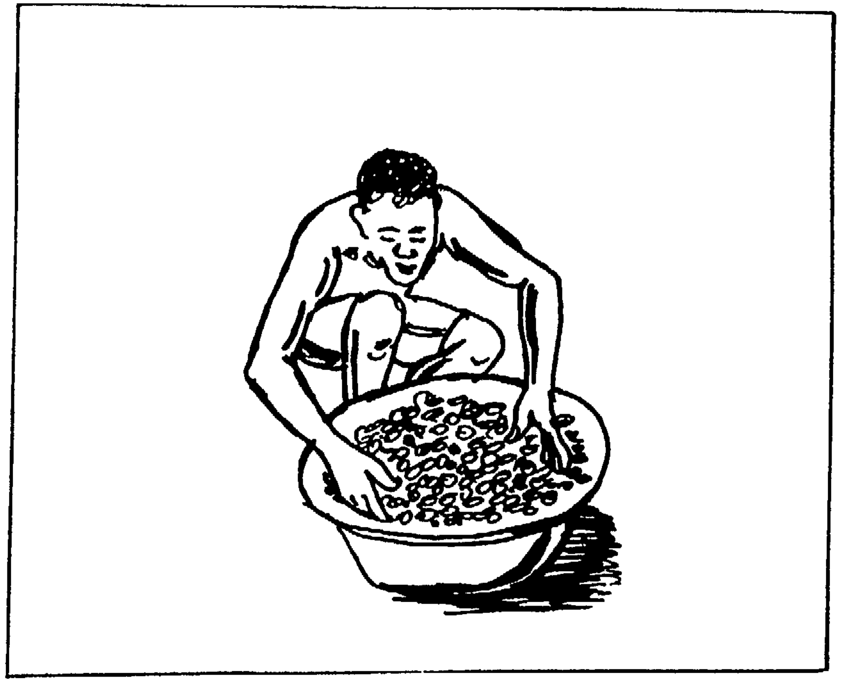
Thus, in order to treat a whole sack of beans (100 kg) with neem oil, four measures of oil (= 280 ml) are needed



Or to treat ten bowls (of 2 5 kg each) one measure of neem oil is required



A large bowl is needed when treating the beans Depending on the quantity of beans (for example, ten bowls = 25 kg) the appropriate quantity of neem oil is added to the bowl of beans (in the example 1 measure = 70 ml)



Then the beans are mixed thoroughly to ensure that the oil is well distributed It is important that the oil is spread evenly on all the beans for an effective treatment For this reason, it is expedient to add only part of the oil at first, mix it with the beans and then add the rest of the oil and mix again After treatment the beans are stored in sacks or pots as usual

Neem Oil and its Effect

Neem oil is not directly poisonous for Bruchidae Thus, if the beans are already infested, the parasites will not be killed immediately However, neem oil inhibits the further development of the beetles' larvae and the laying of eggs by adult beetles Pupae and adults are not killed off by the oil Thus live beetles may still be found in the beans two weeks after treatment

However, they cannot multiply further, no longer cause major damage and soon die Once they have died the population is completely destroyed and the neem oil protects the beans from renewed infestation for at least six months

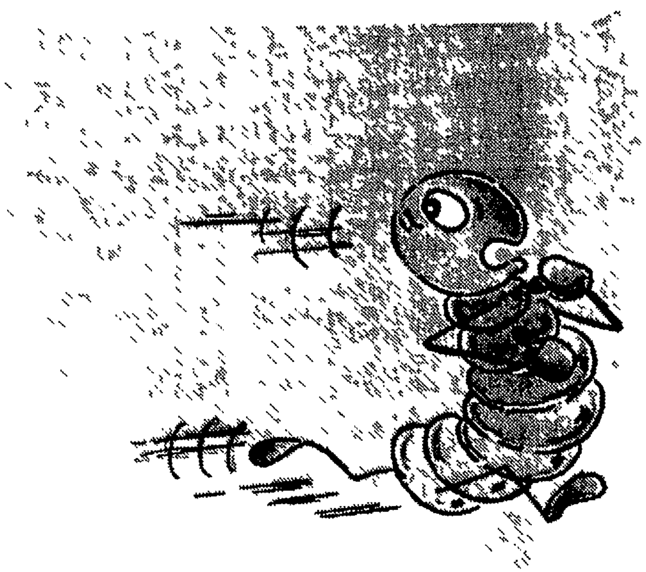
Neem oil is extremely bitter but, as already mentioned, not poisonous As the concentration is very low there is little danger that the beans will taste bitter later on People who were served dishes with beans treated with neem oil did not notice a bitter taste

However, should the beans taste bitter, they are to be soaked in hot water for a few minutes to remove the bitter substances before preparing them

Neem oil does not affect the germination capacity of the beans Thus it can also be used for preserving seeds

SECTION V

NEEM A NATURAL INSECTICIDE



What is the aim of this brochure?

This brochure contains information on the use of insecticides from the neem tree It shows how substances which are already present in nature can be used to control and drive away cater pillars larvae of beetles, grasshoppers plant and leafhoppers and other plant pests

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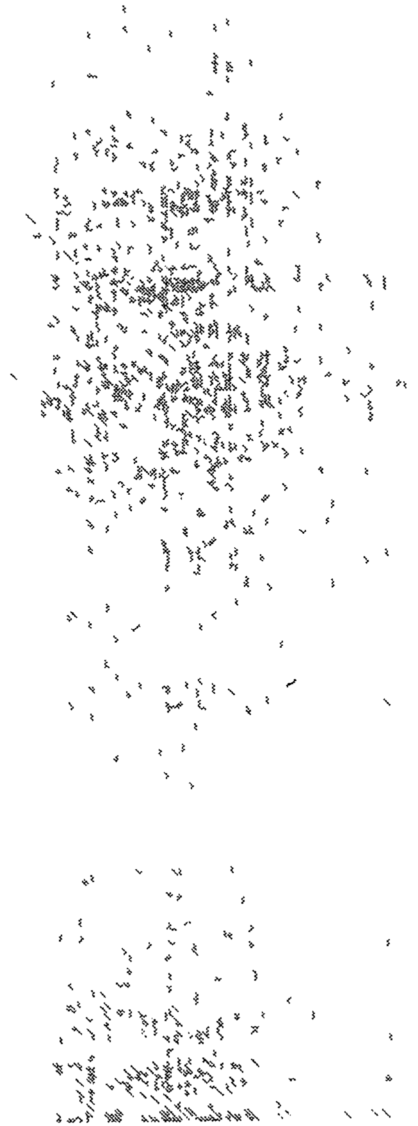


Damage to crops

Insects can inflict great damage to crops Many farmers there fore, use synthetic pesticides in order to drive away or to control these pests However, many of these synthetic pesticides are also highly poisonous for humans and livestock Moreover these substances destroy a great number of useful insects which are an important factor in the natural control of pests As a result, the plants are left unprotected against pests and increased spraying of pesticides is thus necessary

These disadvantages can be avoided by using biological pesti cides such as extracts from the neem tree which are both effec tive in controlling pests and, at the same time, harmless to humans and other warm blooded organisms

Azadirachtin the most important insecticidal substance contained in the plant has, even in very small doses a growth disrupting effect on many insect larvae i e insects which eat this substance are unable to develop to the next larval/nymphal stage and die off Other pests, such as grasshoppers avoid or reduce feeding as a reaction to azadirachtin As tests have repeatedly confirmed due to its special mode of action the neem extract is quite harmless for useful insects Unlike synthetic pesticides tests carried out over a longer period indicate that development of any resistance to the neem extract is in the short term unprobable However, where intensive vegetable cultivation is practiced the exclusive use of neem extract is inadvisable
One great advantage of the neem extract is that even after repeated application on vegetable crops, it remains perfectly harmless for humans

Further information is available from the consultant or from the coordinator of the following project

Gewinnung natürlicher Insektizide aus tropischen Pflanzen

Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ)
Postfach 5180
6236 Eschborn 1
Bundesrepublik Deutschland

What exactly is a natural insecticide?

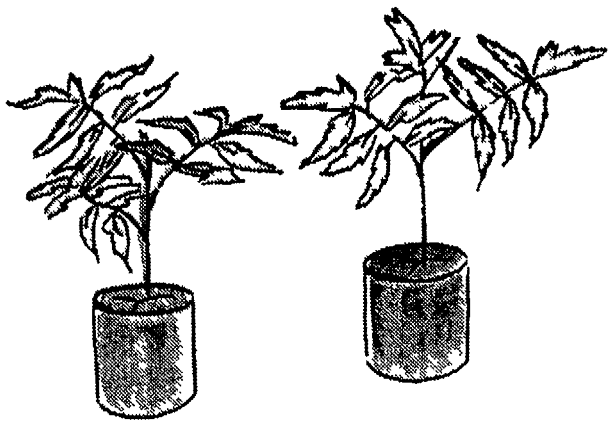
Many plants have a natural protective mechanism which aids them in resisting and driving off pests. Some plant species produce substances which repel or poison the insects. The neem tree contains such substances which can be easily extracted and turned into a natural insecticide. Crushed seeds or seed kernels are mixed with water and the resulting solution used to treat the plants

What is the neem tree?

The neem tree is native to tropical South-East Asia where it is recognized as an important medicinal plant As it grows quickly and is extremely drought resistant, it has been cultivated for a long time in the arid zones of Asia, Africa and Central America as a source of timber. In India and Sri Lanka, its seeds and leaves are used for store pest control and oil is extracted from the seeds for the production of soap Both the cold pressed neem oil and the oil-free part of the seed kernel can be used for pest control The leaves of the neem tree also contain insecticidal and repellent substances although in much lower concentrations

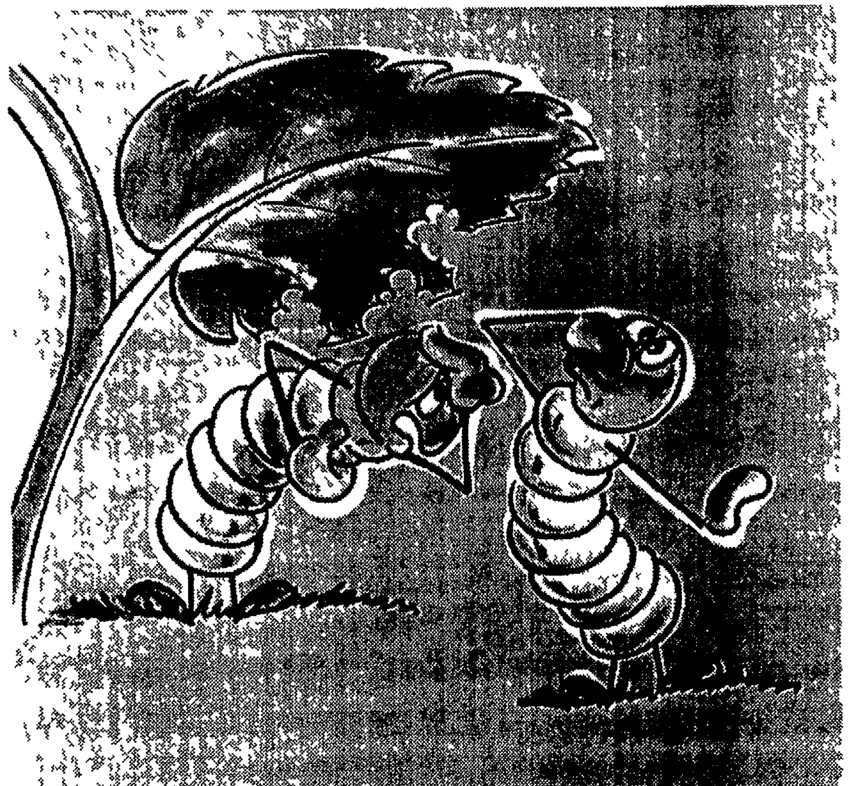
Some additional information

The neem tree (Azadirachta indica A. Juss) thrives almost anywhere in the tropical lowland, up to 800 m above sea level It is resistant to extreme drought and grows where the annual rainfall is as sparse as 300 mm Moreover, it grows very quickly and makes few demands on the soil fertility The neem tree, therefore, grows in a wide variety of places. Hilltops and infertile, depleted land (e g , eroded hillsides) are as suitable as stony, flat land or hard laterite The neem tree may be used to line avenues, to border roads or fields and in mixed cultivation with fruit trees
The average annual fruit yield from a mature neem tree is above 20 kg Apart from insecticides neem oil may be extracted from the seed 30 kg neem seeds produce 6 - 8 kg oil. The resulting residue can be used to make insecticides in a similar way as from the whole neem seeds described earlier.
All parts of the neem tree can be utilized Insecticidal substances are present in various parts of the tree, the highest concentrations are, however, contained in the seeds.



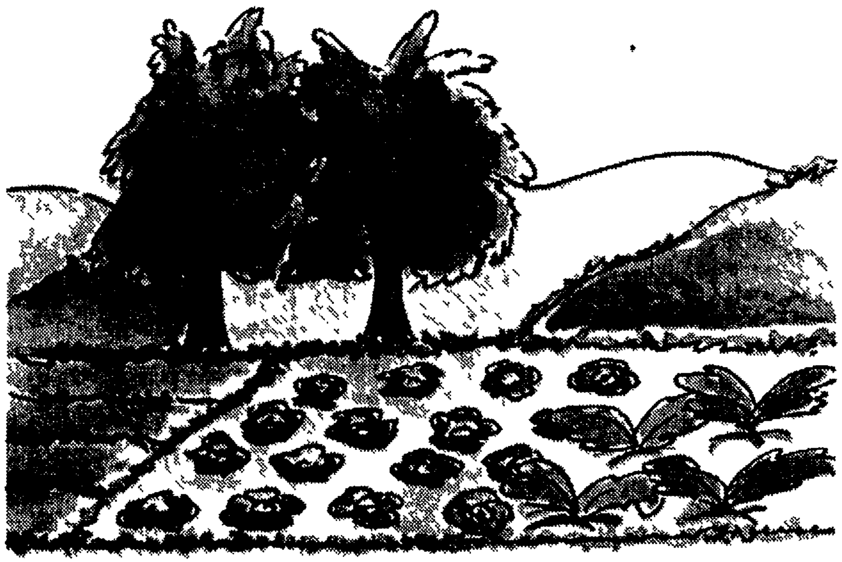
How are the neem trees planted?

The seeds should be as fresh as possible as older seeds often do not germinate. Provided that only a few trees are to be planted and there is sufficient moisture available with minimum weeds the seeds may be sown directly into the ground. Two to three seeds are placed together about 1 cm deep in loose soil. After germination, only the strongest plant should be retained. When planting a large number it is advisable to cultivate young plants first in pots, trays or plastic bags. After about 3 months they should be transplanted into the ground. When using bags or pots care should be taken that the plants are not allowed to develop to a stage where the tap root has pierced the bottom and has to be shortened before transplantation. This weakens the trees and substantially slows their growth.



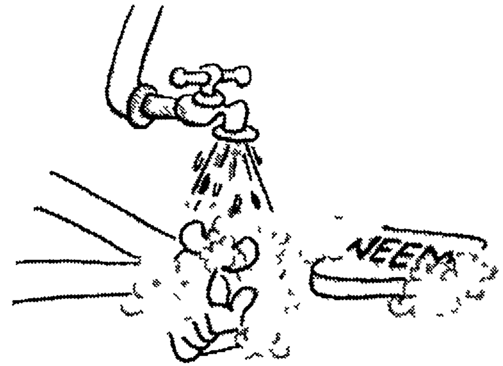
How do these substances affect insects?

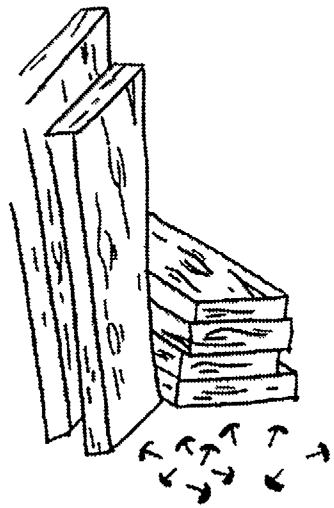
Numerous insect species are repelled by the neem substances. As they find the taste and smell unpleasant they avoid the plants that have been treated with neem extracts. Other insects die some time after having eaten leaves or other parts of the plant treated with these substances. They alter the behaviour in some insects or reduce their ability to lay eggs. Other pest species are affected minimally or not at all by the neem substances, probably as a result of their hidden biology

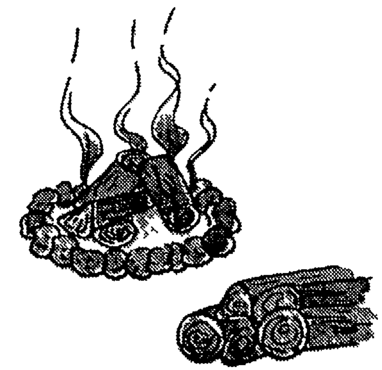


Which types of crops are best suited for treatment with neem insecticides?

Neem extracts are particularly suitable for use on vegetables and small scale field crops If sufficient water and sprayers are available it is also possible to treat larger fields





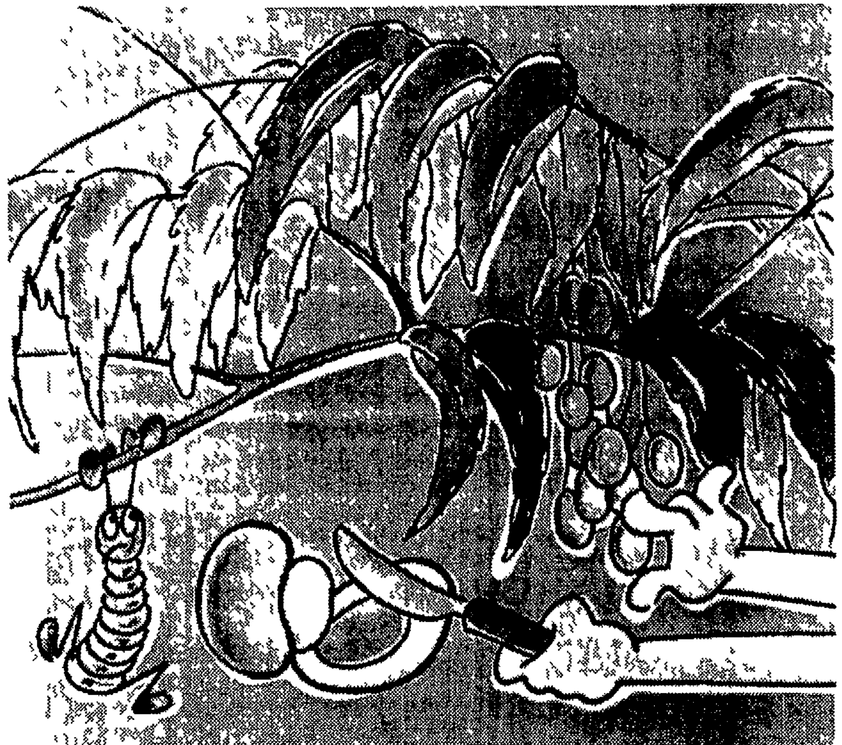


What other uses are there for neem oil?

Apart from its previously described application for storage protection neem oil is extremely suitable for the manufacture of soap The oil is processed into soap in the usual way with potash or soda

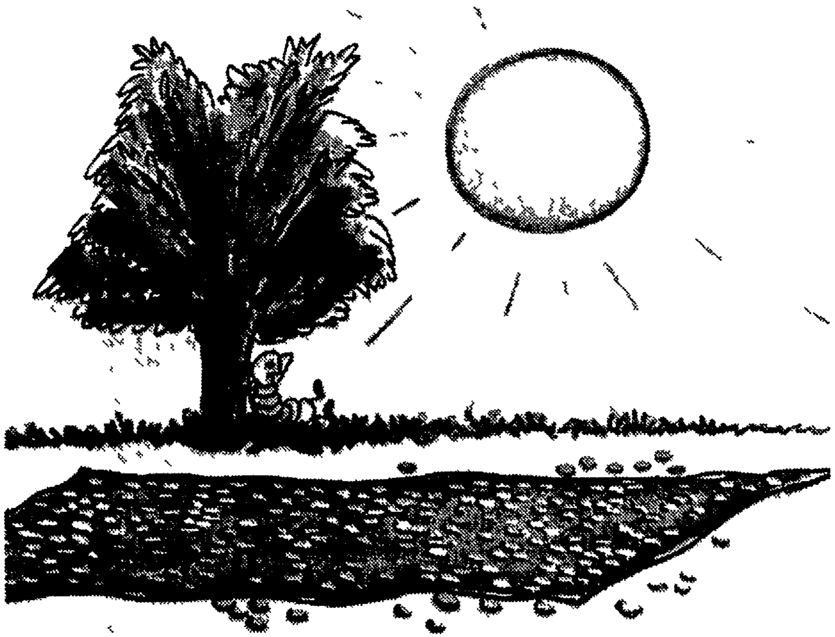
In what other ways can the neem tree be used?

Apart from its suitability to provide shade and for afforestation the wood of the neem tree is very much in demand The trunk and branches are ideal for building being both strong and rather resistant to termites It is also used for firewood and in the making of charcoal
There is an important point to remember when using neem for firewood If as is common practice in many countries the branches and the top of the tree are regularly pruned it will be some time before the trees again produce fruit as they will first try to re establish branches Thus the combined use of the neem tree for insecticide and firewood is only possible when the tree is left undisturbed for several years In other words In order to produce insecticide the original branches should be left intact (fruit production begins in 3 - 4 years) Only trees that are at least 10 years old should be used for firewood and only after the younger trees planted later, have begun to produce sufficient fruit



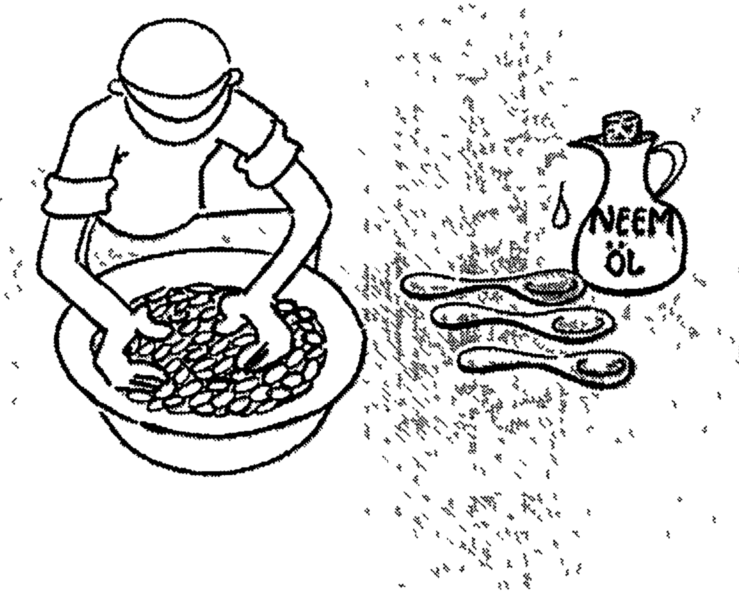
How are the neem seeds harvested ?

Neem trees bloom for the first time when they have reached the age of 2 to 3 years, and bear fruit at the age of 3 to 4 years They normally produce fruit once a year, but in some moist zones twice a year The fruit of the neem can either be shaken off the tree, picked, or stripped from the branches When ripe it is yellow in colour, about 2 cm in length and oval-shaped In the soft, sweet fruit there is a light-coloured seed of about 1.5 cm in length, containing one, or sometimes two, brown seed kernels. After harvesting the fruit the ripe pulp should be removed as quickly as possible In some regions, birds or fruit bats eat the sweet pulp, so that a lot of clean seeds can be found on the ground



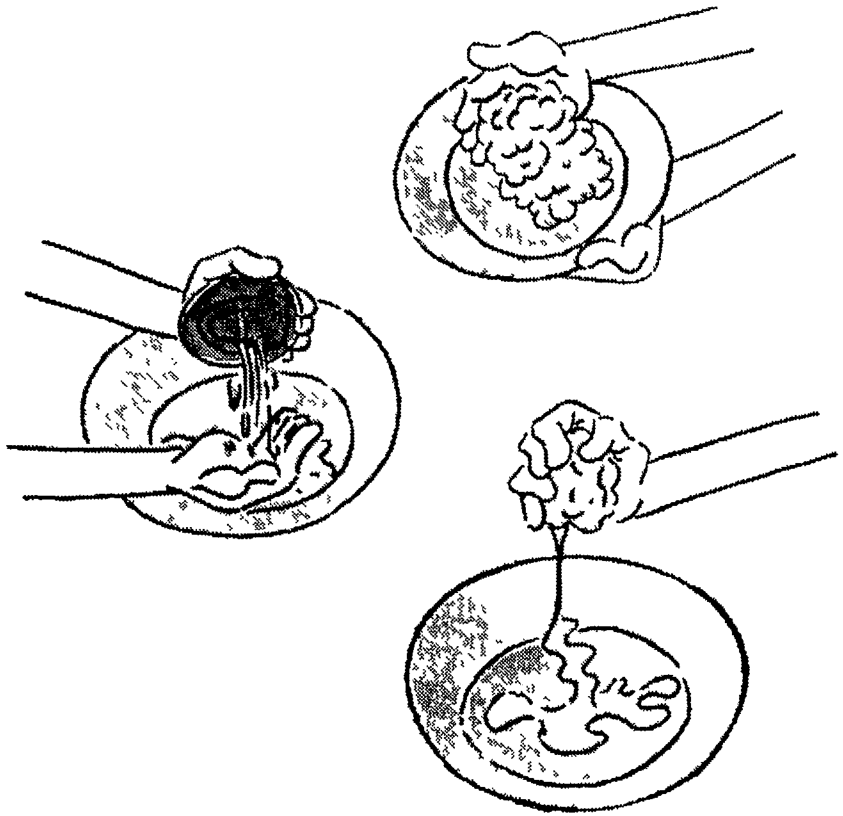
How to dry the neem seeds?

In order to dry the seeds, they are spread out for a few days on a solid and dry ground in the sun The layer of seeds should be as thin as possible, as when drying grain, legumes coffee or cocoa beans The drying process must be carried out very care fully as undried seeds can become mouldy quickly During the rainy season the seeds to be dried should be promptly covered over or brought indoors before rain showers begin



By alternating kneading and pressing of the paste in a bowl the neem oil is released Using this method it is possible to extract 150 ml oil from 1 kg powder The legume seeds are treated with neem oil extracted in the following manner The appropriate amount of neem oil is mixed with the legume seeds in a large bowl or similar container (3 ml per 1 kg grain); then the seeds may be stored in the usual way

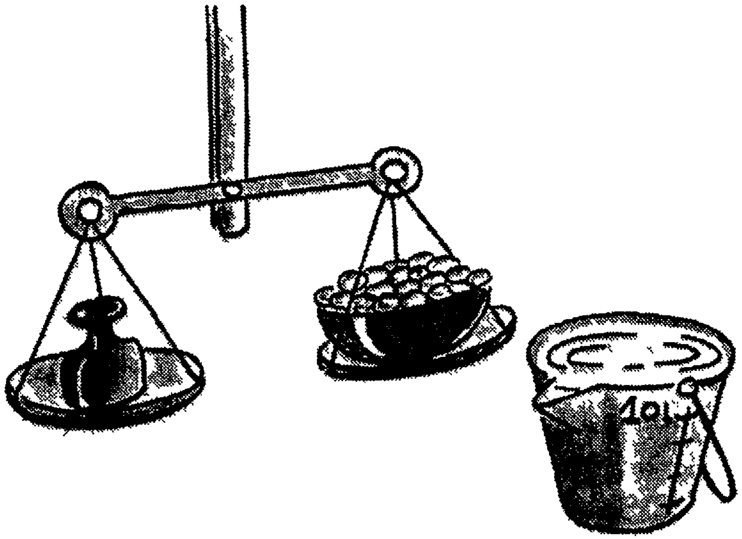
Neem oil is non poisonous but very bitter, thus freshly treated legumes taste at first very sharp This taste disappears, however, after 3 to 4 weeks



If the crushed seeds are very hard and brittle they should be moistened and left to stand for several hours until they can be pressed together by hand Crushing the seeds in a mill or mortar produces a rough sticky mixture out of which oil can be pressed by kneading Usually it is necessary to add a little water to make kneading easier

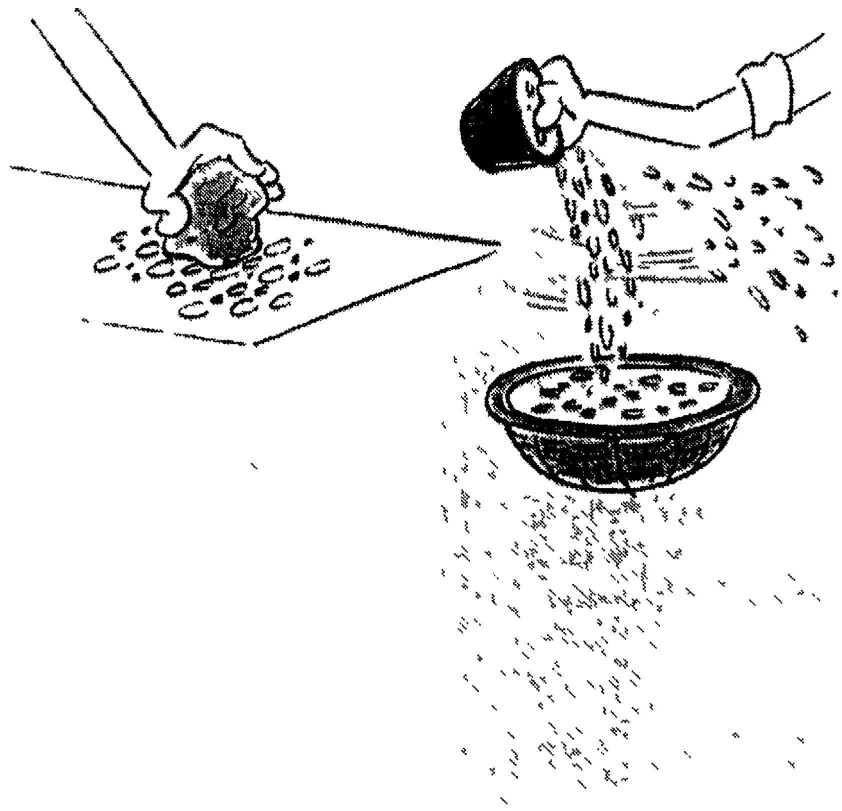
How are neem seeds stored?

As the dried seeds can also become mouldy during storage, they should only be stored in airy containers (eg. jute sacks or baskets) Airtight containers such as plastic bags or pots are unsuitable.



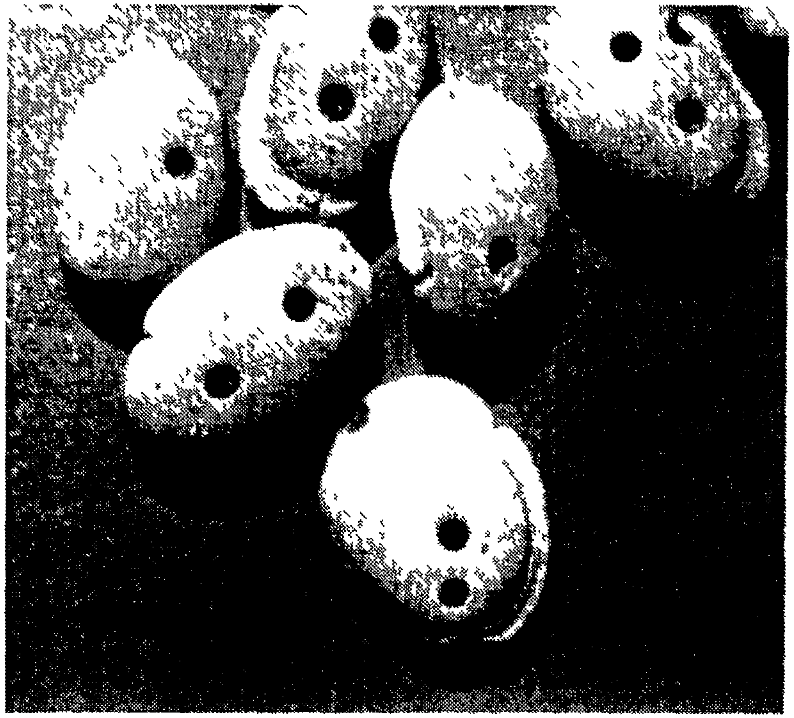
How are neem seeds processed?

To produce a spraying mixture with 10 litres of water 500 g neem seeds are required If it is not possible to weigh the seeds contai ners, such as traditional measuring tins ana pots etc where tne capacity is known are equally suitable for measuring the correct amount of seeds and water



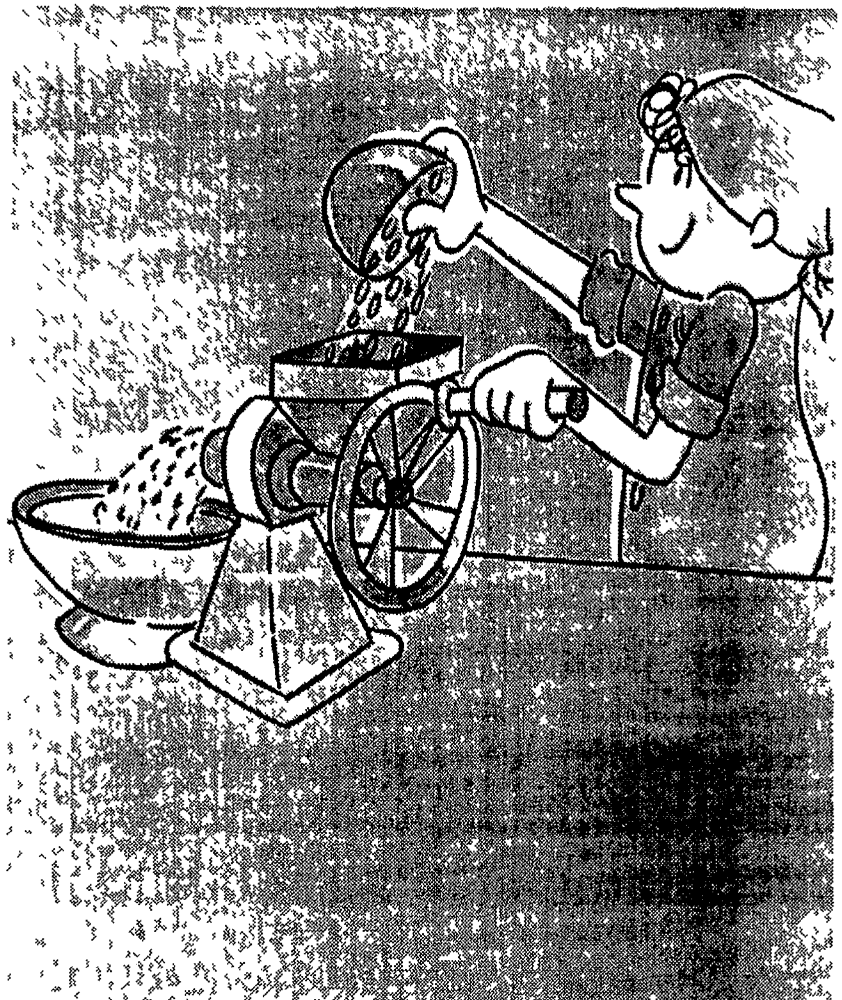
Bruchid pest control in stored legumes using neem oil

This oil is extracted from the neem seed kernels (oil content 40 - 50 %) When used for storage protection it should be carefully pressed either by machine or various other traditional methods As only a very small amount of oil (30 ml oil per 100 kg grain) is required, pressing by hand is practicable. The seeds must first be shelled, by cracking the shells with a stone or gently poun ding in a mortar and finally by winnowing to remove the shell par- ticles

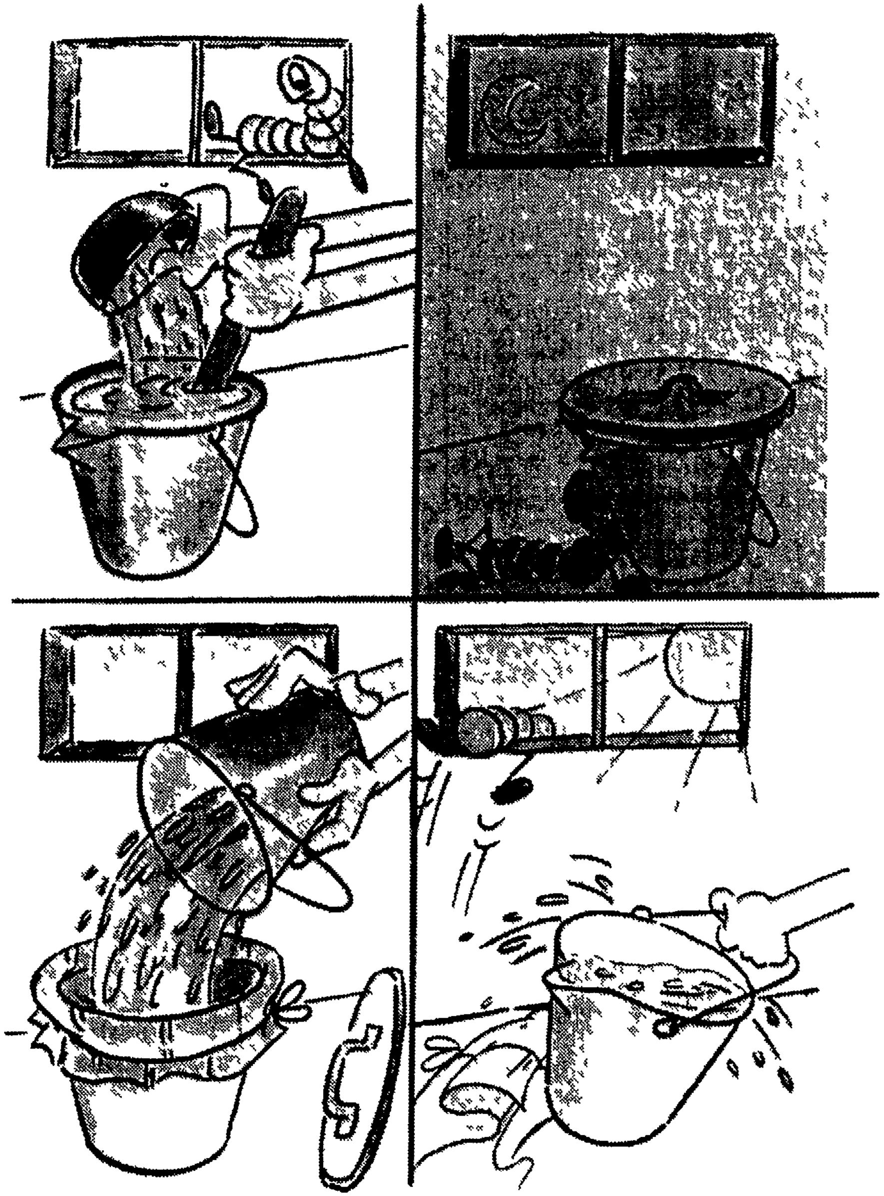


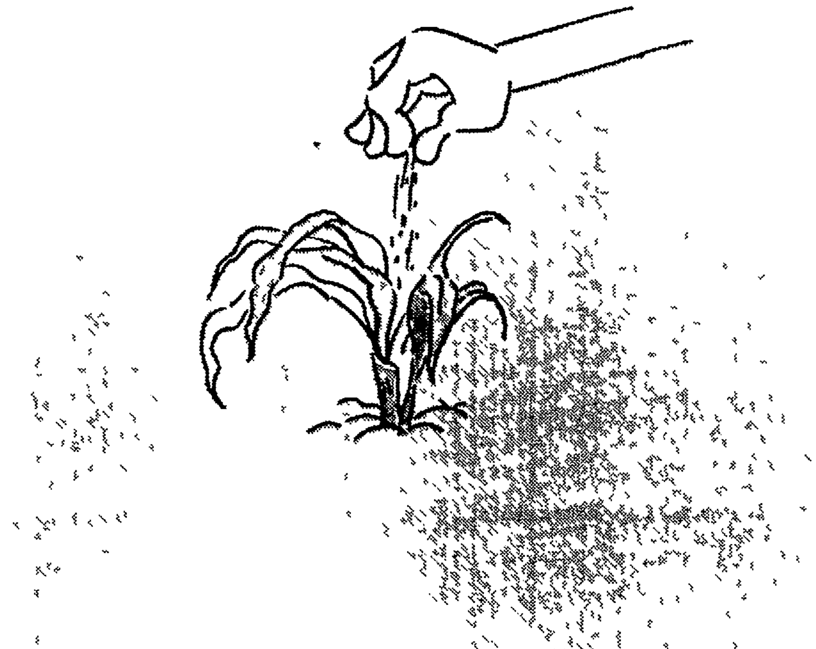
Bruchids in stored beans and other legumes

Stored grain legumes can easily be infested with bruchids. These are small beetles whose larvae eat into the grain. The bruchids can be controlled simply by mixing the legumes with neem oil.



Before mixing, the seeds are crushed or pounded preferably in a mill or mortar, then the crushed seeds are poured into the water and stirred vigorously.
This mixture should now be left to stand for at least 5 hours - if possible overnight - in order that the neem substances are fully released from the seeds into the water solution.





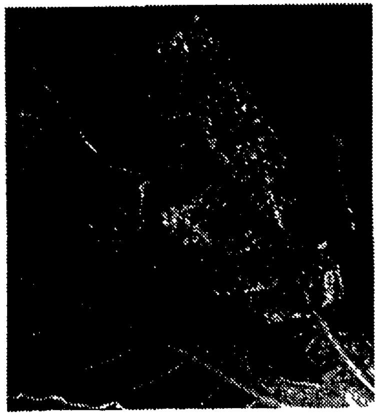
How can neem powder help to control stem borers on young plants?

Stem borers on young corn and sorghum plants can be controlled relatively easily with crushed neem seeds (the powder normally used to mix with water) A small amount of powder mixed with sawdust or dry clay at a ratio of 1.1 is placed in the funnel 1 kg powder should be sufficient for 1500 - 2000 plants.

In this method, rainwater dissolves the substances in the neem seeds as it gathers in the funnel and washes out the powder Where rainfall is irregular a liquid neem seed extract can be sprayed into the funnel

This treatment should be repeated every 8 to 10 days during the sensitive growing phase Thus, roughly three treatments are sufficient for protection against stem borers This recommendation applies only for young plants before flowering and not for older plants

Lesser melon fly (larvae)
(Dacus ciliatus)



Damages ef ected by spider mites to manioc

Poor pest control

Fruit flies

Larvae of these pests feed inside fruits, where they are protected from neem applications. Therefore, it is not possible to control them with neem extracts

Poor pest control

Spider mites

These are very small pests which suck on leaves. In field tests, efforts to control them with aqueous or alcoholic neem extracts have not been successful

How is the neem insecticide applied to the plants?

The neem extract can be applied in two ways. When using a sprayer the rough particles must first be filtered out of the mixture to prevent clogging the nozzle. This is done by covering a bucket or similar container with a coarse cloth or gauze through which the mixture is poured. The sprayer is filled with the filtered solution and spraying of the vegetable crops can begin.

If no sprayer is available the extract may be applied with a straw brush In this case, it need not be filtered A brush made with fine flexible straw is simply dipped into the solution and shaken over the plants until all the leaves are moistened The effect of the neem substance lasts between 3 to 6 days, regardless of how it was applied

He met scale (Saissetia coffea)

Green stink bug (Nezara viridula)

Fair pest control

Bugs

These are very active plant pests of various sizes which are found on practically all major crops In practice neem extracts have had some effects on developing stages but not on the adults of these bugs

Poor pest control

Mealybugs/Scale insects

Both are significant pest groups particularly in fruit trees and on other perennial crops To date, no significant influence of neem extracts on these insects has been demonstrated

Green peach aphid
(Myzus persicae)

Tobacco wh tefly (adults)
(Bem sia tabaci)

Fair pest control

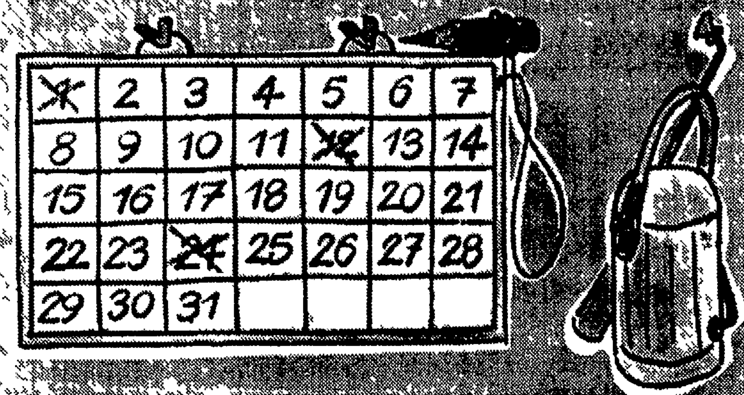
Aphids

A single application of neem extract is seldom successful in reducing aphids in field crops Regular spraying with higher concentrations of water extracts or other oil-rich products can, however, reduce their number considerably

Fair pest control

White flies

These are very small insects As fully grown insects, they settle on the underside of the leaves and fly off when the leaves are touched It has been observed, in some cases, that white flies were repelled by the neem sub stances and avoid settling and egg laying on neem treated plants for some time



How often does neem have to be applied?

If and when spraying is necessary depends very much on the individual case and this can only be decided by the farmer or the appointed adviser. In general, it may be said that in areas of vegetable cultivation, where pests are a great problem, weekly spraying is necessary. If, on the other hand, infestation is only slight, treatments in intervals of 10 to 14 days are adequate. Often a single treatment of the plants is sufficient. Just as with chemical insecticides, the insect species and crop are important factors in deciding how often spraying should occur. According to scientific research the extract is not poisonous for humans, thus, it is not necessary to wait long between final spraying and harvesting.

. hard times for insects!

Cotton jassid (nymphs)
(Amrasca biguttula)

Brown leaf beetle
(Ootheca mutabilis)

Good pest control

Leaf and planthoppers

Leaf and planthoppers suck on leaves stalks and fruit Larvae which feed on neem residues show growth disruption while the females lay fewer eggs The majority of leaf- and planthoppers studied to date were also deterred from settling on plants treated with neem

Fair pest control

Adult beetles

This refers to species which feed on the leaves of crops when these insects are fully grown Some are totally repelled by the factive substances while others are only slightly deterred Egg-laying may be strongly reduced It remains ultimately up to the user to acquire experience with the type of beetle in his particular area

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Desert locust
(Schistocerca gregaria)

Damage effected by larvae of a leaf miner (Liriomyza trifolii) to a sweet melon

Good pest control

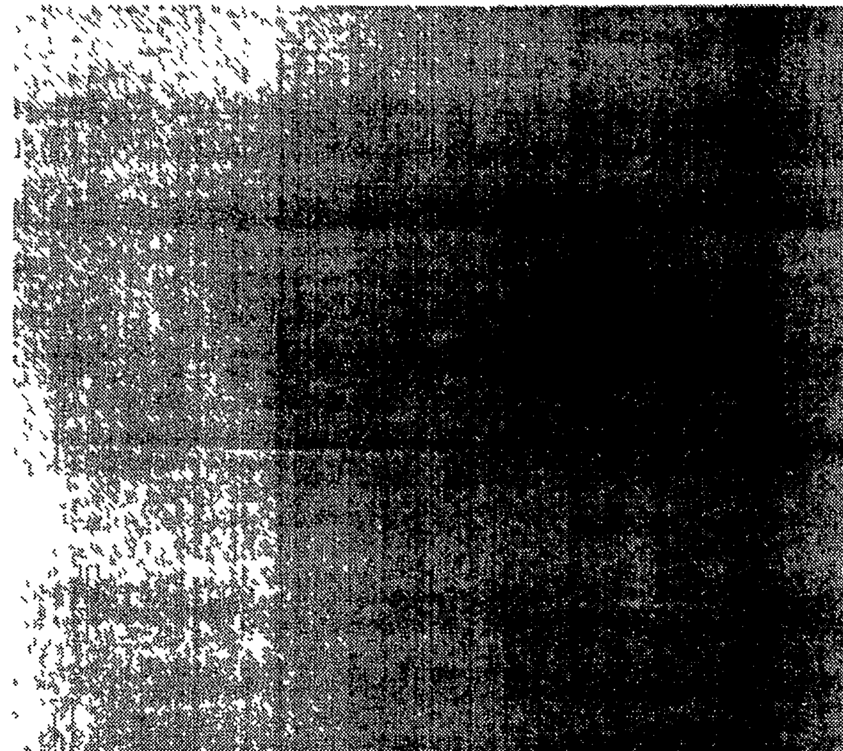
Grasshoppers

Neem substances disrupt the growth process of grass hopper nymphs and reduce the egg laying capacity in the full-grown insects. Many grasshopper species in Asia and Africa are deterred from feeding on plants which have been treated with neem extracts.

Good pest control

Leaf miners

These small larvae of moths and flies eat their way into the leaf substance leaving only the outer skin (epidermis) on the upper and lower side of the leaf. This results in transparent patches on the leaves known as mines. Further development of these larvae is prevented by neem extracts.



Which pests can be controlled with [illegible]

The neem extract does not have the sam[illegible] species. Some pest groups can be [illegible] ing behaviour of other groups may be influ[illegible]bility to reproduce impaired, but this does not [illegible] to the plants. Some insects react minimally [illegible] extracts.
On the following pages you will find more detaile[illegible] on the reactions of pests to neem extracts. It is importan[illegible] however, that this is not intended as a precise desc[illegible] the effects of neem extracts but as a guide which give[illegible] advice as to which pests may be controlled by applica[illegible] of neem.

Very Good Pest Control:
- Beetle larvae
- Butterfly and moth caterpillars

Good Pest Control:
- Grasshoppers
- Leaf miners
- Leaf- and planthoppers

Fair Pest Control:
- Adult beetles
- Aphids
- White flies

Poor Pest Control:
- Mealybugs/Scale insects
- Adult bugs
- Fruit maggots
- Spider mites

Diamondback moth larvae
(Plutella xylostella)

Mexican bean beetle larvae
(Epilachna varivestis)

Very good pest control

Caterpillars of butterflies and moths

Almost all types which feed openly on leaves and other parts of plants can be controlled This applies both for small and large caterpillars The insects react with growth disruption after spraying they reduce feeding and die usually within 2 - 4 days

Very good pest control

Larvae of beetles

Some types of larvae of beetles feed on leaves and in this way inflict great damage The reaction of the larvae is similar to that of the caterpillars their growth is disrupted their feeding activity reduced and finally they die off

SECTION VI

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1988 Focus On

Phytochemical Pesticides

Volume I

The Neem Tree

Editor

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Silver Spring Maryland

CRC

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Boca Raton Florida

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FOCUS ON PHYTOCHEMICAL PESTICIDES

SERIES INTRODUCTION

There is ample evidence to show that the plant kingdom is a vast storehouse of chemical substances manufactured and used by plants for defense from attack by insects, bacteria, and viruses Many of these plants, as well as their chemical components, have been used since ancient times to prevent and treat diseases occurring in higher animals, including humans The scientific and pseudoscientific literature is replete with such reports, some of which have been confirmed by laboratory and clinical trials, and yet others which have been shown to be worthless for these purposes

The CRC Series *FOCUS ON PHYTOCHEMICAL PESTICIDES* is envisioned as a comprehensive series of state-of-the art volumes covering all aspects of plant use as crop protectants from attack by insects, diseases fungi nematodes, and predatory wildlife such as coyotes wolves and rodents Coverage will not however, be limited to protection of crops but will also include the use of plants to protect humans and farm animals from diseases transmitted through mollusks, fungi and viruses Each volume in this series will contain detailed compilations contributed by known authorities in the particular field The high quality of the information contained in these volumes will be assured with the aid of an Advisory Board composed of worldwide authorities in the phytochemical pesticide field

M Jacobson
Editor-in Chief

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PREFACE

Volume I The Neem Tree

Approximately one third of the world food crop is damaged or destroyed by insect pests during growth, harvest, and storage Losses are considerably higher in many underdevel oped countries of Asia and Africa The monetary loss due to feeding by larvae and adults of pest insects amounts to billions of dollars each year Furthermore, the comfort and well being of humans and beneficial animals are affected directly by household and environmental pests such as lice, ants, roaches, ticks, wasps, and mosquitoes, some of which are disease carriers and transmitters Many of the synthetic pesticides previously used for insect control have been banned or their use seriously curtailed because of concern about health and environmental effects Also, the adaptability of insects threatens to undermine the effectiveness of existing pesticides It is therefore imperative that safe, biodegradable substitutes for the synthetic pesticides be discovered

Over the years, a wealth of literature has accumulated in scientific journals books and other reports on the effectiveness of plants as insect feeding deterrents repellents toxicants, and disruptants of insect growth and development Heading the list of effective plants, from the standpoints of number of pest species affected, high activity, availability safety, and resistance to predators, is the subtropical neem tree, *Azadirachta indica* A Juss, a hardy member of the plant family Meliaceae It is therefore fitting that the first volume in the series *Focus On Phytochemical Pesticides* should be devoted exclusively to this "wonder tree"

Based on the wealth of scientific records both oral and printed on the effectiveness of all parts of this tree against countless species of insects nematodes, bacteria and viruses the First International Neem Conference was held June 16—18, 1980, at Rottach-Egern West Germany, with more than 40 scientists (chemists, entomologists botanists physiologists, and zoologists) from 4 continents in attendance At this Conference, an informal steering committee was appointed that quickly became known as the "Neem Mafia", consisting of Professors K R S Ascher (Volcani Center, Bet Dagan Israel) E D Morgan (University of Keele, U K), H Rembold (Max Planck Institute of Biochemistry, Munich West Germany) R C Saxena (International Rice Research Institute Manila Philippines) H Schmutterer (Justus Liebig University, Giessen West Germany) L M Schoonhoven (Agricultural University, Wageningen The Netherlands), and me This Conference was so successful in stimulating worldwide interest and activity in the efficacy of the neem tree that it was followed by the Second International Neem Conference, held May 25—28, 1983 in Rauischholzhausen, West Germany (105 participants) and the Third International Neem Conference held July 10—17 1986 in Nairobi, Kenya (64 participants)

We express our heartfelt thanks to the Gesellschaft für Technische Zusammenarbeit (GTZ) Eschborn West Germany for sponsoring and providing generous funding of all three Conferences, making possible the attendance and participation of numerous scientists from Asia and Africa where the neem tree is naturally endemic and widely used as a pesticide We are also grateful to Drs B S Parmar and R P Singh Indian Agricultural Research Institute (IARI), New Delhi, India, for their continuing efforts to keep neem scientists worldwide informed of progress through quarterly publication and distribution of the *Neem Newsletter*, which began in 1984

Cooperative research between botanists, chemists and entomologists has very recently resulted in the commercialization of neem formulations as insect control agents in Asia Europe, and the U S , as well as the successful cultivation of the tree in many areas where it had not previously existed

M Jacobson

THE EDITOR

Martin Jacobson received his B S degree in chemistry from the City University of New York in 1940 He then accepted an offer as a chemist with the Industrial Hygiene Division of the National Institutes of Health in Bethesda, MD In 1942, he transferred to the Bureau of Entomology and Plant Quarantine of the U S Department of Agriculture (USDA) Agricultural Research Center, Beltsville, MD, as a research chemist to isolate, identify, and synthesize phytochemical pesticides, insect hormones, and insect sex pheromones During this period he pursued evening graduate studies in chemistry and microbiology at George Washington University, Washington, D C He also served as a part-time Research Associate in Chemistry at that University during the period 1944 to 1948

From 1964 to 1972, Mr Jacobson was an Investigations Leader with the Entomology Research Division at Beltsville Chief of the Biologically Active Natural Products Labora tory from 1973 to 1985 and Research Leader (Plant Investigations) with the Insect Chemical Ecology Laboratory until his retirement from Federal Service in 1986 He is currently an agricultural consultant in private practice in Silver Spring MD

During his long career with the USDA Mr Jacobson spent several weeks in 1971 as a Visiting Scientist teaching a graduate course on insect pheromones and hormones in the Department of Chemistry, University of Idaho, Moscow He was invited to organize numerous symposia and speak at national and international scientific meetings in the U S , Europe, Asia, and Africa in the field of pesticides and sex pheromones occurring naturally in plants and insects, respectively His awards include the Hillebrand Prize of the Chemical Society of Washington in 1971, USDA Certificates of Merit and cash awards for research in 1965, 1967, and 1968, the McGregory Lecture Award in Chemistry at Colgate University (Syracuse NY), two bronze medals for excellence in research at the 3rd International Congress of Pesticide Chemistry Helsinki Finland in 1974 USDA Director s Award on Natural Products research in 1981 and an Inventor's Incentive Award for commercializa tion of a boll weevil deterrent in 1983

Mr Jacobson has been a member of the American Chemical Society Chemical Society of Washington, Pesticide Science Society of Washington American Association for the Advancement of Science, New York Academy of Sciences and a Fellow of the Washing-ton Academy of Sciences He is the author or coauthor of more than 300 scientific reports in numerous journals the author of four books (*Insect Sex Attractants* John Wiley & Sons 1965 *Insect Sex Pheromones* Academic Press 1972, Insecticides From Plants A Review of the Literature 1941—1953 USDA Handbook 154 1958 Insecticides From Plants A Review of the Literature 1954—1971 USDA Handbook 461, 1975) and editor of the book *Naturally Occurring Insecticides* Marcel Dekker 1971 He also holds six U S Patents on naturally occurring insecticides

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1 Cultivation and Propagation of the Neem Tree

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I DISTRIBUTION

Neem is thought to have originated in Burma and is common throughout the open scrub forest in the dry zone and on the Siwalik hills, and if it is native to India it occurs naturally only in Karnatak and in parts of the Deccan Peninsula [1] In its native environments, neem is generally found growing in mixed forests, and associated with other broadleaf species, such as *Acacia* sp and *Dalbergia sissoo* It grows in tropical to subtropical regions, semiarid to wet tropical regions, and from sea level to over 610 m (2000 ft) It is cultivated throughout India, and in many places has become wild (The fruit is not toxic to birds and bats and it is reported that they are mainly responsible for the spread of wild neem) It is now found in many places outside its native distribution to the sub Himalayan track including the northern part of Uttar Pradesh at 610 m (2000 ft) and the southern part of Kashmir at 670 m (2200 ft) [2]

However according to Ahmed and Grainge [3] neem is native to the Indo Pakistan subcontinent while others attribute its nativity to the dry forest areas of India Pakistan Sri Lanka Malaysia, Indonesia Thailand and Burma [4] Nevertheless neem is found throughout Pakistan, Sri Lanka, southern Malaysia Indonesia Thailand and the northern plains of Yemen and has been recently introduced into Saudi Arabia The Philippines has also begun widescale plantings of neem for fuelwood and pesticide production It is known that 19th century immigrants carried the tree from the Indo-Pakistan region to Fiji and it has now spread to other islands in the South Pacific

East Indian immigrants introduced neem to Mauritius and it is thought that they took it to a number of African countries It is now widely cultivated on the African continent in Ethiopia, Somalia, Kenya Tanzania, Mozambique, Mauritania Togo Ivory Coast Cameroon Nigeria, Guinea Ghana Gambia, Sudan, Benin Mali Niger Burkina Faso Chad and Senegal, particularly in rainfall deficient regions

Neem was also introduced into several Caribbean nations by East Indian immigrants and is now propagated by Indian communities as a medicinal plant in Trinidad and Tobago Jamaica Suriname Guyana and Barbados [5] Neem plantings are also abundant in Guatemala Bolivia Ecuador Honduras Argentina, Brazil Cuba Nicaragua, Dominican Republic St Lucia and Antigua and large numbers are now being planted in Haiti In addition to the ongoing experimental cultivation of neem in Puerto Rico and the U S Virgin Islands plantings in southern Florida are thriving and the field cultivation of neem in Oklahoma southern California and Arizona has begun [3,6-9]

II ADAPTATION

Neem grows well from sea level to over 670 m (2000 ft) and can be established in hot and dry regions without irrigation Neem thrives under subhumid to semi arid conditions and can be established in areas with an annual rainfall of 450 to 750 mm (18 to 30 in) Optimum growth is obtained in higher rainfall areas (1150 mm) 130 mm/year is sufficient for survival [4] but it needs 450 mm to grow successfully It grows where maximum shade temperature may be as high as 49°C (120°F), but it does not stand excessive cold Neem is frost-tender especially in the seedling and sapling stages but it is grown in frost zones of the sub Himalayan tract by protecting seedlings during the winter with screens [7] Fire often kills it outright [2,8,9] According to Gorse [10] neem is not a very sociable tree does not grow well in pure stands (plantations in Africa often die out in 3 to 10 years) and is very competitive for water and soil nutrients thus it does not grow well on marginal soils

Neem seems to grow best in deep sandy soils that are well drained but can grow in practically all sorts of soil it thrives on black cotton soil in India and does not do badly even on clay It does better than most species in dry localities, on sandy, stony shallow soils with a waterless subsoil or in places where there is a hard calcareous or claypan (hardpan) not far from the surface However, neem will grow much better if this hardpan is broken up before planting Occasionally, neem will initially grow well on soils that appear to be sandy but quickly die out when roots hit a deep layer of dense clay Neem can grow even on saline and on alkaline usar soils [11] however, neem has been reported to be susceptible to moderate salinity in the Sudan [12] Thus within the species, some provenances must be more genetically tolerant to salinity than others Fishwick[13] observes that the best neem growth is found on sites with a soil pH of between 6 2 and 7 +

Neem does not tolerate waterlogged soils, and does not do well on soils with impeded drainage and on soils subject to inundation Growth is not good on poorly drained soils, because the taproot tends to rot and the trees gradually die In Nigeria, De Jussieu[14] reported that the best neem groves grew where the water table was 1 5 to 1 75 m down at 2 5 m, the groves were only mediocre and at 8 m the groves died out In his report the method of planting the neem trees was not given, and in many places in Africa it was commonplace to establish plantings by stump cuttings, whereby the taproot was pruned When this is done a normal length taproot will not regenerate, and the tree develops extensive lateral root systems with only pseudo taproots developing that do not penetrate deep into the subsoil In some soils the water table markedly rises during the rainy season and if this rise persists the roots of neem trees may smother

Neem does not grow well in soils with high proportions of very fine sand or silt or finely divided mica the yellowing of leaves is often followed by death [8] This may be a result of nutrient deficiency Research by Zech[15] determined that zinc and potassium deficiencies reduce neem growth evidenced by chlorosis of leaf tips and leaf margins, particularly on the older leaves the first symptom of zinc deficiency is yellow coloration of the intercostal areas leading to complete breakdown of the chlorophyll The shoots exude much resin with shedding of the older leaves With potassium deficiency leaf tip and marginal chlorosis and necrosis result

In Nigeria where systematic tests have been conducted, it was observed that very successful neem groves could be found in soils having a high clay content (67%) while trees died out on soils with a high sand content (83%) [14]

Neem has been planted on plantation scale in Nigeria since 1936 Most of the forests in the Sokoto region are of this species The introduction of neem to Sokoto was cited as the greatest boon of the century The tree grew quickly and met the local demand for firewood and poles for house construction and fence posts in addition to providing welcome shade in towns and villages [16] Gorse[10] states that neem is often the preferred species for planting in semiarid areas because animals do not readily browse it, and when they do mortality is low and neem recovers rapidly However, Welle[17] reports severe stunting of neem girdled from bark feeding by goats

III SILVICULTURAL AND PLANTATION CHARACTERISTICS

In India, neem is generally found in mixed forests So far, little is known about the behavior of neem in plant communities and its ecological potential and limitations Individual neem trees are reported to live for 200 years [2] It seems to do much better on an isolated basis than in full groves, and grows beautifully along roadsides, or as isolated shade trees It also does well in mixed species plantings and in relatively well-spaced rows (approximately 3 m apart) along contour line ditches [14] Michel-Kim and

Brandt[18] report that experience in India and Africa indicates that neem may not be suited for monoculture This contention is supported by Gorse[10] who states that neem is not a sociable tree and plantations often die after 3 to 10 years, especially on poorer sites He contends that neem must be pruned or it will die back, which can be avoided by pollarding the tree However, many report neem growing well in monoculture in plantations [9 13 19,20] One explanation for this variance is that neem is very demanding on both water and mineral nutrients, and on soils where nutrients are limited neem will not do well in monocultural plantations

Neem grows better with shade in its early stage of growth, but demands light as it matures Therefore, it has a great capacity for pushing its way through thorny scrub in its youth Welle[17] reports neem growing exceedingly well in plantations in Haiti where *Leucaena leucocephala* is interplanted as a nurse crop with trees having a better form (the elephant-foot stump type growth with a large taper is reduced) Radwanski and Wickens[8] report that transplants are likely to be seriously injured by developing leaf spot (clorosis) as a result of insolation (grown in full sunlight) thus neem does best in its earlier years when planted with a nurse crop However once mature neem does best in full sunlight, and does not do well as an understory

IV GROWTH

Neem is reported to grow relatively fast, but varies greatly depending upon its environment, site characteristics, and the genetic capability of the plant material Slower growth results at higher elevations, at colder temperatures and on drier sites Radwanski[7] reports that 66% of the total growth of the tree will occur in the first 3 years during which it will reach a height of 4 to 7 m, it will reach 5 to 11 m in the following 5 years Seedlings show moderate development, ordinarily reaching a height of 10 to 20 cm (4 to 8 in) by the end of the first year As a rule, trees put on a mean annual girth increment of 2 to 3 cm (0 9 to 1 2 in) though more rapid growth is obtained under more favorable conditions De Jussieu[14] reports that in irrigated groves in India, 16-year-old neem trees reached diameters over 40 cm, but trees grown in this way break more easily and are subject to wind damage Under mediocre conditions the average diameter of trees in a 44 year-old grove was 25 5 cm and average height was 10 5 m In Africa, it is generally assessed that at 1 year in good soil, a grove reaches a height of about 1 5 m at 2 years a height of 2 m and during the fourth year trees reach a diameter of 7 to 8 cm and a height of about 4 5 m

Fishwick[13] notes that on poor sites, there was evidence that neem stagnated after the first 5 to 6 years and for this reason rotations were reduced to 7 years which appeared to be more profitable Furthermore, it appears that the critical time in the development of the trees in the plantation occurs when crowns begin to touch the third or fourth year with a spacing of 8 ft (2 44 m) × 8 ft and fifth and sixth year at a spacing of 15 ft (4 57 m) × 15 ft thus on poor sites the wider spaced trees would cost less to plant would be larger and would have a greater economic value (Comparing two plantations on poor sites, the value of the trees at the wider spacing was four times greater)

Because weeds compete for moisture and nutrients early growth of seedlings is much retarded and regular weeding and cultivation stimulates neem growth and vigor Research carried out in Dehra Dun India has shown that seedlings that were weeded reached a height of 0 6 to 1 4 m (2 to 4 5 ft) by the end of the second season but only 0 5 to 1 m (1 66 to 3 25 ft) if not weeded Later, the seedlings that were not weeded were killed by weed suppression and frost[1]

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V. YIELD

According to Michel-Kim and Brandt,[18] the yield of neem varies between 10 and 100 tons of biomass (dried material) ha/year, depending upon rainfall, site conditions, and spacing, and 40 tons [12 5 m^3 solid wood/ha/year (based on 1 m^3 = 800 kg)] can be achieved easily under the proper conditions About 50% of the biomass is contained in the leaves, about 25% in the fruit, and 25% in the wood

Gravsholt et al [9] reports that the first rotation yield in Ghana was 30 to 38 cords of fuelwood per hectare (approximately 13 5 to 17 m^3/ha/year solid wood), and in Samaru in northern Nigeria 7 5 to 67 cords (approximately 2 4 to 21 m^3/ha/year) Commonly in West Africa, plantations are cropped on an 8-year rotation with a spacing between trees of 8 × 8 ft (2 4 m × 2 4 m)

Fishwick[13] reports that on more suitable sites in Bornu Province in Nigeria the yield was 15 to 27 cords/ha/year (13 5 to 24 3 m^3 solid wood) on a 7 year rotation The plantation spacing was 8 ft (2 43 m) × 8 ft and site conditions included soils comprising drift sands with a pH ranging from 5 0 to 7 5 and a mean annual rainfall varying from 380 to 762 mm (15 to 30 in) An average annual yield for all plantations was 7 to 15 cords/ha (6 3 to 13 5 m^3) In Nigeria neem poles are in great demand for house construction and fence posts because they are semiresistant to termites, poles thus realize a greater price than fuelwood

McComb[19] reports plantation yields in Samaru Zaria, Nigeria, of 300 to 2250 ft^3/acre for the first 8 year rotation crop (2 55 to 19 67 m^3/ha/year solid wood) and 350 to 2250 ft^3 (3 to 19 67 m^3/ha/year) for the 8-year coppice crops on the same plantations (The lower yields were for class IV sites while the higher ones were for class I sites and the spacing between trees was 2 4 × 2 4 m) Interestingly, the first 8-year rotation crop on class I plantation sites showed an average incremental growth rate of 350 ft^3/year (after the second year) while the coppice crop averaged only 250 ft^3/year There were no significant growth rate nor yield differences on the class IV sites, and on the class I sites the volume of the coppice growth by the third year was almost equal to the growth by the fifth year of the first 8 year rotation crop

Radwanski[21] gives the yields of the Majiya plantation near Sokoto Nigeria as 520 ft^3/acre of fuelwood after 7 years (5 2 m^3/ha/year) and after coppicing 820 ft^3 solid volume of fuelwood and 290 ft^3 solid volume of timber per acre (total yield of 8 6 m^3/ha/year) The plantation was planted in 1945 with open-root neem seedlings (assumed to mean bare-root) spaced 6 × 6 ft (approximately 1 8 × 1 8 m) The average annual rainfall in this region was 31 in (787 mm) with a maximum of 47 in (1194 mm) to a minimum of 20 in (508 mm)

Welle[17] reports that trees grown in plantations in Haiti at 4 years of age averaged a yield of 1 pole plus and 0 09 m^3 of fuelwood, but the volume of the pole was not given Radwanski[22] gives a volume of 1 05 m^3 for neem poles in one plantation in Nigeria while McComb[19] reports a pole volume ranging from 37 to 85% of the total wood produced

VI COPPICE GROWTH

Early growth is faster from coppice than from seedlings, reaching a height of 8 5 m (28 ft) in 3 years after cutting However, in Nigeria, the height of 8-year-old coppice was reported to have only equaled that of 8-year-old trees started from seedlings In plantations there, trees reached a height of 7 m (23 ft) in 3 years and 12 m (40 ft) in 8 years Approximately 66% of height is achieved in the first 3 years after planting [23] Fishwick[13] reports that plantations in Nigeria were cut to a stump height of 8 cm (3 in) and coppice from such low stumps is less likely to suffer from wind damage than from higher stumps Higher stumps also have a higher incidence of dying off Grose[10] observed that by cutting at a stump height of 1 to 2 m, the number of poles produced by coppice will increase Radwanski[7] recommends a coppice management system every 3 years for maximum biomass yield based on the observation that 66% of the growth of the tree occurs in the first 3 years However, this merits further research, since much faster growth of coppice occurs once the root system is established, and a much shorter rotation may give a maximum yield

VII INTERCROPPING

Radwanski and Wickens[8] report, ' Neem cannot be grown among agricultural crops since it will not tolerate the presence of any other species in its immediate vicinity and if not controlled, may become aggressive by invading neighboring crops Troup[1] reported that seedlings that were not weeded were suppressed and eventually killed because of weeds (and frost) But Makay[24] reported that even though neem seedlings had been hidden from August and September under a 10-ft (3-m) high crop of millet neem did surprisingly well The seedlings were still healthy, did not appear to have been retarded after the millet was harvested in October and a healthy stand of neem was left behind Others state that neem can be planted in combination with fruit cultures and crops for feeding cattle (e g , *Pennisetum pedicellatum,* as suggested by Misra) [25] Also recommendations have been made for combinations of neem with sesame cotton and hemp,[26] with peanuts, beans sorghum,[7,27,28] with *Acacia arabica* (synonym *A nilotica*) and cotton,[1] and with *Khaya senegalensis* [29]

In Nigeria, a form of taungya was used for neem plantation establishment and farmers cultivated groundnuts, beans, and millet between the trees but the forest department planted the trees These plantations were superior in survival and quality to plantations established by other means, and the cost was much lower In areas where neem plantations were cleared groundnuts were cultivated and yielded three times the average for other fields [13]

It is known that the compounds found in neem are not only effective against insect pests, and beneficial in the efficient use of nitrogen but they also affect some fungi and bacteria Thus the tree may have a significant influence on the balance within the microfauna fungi and bacteria communities Because plants depend upon a certain microfauna and a special complex of bacteria and fungi, it is possible that where neem changes the composition significantly problems may arise The effect of neem may be both positive and negative, and research is needed to prove or disprove these factors [18]

Perhaps neem is allelopathic to some crops There are many conflicting statements as to its compatibility for 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 to other crops or vice versa Or the reason may be that since neem fruits produce a systemic somewhat repugnant chemical food crops may take up this chemical from fruits falling on the ground once the tree begins bearing fruit (usually at 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 the incompatability of neem as an intercrop and agroforestry species

The answer may be to plant neem in mixed forests in combination with pasture Michel-Kim and Brandt[18] suggest that up to 20% of the area could be planted to neem

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and village plantings could constitute up to 15% Neem would also be a good species for use in a sequential agroforestry system as illustrated in the Radwanski and Wickens paper [8] Another excellent use of neem in agroforestry systems is for windbreaks In the Majjia Valley in Niger, over 500 km of windbreaks (a form of agroforestry) comprising double rows of neem trees have been planted to protect millet crops and to supply wood to local villagers This has resulted in a 20% grain yield increase for local farmers and the windbreaks are lopped and provide needed fuel and construction wood to villagers [30,31]

Perhaps one of the best agroforestry potentials of neem is growing it for its various useful products where it is not intercropped with food crops, and the products (leaves, neem cake etc) are processed or used in a cut-and-carry system and applied to food crops as a fertilizer and pesticide

VIII NEEM SEEDS AND PROPAGATION

Neem begins to bear fruit in 3 to 5 years [32] The period of collection of neem fruits naturally varies from place to place, depending upon the regional climatic conditions In India collection may begin as early as May and extend through September however there seems to be two distinct fruiting periods May — June and August — September The fruits are collected from the trees when fully ripe or are gathered from beneath trees

A. YIELD

Neem produces fruits in 3 to 5 years and becomes fully productive in 10 Ketkar[2] gives a yield of about 50 kg (110 lb)/tree/year Ahmed and Grainge[3] 30 to 50 kg (66 6 to 110 lb), and Radwanski[33] lists 11 4 to 34 kg (25 to 75 lb), averaging about 20 5 kg (45 lb) About 2000 to 3000 fruits weigh 1 kg the depulped fruit yields about 1800 seeds/kg,[14] and 9 to 10 dry seeds weigh 1 g [34] The ratio of seed to pulp is approximately 1:2, and fruit pulp and kernels account for 47 5 and 10 1%, respectively, of fruit weight [35] For reproduction seed preparation the fruits are rubbed and washed to remove the flesh from around the seeds After washing the seeds are dried in the shade and preferably stored in dry, airtight containers

B VIABILITY

Usually neem seeds remain viable for only a few weeks, about 1 to 2 months, and normally they are collected when thoroughly ripe and sown as soon as possible But when mature seeds are depulped and adequately dried and cooled, they can be stored for longer periods Reportedly, germination rates rapidly decline during storage However, Brouard[36] cites work by Dr Paul B Tompsell at the Royal Botanical Gardens in Great Britain, who froze seeds after drawing the seed moisture content to below 8% and they remained viable up to 2 years To obtain a high germination percentage, seeds must be collected when they are fresh, cleaned thoroughly, and handled carefully (to avoid cracking)

C GERMINATION

Seeds germinate in about 2 weeks after sowing Fresh neem seed germinates quite readily and scarification is generally not needed Research at the Royal Botanic Gardens in Great Britain indicates that germination is improved if the inner shell is removed to expose the embryo before planting [6] and Smith[37] reports the same However, Singh[34]

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recommends that the seeds be cut across with a sharp blade and the cotyledons examined if the cotyledons are green the seeds are sound but if they have turned yellow or brown, they will not germinate

In more efficient containerized nurseries, it is desirable to produce a sprouted seed in every container because less space is required and it reduces per-seedling labor costs Experiments were conducted by Operation Double Harvest in Haiti in an attempt to pregerminate neem seeds for transfer to container, however, the research showed that 47% of pregerminated seed had a major taproot deformity (crooked or looped), while the roots of only 7% of dry sown seed were deformed [38]

Fagoonee[39] found that germination is best when seeds that have fallen from trees during the preceding week are soaked in water for about 3 d, depulped and cleaned then sown directly into the nursery in damp soil The soaking breaks the dormancy by neutralizing the germination inhibiting chemicals found in the shell of the seed

However, Ezumah[40] concludes that neem seeds do not require a period of after-ripening Seed origin, year and time of producton have no significant effect on germination and longevity Sun-drying does not adversely affect viability and appears preferable to air-drying to bring seed moisture content to 10% or less before storage The method of seed cleaning also 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 Cold storage adversely affects the viability of neem seed, seeds stored at room temperature (20 to 28°C) retained some viability for 16 weeks, while viability lasted for only 12 weeks at cold storage (6 to 7°C)

IX PROPAGATION TECHNIQUES

Most commonly neem seedlings are propagated in the nursery and transplanted to the field, although direct sowing has been successful in some areas if rainfall is adequate [1,17]

Although neem needs light young seedlings can suffer from strong solar radiation thus a light shade is desirable during the first season of growth Sudden exposure of seedlings without first hardening off will result in a high rate of mortality Seedlings naturally regenerated under old stands often die when the trees are cut and the canopy is opened [13]

A NURSERY CARE

In the nursery, seedlings are either grown in containers (plastic bags or root trainers) or in seedbeds Germination starts in about 8 d and continues to about 3 weeks

1 Bags and Other Containers

Seeds are sown directly into the container filled with potting soil and are ready for transplanting in 12 weeks [41] In Haiti seedlings are grown in containerized nurseries and transplanted in 3 to 5 months depending upon the rainfall pattern [17]

2 Seedbeds

If the nursery is irrigated seeds can be harvested early in April and planted in the nursery The seed should be lightly covered with earth and sparingly watered the soil kept loose to prevent caking Singh[34] recommends a spacing of 5 cm in-row and 20 cm inter-row planting the seed at a depth of no less than 1 cm to minimize rodent damage Fishwick[13] states that seeds should be sown thickly in lines 30 cm apart selectively thinned when the seedlings are about 8 cm high (3 in) to a spacing of 8

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cm, and selectively thinned again in 4 to 5 months with only the best stock remaining at a spacing of about 23 cm (9 in.)

3 Seedlings

Recommendations when seedlings are ready and what the height is at the time of transplant vary. If seeds are planted early in April, seedlings should be ready for transplanting by July (4 months), reaching a height of 15 to 20 cm. De Jussieu[14] and Troup[1] report that neem fruits from April to July, and seeds are planted in seedbeds in a partially shaded nursery as soon as possible after harvest, around the middle of July when the rains begin, and are ready for transplant by the next rainy season, after reaching a height of about 0.80 to 1 m. Radwanski[7] and TAREC[41] indicate that seedlings are ready for transplant in about 12 weeks when they are 7.5 to 10 cm high (3 to 4 in.), with a taproot approximately 15 cm long (6 in.). Mitra[42] recommends transplanting when seedlings reach 7.5 to 10 cm (3 to 4 in.) high. According to Singh,[34] seedlings transplanted younger than 1 year have a poor survival rate; this does not hold true according to experience in Haiti where the survival rate of 3 to 5-month container-grown neem transplants is 85%.[17]

4 Root Balls

Seedlings that have not been planted during the first year are kept until the following season and sometimes until they are 2 years old. Year-old seedlings are carefully uprooted from the nursery leaving a ball of soil around the roots and transplanted as soon as possible. Planting is done in July — August in pits dug in April — May which allows weathering of the soil, and if rain immediately follows, good survival rate is ensured. In dry areas, about 90% of the leaves are removed, reducing evapotranspiration, and decreasing transplant shock. The areas in the vincinity of the trees must be kept weed-free.[34]

5 Stumps

In India, stumps are usually prepared from 2-year-old seedlings, although in irrigated nurseries, year-old seedlings may attain the desired size for stump preparation. The seedlings should be uprooted with care to avoid splitting or breaking the taproot. Stumps are prepared with 22-cm roots and 5-cm shoot portions and wrapped (bare-rooted) in moist gunney sacks and kept in the shade until transplanted. Just before planting in 30 cm^3 pits, desiccated root and shoot tips are pruned.[34] In Nigeria, Fishwick[13] found that seedlings cut to a stump height of 0.3 m (1 ft) were better than taller ones because they were easier to handle and provided sufficient buds for sprouting, and were not damaged by wind, which whipped taller ones, loosened the soil and exposed the roots. Roots were trimmed to 30 cm (12 in.) with most of the new growth produced by the callus that forms at the point where the roots are trimmed. Survival was increased when the seedlings were cut in the seed bed rather than at the time of lifting because shock was reduced by not cutting, lifting, and transplanting at the same time, and a callus tissue would form on the shoot wound before lifting. In Africa, Gorse[10] cut canes to a height of 1.5 m and removed all leaves before transplant, and in this way the bark is already hardened and not as susceptible to damage by animals.

6 Disadvantages

There are distinct disadvantages to planting overage seedlings. First, it is very costly to keep and care for seedlings for 1 to 2 years. The added weight of seedlings with a soil root ball drastically increases transportation costs and reduces the number of seedlings that can be delivered to the planting site, especially if they are hand carried. Another problem when seedlings are transplanted bare-rooted, they suffer severe transplant shock roots dry out, root hairs and beneficial mycorrhizae die Survival rate is decreased, and growth rate is retarded

B TISSUE CULTURE

The use of tissue culture and cuttings to produce neem for reforestation has been deemed unrealistic in most cases because of the high cost of a production facility, and the relative ease of producing seedlings [43] Also, it is questionable whether tissue-cultured plantlets and cuttings will develop full taproots However, it could be economically justified to screen and reproduce plants of unique germplasm (such as a tree with an unusually high azadirachtin content) in this manner for seed orchard establishment in more moist areas, which would not be affected by limited taproot development

Neem has been successfully tissue-cultured from leaflet callus tissue and from stem tissue by growing it in modified Murashige and Skoog media producing roots in 40% of the cultures and developing into complete plantlets in a supplemented medium [44-46] In further tissue culture research Schultz[47] was not able to achieve root initiation as reported by Sanyal et al [44] which supported research by Rangaswamy and Promila[48] describing the differentiation of growth centres in *Azadirachta* callus and the eventual shoot bud formation with rarely any rooting Again, it is questionable whether a normal length taproot will develop from tissue-cultured plantlets, which would exclude their planting in water-stressed areas

C CUTTINGS

Neem can also be propagated by cuttings, which require a production period of 6 months to 1 year,[41] but again the development of a normal taproot would be doubtful Air-layered branches treated with IBA or NAA in lanolin paste at 0 1% develop roots satisfactorily [49] In Nigeria, Fishwick[13] records that in Maiduguri a number of neem shoot cuttings were treated with a rooting hormone (Seradex B) and then placed in pots A number took but did not survive after being transplanted In Sokoto, the work was repeated but cuttings were covered with polythene bags, and a number survived after being transplanted It was found that a significantly higher proportion of the cuttings took root when they were taken and prepared at the start of the rainy season

D DIRECT SEEDING

In the literature the term 'direct seeding (sowing) is used in two ways — direct seeding in the nursery and direct seeding in the field In India and Nigeria direct sowing is reported to have proven more successful for reforestation than transplanting however, this is when areas to be sown are well prepared (similar to land preparation for sowing food crops) Direct seeding on hard and inhospitable soils has not been very successful, but establishment and growth can be greatly enhanced when seeds are sown in bore holes that have been dug in these hard soils and filled with a fertile potting mix Research has shown that hole size on difficult sites can significantly enhance establishment and growth of transplanted seedings Although drilling bore holes with a post-hole auger and filling them with a potting mix may to some seem expensive, the cost is comparable to nursery raising and transplanting seedlings

When direct-seeded, neem establishes an extensive root system before aerial growth becomes rapid [4] Site preparation and transplanting are the two biggest costs of reforestation, and direct seeding can markedly reduce transplanting costs De Jussieu[14] reports that aerial seeding has been tried but yielded poor results since the chances of survival for the seeds is much lower than direct seeding or prepared land Gorse[10] recommends the use of a groundnut planter and weeder for direct seeding and weeding and covering the seed beds with a 10 to 15-cm mulch of groundnut hulls

Welle[17] reports that direct seeding has proven to be a viable method of establishment in Haiti. Seedlings raised in nursery beds are ready for tranplanting during the first rains when they are 7.5 to 10 cm (3 to 4 in.) high. Sometimes seedlings are retained in nursery beds and transplanted during the second rainy season.[11]

Methods of direct seeding vary.[7,11,34] In India:

1. The soil is worked to a depth of about 15 cm and the seeds are sown at a depth of 1.5 cm. Sowing is done either in patches or lines; in the former they are spaced about 3 × 3 m, and spacing between lines is about 3 m, using 3 to 4 kg of seed per hectare. Weeding is necessary and seedlings are thinned at the end of the first season, leaving two seedlings per patch or two seedlings per meter length of the line.
2. Seed was sown at high and dry sites that had been plowed twice. No watering was done, but the seedlings were kept free of weeds. In less than 3 years, the plants were 7 to 8 ft high, the growth being equal to or better than that of transplants that had been carefully watered and tended. Trees in similar plantings at another site measured up to 12 ft in 3 years.
3. Direct seeding into mounds of earth 12 × 4 × 1.5 ft on sites receiving 24 in. (600 mm) of rain annually produced plants that reached a maximum height of 4.5 ft in 1 year.
4. Neem was sown in combination with the cultivation of sesame, cotton, and the lesser hemp in an area with an annual rainfall of less than 500 mm (20 in.). The sown lines were 0.3 m (1 ft) apart, three lines of field crops to one line of trees so that the latter were 1.2 m (4 ft) apart. Sowing of both field crops and trees was done after site preparation by plowing and harrowing. The lines of trees were weeded twice during the first rains. The trees reached a height of 5 m (16 ft) and girth of 43 cm (17 in.) in 3 years.
5. Direct sowing into plowed furrows in black cotton-soil produced trees with a maximum height of 1.5 m (5 ft) after 1 year.
6. Success has been achieved by dibbling neem seed under Euphorbia bushes.

In Nigeria, Fishwick[13] reports successful direct seeding at the bases of the native cover, with a survival rate of about 40 trees/ha. It was observed that although the rate of growth is generally slower than on cultivated sites, it had merits of simplicity and cheapness to enrich degraded forest area.

In northern Nigeria, neem interplanted on farms among groundnuts, beans, and millet showed markedly superior growth. When the crop was harvested, a healthy stand of neem seedlings was left behind.[4]

E. SPACING

Neem seems to be very nutrient-demanding, and has been known to send out lateral surface roots reaching over 18 m.[50] In Nigeria, a spacing of 1.8 × 1.8 m is recommended,[14] and Gorse[10] recommends a much wider spacing on poorer sites.

F. ROOT FORMATION

Roots that have been pruned (as suggested in the stump planting method) may not regenerate into a long, normal taproot (rather they develop several shorter pseudo taproots, which are not as long as a normal one). Fishwick[13] found, by digging, that a 2-year-old tree planted from a stump possessed seven taproots, each with a 1.27-cm (1/2-in.) diameter at a depth of 12 ft (full depth of penetration was not recorded). The author does not know if neem, under normal circumstances from a seed with an un-damaged root system, would develop only a single, deep taproot Without a normal taproot, the plant would be limited in its ability to penetrate into low water tables and reach nutrients in lower soil horizons During drought, when water tables drop considerably, the trees may die Similar difficulties would be encountered when trees are established from cuttings, for they do not generate normal taproots This might explain the die-off of the neem plantations (established by stump cuttings and from seedlings with the taproot pruned) in Maiduguri, Nigeria, reported by Fishwick[13] and elsewhere by others [50]

G SURVIVAL

The rate of seedling survival is influenced by a number of factors besides age of seedlings and methods of transplanting Genetics play an important role, and seeds should be gathered from plus trees of the desired phenotype and ecotype Also the size of the seed influences survival and early plant growth, larger seeds produce a much stronger seedling (maternal influence) Seedlings with a well developed root system (such as those promoted by root trainers, and through fertilization and those which have been inoculated with mycorrizae) can withstand drought much better and have the capacity for a more immediate and larger uptake of moisture and minerals thus will have a higher survival rate

H NATURAL REPRODUCTION

Under natural conditions, the fruit (seed) ordinarily drops to the ground during the rainy season, and germination takes place in 1 to 2 weeks Neem reproduces naturally with tolerable freedom, especially around trees growing in moist, sandy soils Naturally regenerated seedlings have been used for reforestation, but they do not compare in vigor with good nursery stock Their root systems are poorly developed they are very sensitive to sunlight, and they lack buds [13] In Haiti, a number of volunteer seedlings were dug up from under a tree 22% were highly deformed, and only 39% could be rated as having well shaped taproots [38] Neem establishes well under bushes and scrub [1] though initial growth is usually slower [4] Bats and birds are reported to spread neem by eating the fruit and depositing the seed elsewhere, and spontaneous individual trees and stands of neem trees are reported to have been established in this manner in several countries in Africa, India and Haiti Some feel that bats spread more seeds than birds, and larger numbers of volunteer seedlings can be found under trees where they roost [10 14 51]

X GERMPLASM

There is great variation in the germplasm of neem in terms of azadirachtin content seed oil content, seed yield, form (clean, straight bole, branchy, etc), fast-growth tolerances to different environments, and resistance to diseases and pests If neem is to be grown for pesticide production, it is necessary to develop trees that produce high yields of fruit with maximum azadirachtin content Therefore, there is a great need to exploit the germplasm resources of neem in the area of its origin as well as in exotic regions and to conduct research on its performance There is also a need to broaden out the germplasm in exotic areas to avoid disease and pest infestations where it is widely planted Since neem is native to the Burma-India area all germplasm originates there

There is a great variance in the azadirachtin content of the seed which may depend upon a number of variables, and it is difficult to determine which one(s) The differences in azadirachtin content may be determined genetically and may be environmentally triggered or influenced, perhaps by water stress high humidity, high or low levels of rainfall or soil nutrient content Azadirachtin content may also vary greatly depending upon the age of the tree, when the seed is picked how it is dried, stored, shipped, exposed to light, heat or cold, etc Some think azadirachtin content of seed from trees 5 or more years of age is higher than that from younger trees The only way this can be determined is by scientifically noting the environment where the trees are growing (altitude, soil type, latitude, rainfall, and pattern — e g , was the tree water-stressed before fruiting?), determining the age of the tree, collecting all seed at the same age or stage after fruiting (green ripe but still on the tree fallen to the ground), and cleaning drying, storing, handling, and analyzing the seed in the same manner

Jacobson[6] analyzed seed from some varieties from India that contained only 1 to 3% of the chemical, while seed from Africa tested at 5 to 6%, and some as high as 9% Also, collections of neem seeds (reared from Togo-bred seeds) in June and September have shown that the seeds from older trees contain larger quantities of pesticidal com pounds, especially azadirachtin [51] Ermel et al [52] analyzed seed from 66 sources The highest contents were measured in samples from Nicaragua and Indonesia showing 4 8 and 4 85% azadirachtin respectively High contents were also measured in kernels from Togo, India, Burma, and Mauritius (3 3 to 3 9%) wherease samples from Sudan and Niger gave lower yields (1 9% and 1 5%) The incubation of kernels under increasing temperatures and high air moisture resulted in time-dependent decrease of the azadi rachtin contents The exposure of extracts to sunlight and ultraviolet radiation also decreased the azadirachtin contents remarkably Singh[53] notes that an attempt to cor relate the antifeedant efficacy with extract yield and oil content and these three factors with environment often failed However it was observed that seeds from neem trees growing in dry areas near the desert possessed much higher biological activity than those from trees growing in coastal areas

Reports on the amount of oil in the seed vary from as low as 17 to over 59% According to Radwanski,[33] the kernels constitute about 45% of the fruit and yield about 45 to 49% oil (25% of the whole fruit) proper handling of the seed and more refined methods of extraction yield higher levels of oil The yield of oil from the Ceylonese seed kernels is reported to be the highest at 59 25% Larson[54] states there is no evidence at this time that the azadirachtin level rises linearly with the percentage of the oil since the azadi rachtin does not tend to follow the oil in the extraction process using ethanol Mitra[42] and Ketkar[2] estimate neem seed to contain about 20% oil, which contains about 2% active ingredients with manufacturing potential for producing pharmaceutical and insect repellent preparations Singh[53] notes that kernels from trees growing in humid areas or areas with more rainfall yielded more oil than those from other places Again, the amount of oil in the kernel is probably inherited and may be environmentally influenced

It is also necessary to develop fast-growing neem germplasm for two other purposes (1) maximum clean bole height and (2) maximum branching at a low height that produce straight coppiced poles, in order to remit maximum income to farmers in developing countries

XI TOXICITY, PESTS, DISEASES, AND LIMITATIONS

Neem is said to have few pests and its naturally occurring pesticide is nontoxic to man and animals However, there is evidence that this may not be so

A. TOXICITY

Radwanski and Wickins[8] state that one of the most significant attributes of neem oil as an insecticide is that it is effective and reportedly nontoxic to man or animals, and nonpolluting to the environment However, a syndrome similar to Reye s syndrome has appeared in children given large doses of neem oil,[55,56] although infrequent, this man ifestation has been fatal Because Reye's syndrome and the neem oil-induced Reye s like syndrome are poorly understood, neem extracts should be tested more thoroughly before being used for medicinal purposes Also, neem extracts have been found to be toxic to guinea pigs and rabbits,[57] the insectivorous fish *Gambusia* spp , and tadpoles died at 0 04% concentration of neem extracts [58] Welle[17] observed that neem seeds falling into fish ponds in Haiti proved fatal to Talapia fry This indicates the need for systematic follow-up toxicological studies

Pereira and Wohlgemuth[59] report that neem seeds carry *Aspergillus flavus*, which in certain conditions produces aflatoxins, this is a particular concern in waste piles at preparation sites

B ALLELOPATHY

There is some concern that neem compounds may be allelopathic, but no research evidence supports this contention (also see Section VII)

C PESTS

Roberts[60] lists 14 insect species and 1 parasitic plant as recorded pests of neem in Nigeria, although few are serious, and most plantations of neem are reported to be insect free, evidently due to the repellant compounds of the tree Insects will eat the radicle of germinating seeds if it is not covered well with soil Occasional insect infes tations by species of *Microtermes* and plant parasitism by *Lorantium* have been observed in Nigeria, but the attacked trees almost invariably recover, though their rate of growth and branch development may be considerably retarded [8] CAB-IIBC[61] reports that *Aonidiella orientallis* has become a pest of neem in some parts of Africa (e g , the Lake Chad Basin Niger, Chad, Nigeria, and Cameroon)

In India, the larvae of *Enarmonia koenigana* Fabr feed on rolled leaves and bore into tender shoots and the larvae of *Cleora comana* Meyrick and *Odites atmopa* defoliate the leaves [62] Warthen[63] lists nine other insect pests that attack neem *Calepitenmerus azadirachta Araecerus fasiculatus Cryptocephalus ovulus, Holotrichia consanguinea H insularis H serrata Pulvinaria maxima, Laspeyresia aurantianna,* and *Orthacris simulans*

Termites have been known to damage trees attacking them at the level of the collet sometimes extending to the trunk and to the cyme but generally not killing them [14] Fishwick[13] reports that termites attack weak sickly trees but at times they also attack and kill young vigorous trees Neem coppice shoots have also been attacked and killed but the roots of the stump were not damaged and produced fresh coppice shoots

Gosh[64] reports that the neem scale *Palvinaria maxima* is a serious pest in central and south India. It feeds on sap, covers the tender shoots and stem in numbers, and sometimes damages a young tree considerably A tree in an advanced stage of infes tation is recognized by the thick coating of white, mealy patches formed on the foliage shoots, and bark Another scale insect *Aspidiotus orientalis* thickly covers the shoots and stems of seedlings of about 0 6 to 2 5 cm in diameter, appearing on the new shoots and spreading to the leaves In severe infestations, the growth is retarded, leaves are shed the stems die back and young trees may be killed Also *Aspidiotus pseudocer iferus* feeds on the sap, and the nymphs of *Helopeltis antonii* feed on sap by puncturing the soft plant tissue which blackens and dries The wounds cause deformation of leaf and shoot or the whole shoot may dry up and die back

D DISEASES

Recorded pathogens attacking neem are *Ganoderma lucidum*, causing root rot, *Corticium salmonicolor*, causing stem and twig blight, *Cercospora subsessilis*, causing leaf spots, *Oidium* sp , causing powdery mildew, and *Pseudomonas azadirachtae*, causing leaf spot and blight [65,66] Sankaran et al [67] reports additional diseases attacking seedlings in nurseries in India *Rhizoctonia solani*, causing web blight, *Sclerotium rolfsii*, causing stem rot, *Colletotrichum capsici* and *C subsessilis*, causing leaf spot, and *Fusarium solani*, causing wilt Stem rot, leaf blight, web blight, and wilt reported for the first time caused up to 30% mortality of 2 to 3-month-old seedlings

Singh and Chohan[68] observed a severe canker disease of twigs and shot-holes in leaves of neem and identified a fungus, *Phoma jolyana*, as the cause De Jussieu[14] reports that cankerous lesions can also sometimes be found on the tree in fissures coming up from the collet along the stem The wood becomes brown around the cankers and this coloration can penetrate to the heartwood Gorse[10] observed that canker prevailed on the sunset side of the tree This disease seems to correlate with a sudden absorption of water after a long drought but through exploration of the genetic potential of neem, genetic resistance might be found

E PARASITES

Mistletoes that parasitize neem include *Dendrophthoe falcata* and *Tapinanthus* sp [69]

F WEEDS AND TILLAGE

Neem is intolerant of grass competition and needs thorough weeding, especially in dry areas, to obtain good growth [4] Thorough weeding without watering is found to gain results almost, if not quite, equal to those attained by irrigation and weeding The loosening of soil to prevent caking (in some soils), which promotes soil aeration and increases moisture percolation, is found to be most beneficial Research indicates that on undisturbed soil, less than 25% of the rain falling on it is absorbed, but up to 60% when frequently hoed, mulching plus hoeing increased the absorption up to 90% [13]

However, Fishwick[13] concludes that once weeds and grasses are established and root below the upper zone of competition their presence does not seem to affect the tree growth, although it should be noted that perennial grass roots have been observed at depths of over 3 m (10 ft)

Experiments in Nigeria have shown that some tillage during and at the end of the wet season has a remarkable effect on the growth, health, and survival of neem in the first year when interplanted among groundnuts, beans, and millet [24]

In compacted and eroded soils, survival rate can be influenced by the size of the hole in which the seedling is planted A larger hole allows for increased water infiltration because of the uncompacted soil, and it also allows better development of the root system In nutrient poor soils, it should be possible to gain a higher rate of establishment by boring or augering a hole into the ground about 10 cm (approximately 4 in) in diameter by 15 to 23 cm (approximately 6 to 9 in) deep, replacing the displaced soil with a good nutrient-rich nursery mix, and seeding directly into the hole This would greatly reduce reforestation costs, doing away with the expensive nursery operation

G OTHER PROBLEMS

Neem seedlings are killed by frost and fire, and large trees are frequently snapped off during high winds However, trees seemingly killed by fire will coppice and regrow if cut soon after the burn [10] Regeneration beneath stands of neem is sensitive to sudden exposure to direct sunlight, and clear felling in plantations normally results in the death of this regeneration if seedlings are under 8 cm (3 in) in height [13]

In some localities rats and porcupines girdle neem seedlings and trees gnawing the bark from around the base and killing them In areas with high rodent densities they devour the fruits greedily and consume most of them after they fall to the ground Goats and camels have been known to severely browse young plants and kill them [34]

Because of the potential of pest outbreaks, neem should not be raised in pure stands, and it is recommended that neem should be mixed with leguminous trees like *Leucaena leucocephala, Albizzia lebbeck*, or *Acacia nilotica*, which reduce the risks of infestation by these pests These trees would also complement the non-nitrogenous neem tree Welle[17] reports that neem interplanted with *Leucaena leucocephala* in Haiti grew better than neem in monoculture

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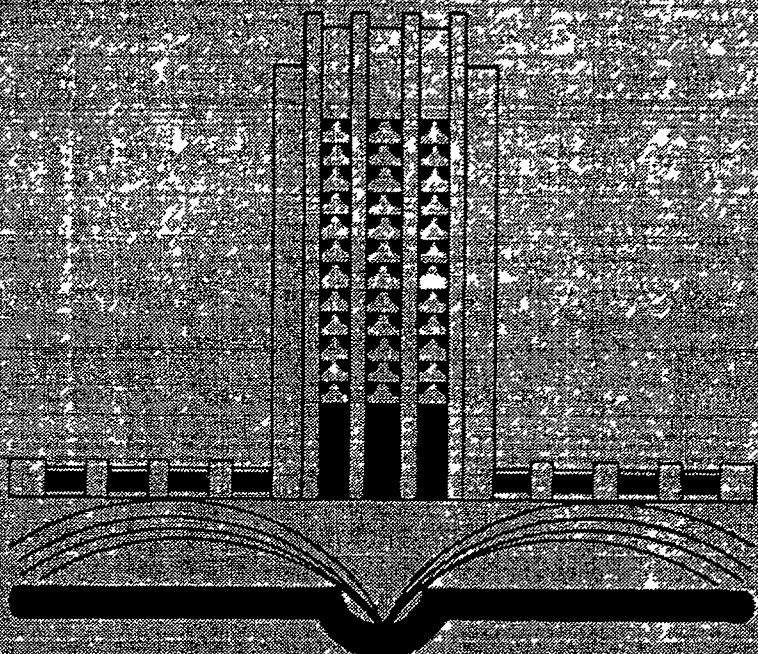

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S3	43	MELIA?()AZEDARACH
S4	9	MELIA?()AZADIRACH
S5	7	CHINABERR?
S6	388	S1-S5/OR
S7	302	AZADIRACH
S8	43	AZEDARACH
S9	426	S6 OR S7 OR S8
S10	398	S9/ENG
S11	11	MARGOSA
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S15	350	S13-S14
S16	158754	PY=1981
S17	315	S15-S16

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Singh B Singh A P Faridabad The Directorate of Plant Protection Quarantine & Storage Plant protection bulletin 1988 v 40 (1) p 14-17 Includes references (NAL Call No DNAL 421 P69)

0067
Effect of neem leaf (Azadirachta indica L) on growth and yield of low land rice
ZAPFA Santhi S R Palaniappan S Berlin W Ger Paul Parey Journal of agronomy and crop science = Zeitschrift fur Acker und Pflanzenbau Aug 1986 v 157 (2) p 114-117 Includes references (NAL Call No DNAL 18 J825)

0068
Effect of neem oil on survival of Nilaparvata lugens (Homoptera Delphacidae) and on grassy stunt and ragged stunt virus transmission
JEENAI Saxena R C Khan Z R College Park Md Entomological Society of America Journal of economic entomology June 1985 v 78 (3) p 647-651 ill Includes references (NAL Call No DNAL 421 J822

0069
Effect of neem on the oviposition behaviour of the fall armyworm Spodoptera frugiperda Smith
ZANEA Hellpap C Mercado J C Hamburg W Ger Paul Parey Journal of applied entomology = Zeitschrift fur angewandte Entomologie Dec 1986 v 102 (5) p 463-467 Includes references (NAL Call No DNAL 421 Z36)

0070
Effect of neem seed oil on the blood glucose concentration of normal and alloxan diabetic rats
JETHDA Dixit V P Sinha R ~Tank R Limerick Elsevier Scientific Publishers Journal of ethno-pharmacology July 1986 v 17 (1) p 95-98 Includes references (NAL Call No DNAL RS160 J6)

0071
Effect of nonedible seed oils on survival of Nephotettix virescens (Homoptera Cicadellidae) and on transmission of rice tungro virus
JEENA* Mariappan V Jayaraj S ~Saxena R C College Park Md Entomological Society of America Journal of economic entomology Oct 1988 v 81 (5) p 1369-1372 Includes references (NAL Call No DNAL 421 J822)
In a greenhouse study nonedible oils extracted from seeds of karanj Pongamia pinnata Pierre mahua Madhuca longifolia Koen Macbr var latifolia Roxb Cheval and pinnai Calophyllum inophyllum L trees were more effective than the oil of neem Azadirachta indica A Juss in reducing the survival of the rice green leafhopper Nephotettix virescens (D stant) and its transmission of the rice tungro viruses (RTV) and as effective as oil of custard-apple Annona squamosa L Insect mortality was 100/ after 4 d on rice plants sprayed with oils at 5/ concentration in contrast to 69% insect survival on control plants RTV infection was 17-35/ in oil-treated plants and 51% in the control

0072
Effect of organic amendment (of margosa cake or sawdust supplemented with nitrogen phosphorus and potassium fertilizers) on phenolic content of soil and (tomato) plant and response of Meloidogyne javanica and its host to related compounds
Sitaramaiah K Singh R S The Hague Plant and soil Dec 1978 v 50 (3) p 671-679 ill 15 ref (NAL Call No 450 P696)

0073
Effect of phosphate on decomposition of different organic materials (Azadirachta indica compost Saccharum spontaneum Uttar Pradesh India)
Singh R D Joshi K C ~Dhar N R Calcutta Agricultural Society of India Indian agriculturist 1982 v 26 (3) p 179-182 Includes references (NAL Call No 22 IN294)

0074
Effect of plant extracts on insect pests of common beans
ZANEA Hongo H Karel A K Hamburg W Ger Paul Parey Journal of applied entomology = Zeitschrift fur angewandte Entomologie Sept 1986 v 102 (2) p 164-169 Includes references (NAL Call No DNAL 421 Z36)

0075
Effect of seed treatment with azadirachtin on root-knot development on and growth of some vegetables
TACUDC Siddiqui M A Alam M M London Association of Applied Biologists Tests of agrochemicals and cultivars Apr 1988 (9) p 20-21 Includes references (NAL Call No DNAL S587 T47)

0076
Effect of some crude and azadirachtin-enriched neem (Azadirachta indica) seed kernel extracts on larvae of Aedes aegypti (Insect growth regulators)
Zeb -z C P W Amsterdam Nederlandse Entomologische Vereniging Entomologia experimentalis et applicata 1984 v 35 (1) p 11-16 ill Includes references (NAL Call No 421 EN895)

0077
Effect of some neem (Azadirachta indica) and karanj (Pongamia glabra) products on utilization of urea nitrogen by upland rice
JINSA Surve S P Daftardar S Y New Delhi The Society Journal of the Indian Society of Soil Science Mar 1985 v 33 (1) p 182-186 ill Includes references (NAL Call No DNAL 56 9 IN2)

0078
Effect of sunlight on azadirachtin antifeeding potency (Degradation of an insecticide produced from Azadirachta indica experiments on Spodoptera frugiperda)
Stokes J B Redfern R E New York Marcel Dekker Journal of environmental science and health Part A Environmental science and engineering 1982 v 17 (1) p 57-65 Includes 13 ref (NAL Call No TD172 J6)

0079
The effect of the traditional preservatives used in northern Togo and of neem oil for control of storage pests
Zehrer W Eschborn W Ger Die Gesellschaft Schriftenreihe der Gesellschaft fur Technische Zusammenarbeit In the series analytic Natural pesticides from the neem tree and other tropical plants / compiled by H Schmutterer and K R S Ascher Proceedings of the 2nd Internat Neem Conference May 25 28 1983 Rauischholzhausen Federal Republic of Germany 1984 (161) p 453-460 Includes references (NAL Call No DNAL HD1417 B8)

0080
Effect of urea and neem cake coated urea on yield and concentration and quality of essential oil in Java citronella (Cymbopogon winterianus Jowitt)
JASIAB Prakasa Rao E V S Singh M -Ganesha Rao R S -Ramesh S Cambridge Cambridge University Press The Journal of agricultural science Apr 1985 v 104 (pt 2) p 477-479 Includes references (NAL Call No DNAL 10 J822)

0081
The effect of various extracts of neem seed kernel on Liriomyza trifolii (Burgess) (Diptera Agromyzidae)
ZPFSA Meisner J Yathom S -Tal S -Ascher K R S Stuttgart W Ger Eugen Ulmer Zeitschrift fur Pflanzenkrankheiten und Pflanzenschutz = Journal of plant diseases and protection Apr 1986 v 93 (2) p 146-152 Includes references (NAL Call No DNAL 464 8 Z3)

0082
Effectiveness and selectivity of technical solvents for the extraction of neem seed components with insecticidal activity
Feuerhake K J Eschborn W Ger Die Gesellschaft Schriftenreihe der Gesellschaft fur Technische Zusammenarbeit In the series analytic Natural pesticides from the neem tree and other tropical plants / compiled by H Schmutterer and K R S Ascher Proceedings of the 2nd Internat Neem Conference May 25-28 1983 Rauischholzhausen Federal Republic of Germany 1984 (161) p 103-114 ill Includes references (NAL Call No DNAL HD1417 B8)

0083
Effects and applied potential of anti-hormones in acridids
Pener M P Chichester E Horwood c1987 Evolutionary biology of orthopteroid insects / editor Baccio M Baccetti p 400-413 ill Includes references (NAL Call No DNAL QL506 E9)

0084
Effects of a formulation of neem extract on six species of cockroaches (Orthoptera Blaberidae Blattidae and Blattellidae)
PHPRA2 Adler V E Uebel E C Bet Dagan Agricultural Research Organization Phytoparasitica Mar 1985 v 13 (1) p 3-8 Includes 8 references (NAL Call No DNAL SB599 P53)

0085
Effects of a neem tree (Azadirachta indica) extracts on diamond-back moth (Plutella xylostella L) (Repellant and antifeedant properties)
Tan M T Sudderuddin K I Kuala Lumpur Malaysian Society of Applied Biology Malaysian applied biology June 1978 v 7 (1) p 1-9 ill 14 ref (NAL Call No S295 M3)

0086
Effects of aqueous neem extracts and neem oil on the main pests of Cucurbita pepo in Togo
Dreyer M Eschborn W Ger Die Gesellschaft Schriftenreihe der Gesellschaft fur Technische Zusammenarbeit In the series analytic Natural pesticides from the neem tree and other tropical plants / compiled by H Schmutterer and K R S Ascher Proceedings of the 2nd Internat Neem Conference May 25-28 1983 Rauischholzhausen Federal Republic of Germany 1984 (161) p 435-443 Includes references (NAL Call No DNAL HD1417 B8)

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JIPHA Souza Garcia E de Rembold H Oxford Pergamon Press Journal of insect physiology 1984 v 30 (12) p 939-941 Includes references (NAL Call No DNAL 421 J825)

0088
Effects of azadirachtin on insect cytochrome P-450 dependent ecdysone 20-monooxygenase activity
BBRC Smith S L Mitchell M J Duluth Minn Academic Press Biochemical and biophysical research communications July 29 1988 v 154 (2) p 559-563 Includes references (NAL Call No DNAL 442 8 B5236)

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Effects of azadirachtin on oogenesis in Aedes aegypti
PENTD Ludlum C T Sieber K P Oxford Blackwell Scientific Publications Physiological entomology June 1988 v 13 (2) p 177 184 Includes references (NAL Call No DNAL QL461 P5)

0090
Effects of azadirachtin on reproduction and egg development of the heteropteran Oncopeltus fasciatus Dallas
ZANEA Dorn A Hamburg W Ger Paul Parey Journal of applied entomology = Zeitschrift fur angewandte Entomologie Oct 1986 v 102 (3) p 313-319 Includes references (NAL Call No DNAL 421 Z36)

0091
The effects of Azadirachtin on the endocrine control of moulting in Locusta migratoria
Sieber K P JIPHA Rembold H Oxford Pergamon Press Journal of insect physiology 1983 v 29 (6) p 523 527 Includes references (NAL Call No 421 J825)

0092
Effects of azadirachtin on the nutrition and development of the tobacco budworm Heliothis virescens (Fabr) (Noctuidae)
JIPHA Barnby M A Klocke J A Devon Pergamon Press Journal of insect physiology 1987 v 33 (2) p 69 75 Includes references (NAL Call No DNAL 421 J825)

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Effects of neem (Azadirachta indica) seed kernel extracts from different solvents on the carmine spider mite Tetranychus cinnabarinus (Insect antifeeding and growth regulating properties)
Mansour F A Ascher K R S Bet Dagan Agricultural Research Organization Phytoparasitica 1983 v 11 (3/4) p 177-185 ill Includes references (NAL Call No SB599 P53)

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Effects of neem (Azadirachta indica) seed kernel extracts from different solvents on the carmine spider mite Tetranychus cinnabarinus
Mansour F A Ascher K R S Eschborn W Ger Die Gesellschaft Schriftenreihe der Gesellschaft fur Technische Zusammenarbeit In the series analytic Natural pesticides from the neem tree and other tropical plants / compiled by H Schmutterer and K R S Ascher Proceedings of the 2nd Internat Neem Conference May 25-28 1983 Rauischholzhausen Federal Republic of Germany 1984 (161) p 461-469 Includes references (NAL Call No DNAL HD1417 B8)

0095
Effects of neem (Azadirachta indica) seed kernel extracts from different solvents on the predacious mite Phytoseiulus persimilis and the phytophagous mite Tetranychus cinnabarinus
PHPRA2 Mansour F Ascher K R S ~Omari N Bet Dagan Agricultural Research Organization Phytoparasitica 1987 v 15 (2) p 125-130 Includes references (NAL Call No DNAL SB599 P53)

0096
Effects of neem cake blended urea on rice yield (Method of fertilizing to prevent nitrogen lors)
Jadhav B B JMAUD Patil V H ~Kadrekar S B Pune D R Bapat Journal of Maharashtra agricultural universities May 1983 v 8 (2) p 124-125 Includes references (NAL Call No S471 I3J6)

0097
Effects of neem derivatives on growth and fecundity of the rice pest Nephotettix virescens (Homoptera Cicadellidae)
ZPFSA Heyde J von der Saxena R C ~Schmutterer H Stuttgart W Ger Eugen Ulmer Zeitschrift fur Pflanzenkrankheiten und Pflanzenschutz = Journal of plant diseases and protection Aug 1985 v 92 (4) p 346-354 ill Includes references (NAL Call No DNAL 464 8 Z3)

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Sombatsiri K Tigvattanont S Eschborn W Ger Die Gesellschaft Schriftenreihe der Gesellschaft fur

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Effects of neem kernel extracts on the fall armyworm Spodoptera frugiperda
Hellpap C Eschborn W Ger Die Gesellschaft Schriftenreihe der Gesellschaft fur Technische Zusammenarbeit In the series analytic Natural pesticides from the neem tree and other tropical plants / compiled by H Schmutterer and K R S Ascher Proceedings of the 2nd Internat Neem Conference May 25-28 1983 Rauischholzhausen Federal Republic of Germany 1984 (161) p 353-364 Includes references (NAL Call No DNAL HD1417 B8)

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Effects of neem seed extract on the post-embryonic development of the tobacco hornworm Manduca sexta
Haasler C Eschborn W Ger Die Gesellschaft Schriftenreihe der Gesellschaft fur Technische Zusammenarbeit In the series analytic Natural pesticides from the neem tree and other tropical plants / compiled by H Schmutterer and K R S Ascher Proceedings of the 2nd Internat Neem Conference May 25-28 1983 Rauischholzhausen Federal Republic of Germany 1984 (161) p 321-330 ill Includes references (NAL Call No DNAL HD1417 B8)

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Akou-Edi D Eschborn W Ger Die Gesellschaft Schriftenreihe der Gesellschaft fur Technische Zusammenarbeit In the series analytic Natural pesticides from the neem tree and other tropical plants / compiled by H Schmutterer and K R S Ascher Proceedings of the 2nd Internat Neem Conference May 25-28 1983 Rauischholzhausen Federal Republic of Germany 1984 (161) p 445-451 Includes references (NAL Call No DNAL HD1417 B8)

0102
The effects of steroids and azadirachtin on the salivary gland and ovary in ixodid ticks
JIPHA Kaufman W R Devon Pergamon Press Journal of insect physiology Papers presented at the VIII Ecdysone Workshop on Ecdysone From Biosynthesis to Mode of Action March 30-April 2 1987 Marburg Federal Republic of Germany 1988 v 34 (7) p 721-723 Includes references (NAL Call No DNAL 421 J825)

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Effects of three different neem seed kernel extracts and azadirachtin on larvae of different mosquito species
ZANEA Zebitz C P W Hamburg W Ger Paul Parey Journal of applied entomology = Zeitschrift fur angewandte Entomologie Dec 1986 v 102 (5) p 455-463 Includes references (NAL Call No DNAL 421 Z36)

0104
Effects of two triterpenoids from neem on feeding by cucumber beetles (Coleoptera Chrysomelidae) (Acalymma vittatum Diabrotica undecimpunctata howardi Azadirachta indica)
Reed D K JEENA Warthen J D ~Uebel E C ~Reed G L College Park Entomological Society of America Journal of economic entomology Dec 1982 v 75 (6) p 1109-1113 10 ref (NAL Call No 421 J822)

0105
Effects of variously formulated neem seed extracts on Acypthosiphon pisum and Aphis fabae
Schauer M Eschborn W Ger Die Gesellschaft Schriftenreihe der Gesellschaft fur Technische Zusammenarbeit In the series analytic Natural pesticides from the neem tree and other tropical plants / compiled by H Schmutterer and K R S Ascher Proceedings of the 2nd Internat Neem Conference May 25-28 1983 Rauischholzhausen Federal Republic of Germany 1984 (161) p 141-150 ill Includes references (NAL Call No DNAL HD1417 B8)

0106
Effects of volatile and non-volatile fractions of two medicinal plants on germination of Macrophomina phaseolina sclerotia
BMSTA Dwivedi R S Dubey R C Cambridge Eng Cambridge University Press Transactions of the British Mycological Society Sept 1986 v 87 (pt 2) p 326-328 Includes references (NAL Call No DNAL 451 B76)

0107
The efficacy of azadirachtin on putative ecdysteroid-sensitive systems in the ixodid tick Amblyomma americanum L
JIPHA Lindsay P J Kaufman W R Devon Pergamon Press Journal of insect physiology 1988 v 34 (6) p 439-442 Includes references (NAL Call No DNAL 421 J825)

0108
Efficacy of diflubenzuron and neem seed kernel suspension against the tobacco caterpillar Spodoptera litura in tobacco nurseries
PHPRA2 Sitaramaiah S Ramaprasad G ~Joshi B G Bet Dagan Agricultural Research Organization Phytoparasitica 1986 v 14 (4) p 265-271 ill Includes references (NAL Call No DNAL SB599 P53)

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0109
Efficacy of Melia azedarach, Linn (Bakain) and morantel against naturally acquired gastrointestinal nematodes in goats
Akhtar M S Riffat S Faisalabad Faculty of Veterinary Science University of Agriculture Pakistan veterinary journal July 1984 v 4 (3) p 176-179 Includes references (NAL Call No DNAL SF604 P32)

0110
Efficacy of 'neem' cake on fodder production photosynthetic pigments and nematodes associated with oats and its residual effect on cowpea
IJNEDT Jain R K Hasan N New Delhi Nematological Society of India Indian journal of nematology June 1986 v 16 (1) p 98-100 Includes references (NAL Call No DNAL QL391 N415)

0111
Efficacy of nitrification inhibiting agents used for augmenting cotton yield in the Vertisol of Madhya Pradesh
MAAJA Jain S C Coimbatore R Jayarajan The Madras agricultural journal Feb 1984 v 71 (2) p 89-92 Includes 9 references (NAL Call No DNAL 22 M262)

0112
Efficacy of soil amendments in control of root-knot nematodes in tobacco nursery
Gowda D N Shivanandappa N -Karegowda C Bangalore Indian Society of Soil Biology and Ecology Dept of Entomology Univ of Agric Sci Journal of soil biology & ecology Sept 1985 v 5 (2) p 131-133 Includes references (NAL Call No DNAL QL 10 J62)

0113
Efficiency of utilisation of digestible and metabolisable energy for milk production with neem cake (Murrah buffaloes)
Maitra D N IJDSA Roy S -Duttagupta R New Delhi Indian Dairy Association The Indian journal of dairy science Sept 1982 v 35 (3) p 368 372 Includes references (NAL Call No 44 8 IN28)

0114
Electronically recorded disturbances in feeding behavior of Nephotettix virescent (Homoptera Cicadellidae) on neem oil-treated rice plants
JEENAI Saxena R C Khan Z R College Park Md Entomological Societ of America Journal of economic entomology Feb 1985 v 78 (1) p 222 226 ill Includes references (NAL Call No DNAL 421 J822)

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ISBCA Pener M P Shalom U Oxford Eng Pergamon Press Insect biochemistry Paper presented at the Fourth Internationa Symposium on Juvenile Hormones Physiology Biochemistry and Chemistry (JH IV) ' September 7-11 1986 Niagara-on-the-Lake Ontario Canada 1987 v 17 (7) p 1109-1113 Includes references (NAL Call No DNAL QL495 A1I57)

0116
The establishment of a new program in the Philippines for crop and harvest protection
Baiuyut A S Eschborn W Ger Die Gesellschaft Schriftenreihe der Gesellschaft fur Technische Zusammenarbeit In the series analytic Natural pesticides from the neem tree and other tropical plants / compiled by H Schmutterer and K R S Ascher Proceedings of the 2nd Internat Neem Conference May 25 28 1983 Rauischholzhausen Federal Republic of Germany 1984 (161) p 527-530 (NAL Call No DNAL HD1417 B8)

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The establishment of neem plantations in the American tropics
Pliske T E Eschborn W Ger Die Gesellschaft Schriftenreihe der Gesellschaft fur Technische Zusammenarbeit In the series analytic Natural pesticides from the neem tree and other tropical plants / compiled by H Schmutterer and K R S Ascher Proceedings of the 2nd Internat Neem Conference May 25 28 1983 Rauischholzhausen Federal Republic of Germany 1984 (161) p 521-525 Includes references (NAL Call No DNAL HD1417 B8)

0118
Evaluation and utilization of neem cake against the brown planthopper Nilaparvata lugens
Saxena R C Justo H D Jr -Epino P B Eschborn W Ger Die Gesellschaft Schriftenreihe der Gesellschaft fur Technische Zusammenarbeit In the series analytic Natural pesticides from the neem tree and other tropical plants / compiled by H Schmutterer and K R S Ascher Proceedings of the 2nd Internat Neem Conference May 25-28 1983 Rauischholzhausen Federal Republic of Germany 1984 (161) p 391-402 Includes references (NAL Call No DNAL HD1417 B8)

0119
Evaluation and utilization of neem cake against the rice brown planthopper Nilaparvata lugens (Homoptera Delphacidae) (Azadirachta indica)
Saxena R C Justo H D Jr -Epino P B College Park Md Entomological Society of America Journal of economic entomology Apr 1984 v 77 (2) p 502-507 ill Includes references (NAL Call No 421 J822)

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0120
Evaluation of aqueous solution of neem seed extract against Liriomyza sativae and Liriomyza trifolii (Diptera Agromyzidae) (Azadirachta indica)
Webb R E JEENA Hinebaugh M A ~Lindquist R K ~Jacobson M College Park Entomological Society of America Journal of economic entomology Apr 1983 v 76 (2) p 357-362 Includes references (NAL Call No 421 J822)

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Evaluation of certain oilseed cake powders as grain protectant against Sitophilus oryzae Linnaeus
IJENA Bowry S K Pandey N D ~Tripathi R A New Delhi Entomological Society of India Indian journal of entomology June 1984 v 46 (pt 2) p 196-200 Includes references (NAL Call No DNAL 420 IN23)

0122
Evaluation of root bark of Azadirachta indica (Meliaceae)
JPMOE6 Sanyal M Mukherjiand A ~Datta P C Jodhpur Scientific Publishers Journal of plant anatomy and morphology July 1986 v 3 (1) p 13 19 ill Includes references (NAL Call No DNAL QK641 J682)

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El-Saved E I Cairo The Society Bulletin of the Entomological Society of Egypt Economic series 1982/1983 (pub 1985) (3) p 39-47 Includes references (NAL Call No DNAL SB931 A1E5)

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Extractives of seeds of the Meliaceae effects on Spodoptera frugiperda (J E Smith) Acalymma vittatum (F) and Artemia salina Leach
JCECD Mikolajczak K L Reed D K New York N Y Plenum Press Journal of chemical ecology Jan 1987 v 13 (1) p 99-111 Includes references (NAL Call No DNAL QD415 A1J6)

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Krause W Adami M Eschborn W Ger Die Gesellschaft Schriftenreihe der Gesellschaft fur Technische Zusammenarbeit In the series analytic Natural pesticides from the neem tree and other tropical plants / compiled by H Schmutterer and K R S Ascher Proceedings of the 2nd Internat Neem Conference May 25-28 1983 Rauischholzhausen Federal Republic of Germany 1984 (161) p 483 489 Includes references (NAL Call No DNAL HD1417 B8)

0126
Feeding inhibition and mortality effects of neem-seed extract on the Colorado potato beetle (Coleoptera Chrysomelidae)
JEENAI Zehnder G Warthen J D College Park Md Entomological Society of America Journal of economic entomology Aug 1988 v 81 (4) p 1040-1044 Includes references (NAL Call No DNAL 421 J822)

0127
Feeding value of neem seed meal for starter chicks
Sadagopan V R Johri T S ~Reddy V R ~Panda B K Madras India Indian Veterinary Association Indian veterinary journal June 1982 v 59 (6) p 462-465 6 ref (NAL Call No 41 8 IN2)

0128
Field evaluation of neem (Azadirachta indica A Juss) seed kernel extracts against the pod borers of pigeon pea Cajanus cajan (L) Millsp
IJENA Singh R P Singh Y ~Singh S P New Delhi Entomological Society of India Indian journal of entomology Mar 1985 v 47 (pt 1) p 111-112 Includes references (NAL Call No DNAL 420 IN23)

0129
Fungal flora of neem (Azadirachta indica) seeds and neem oil toxicity (Aspergillus aflatoxin)
Sinniah D Varghese G ~Baskaran G ~Koo S H Kuala Lumpur Malaysian Society of Applied Biology Malaysian applied biology June 1983 v 12 (1) p 1-4 Includes references (NAL Call No S295 M3)

0130
Further constituent from the seeds of Melia azedarach
PLMEAA Srivastava S D Stuttgart W Ger Georg Thieme Verlag Planta medica = journal of medicinal plant research Feb 1987 v 53 (1) p 100 101 Includes references (NAL Call No DNAL 450 P697)

0131
Germination of storage of neem (Azadirachta indica A Juss) seed
SSTCB Ezumah B S Zurich International Seed Testing Association Seed science and technology 1986 v 14 (3) p 593-600 maps Includes references (NAL Call No DNAL SB117 S455)

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Germination tests with neem seeds
Fagoonee I Eschborn W Ger Die Gesellschaft Schriftenreihe der Gesellschaft fur Technische Zusammenarbeit In the series analytic Natural pesticides from the neem tree and other tropical plants / compiled by H Schmutterer and K R S Ascher Proceedings of the 2nd Internat Neem Conference May 25-28 1983 Rauischholzhausen Federal Republic of Germany 984 (161) p 531-538 I

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0133
Growth-disrupting effects of azadirachtin on the larvae of the Asiatic corn borer (Ostrinia furnacalis Guenee) (Lepid Pyralidae)
ZANEA Chiu S Zhang X ~Liu S ~Huang D Hamburg W Ger Paul Parey Zeitschrift fur angewandte Entomologie = Journal of applied entomology Apr 1985 v 99 (3) p 276-284 ill Includes references (NAL Call No DNAL 421 Z36)

0134
Growth of Azadirachta indica and Melia azedarach at coastal sand using highly saline water for irrigation
PJBOB6 Ahmad R Khan D ~Ismail S Karachi Pakistan Botanical Society Pakistan journal of botany Dec 1985 v 17 (2) p 229-233 Includes references (NAL Call No DNAL QK1 P3)

0135
The gum exudates from Chloroxylon swietenia Sclerocarya caffra Azadirachta indica and Moringa oleifera
PYTCA Anderson D M W Bell P C ~Gill M C L ~McDougal F J ~McNab C G A Oxford Eng Pergamon Press Phytochemistry 1986 v 25 (1) p 247-249 Includes 20 references (NAL Call No DNAL 450 P5622)

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Histochemistry of paraquat treated wood in Azadirachta indica A Juss (Heartwood formation)
Nair M N B Shah J J Leiden International Association of Wood Anatomists IAWA bulletin new series 1983 v 4 (4) p 249 254 ill Includes references (NAL Call No QK647 I2)

0137
Identification of 24-methylenelophenol from heartwood of Azadirachta indica
PYTCA Banerji R Misra G ~Nigam S K Oxford Pergamon Press Phytochemistry 1987 v 26 (9) p 2644 2645 Includes references (NAL Call No DNAL 450 P5622)

0138
Increasing biological nitrogen fixation in flooded rice using neem
Grant I F Seegers R ~Watanabe I Eschborn W Ger Die Gesellschaft Schriftenreihe der Gesellschaft fur Technische Zusammenarbeit In the series analytic Natural pesticides from the neem tree and other tropical plants / compiled by H Schmutterer and K R S Ascher Proceedings of the 2nd Internat Neem Conference May 25 28 1983 Rauischholzhausen Federal Republic of Germany 1984 (161) p 493-505 Includes references (NAL Call No DNAL HD1417 B8)

0139
Inducing melanotic nodules within the fat body of the last instar larvae of Epilachna varivestis (Coleoptera) by azadirachtin
JIVPA Schluter U Seifert G Duluth Minn Academic Press Journal of invertebrate pathology Jan 1988 v 51 (1) p 1-9 ill Includes references (NAL Call No DNAL 421 J826)

0140
Influence of a neem (Azadirachta indica) windbreak plantation on millet yields and microclimate in Niger West Africa
Long S Persaud N ~Gandah M ~Ouattara M Bozeman Mont Montana State University Cooperative Extension Service Great Plains Agriculture i e Agricultural Council publication Paper presented at the International Symposium on Windbreak Technology June 23-27 1986 Lincoln Nebraska 1986 (117) p 183-184 (NAL Call No DNAL S27 A3)

0141
Influence of agricultural chemicals and neem cake on root nodulation and yield of gram (Beans)
Shingte V V Shinde P B ~Patil P I Pune D R Bapat Journal of Maharashtra agricultural universities May 1984 v 9 (2) p 225 Includes 7 references (NAL Call No S471 I3J6)

0142
Influence of azadirachtin on insect nutrition and reproduction
PISBA Karnavar G K Bangalore The Academy Proceedings Animal sciences - Indian Academy of Sciences May 1987 v 96 (3) p 341-347 Includes references (NAL Call No DNAL QL1 I48)

0143
The influence of azadirachtin on the growth and development of immature forms of the Japanese beetle Popillia japonica
Ladd T L Jr Eschborn W Ger Die Gesellschaft Schriftenreihe der Gesellschaft fur Technische Zusammenarbeit In the series analytic Natural pesticides from the neem tree and other tropical plants / compiled by H Schmutterer and K R S Ascher Proceedings of the 2nd Internat Neem Conference May 25 28 1983 Rauischholzhausen Federal Republic of Germany 1984 (161) p 425-433 Includes references (NAL Call No DNAL HD1417 B8)

0144
Influence of host plant on deterrence by azadirachtin of feeding by fall armyworm larvae (Lepidoptera Noctuidae)
JEENAI Raffa K F College Park Md Entomological Society of America Journal of economic entomology Apr 1987 v 80 (2) p 384 387 Includes references (NAL Call No DNAL 421 J822)

0145
Influence of neem cake on the growth of Azolla pinnata
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APEZAW Pathak P H Krishna S S Tokyo Japanese Societ of Applied Entomology and Zoology Applied entomology and zoology May 1986 v 21 (2) p 347-348 Includes references (NAL Call No DNAL SB599 A6)

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Thampatti K C M Padmaja P Gurgaon Haryana India Potash Research Institute of India Journal of potassium research Sept 1987 v 3 (3) p 115-121 Includes references (NAL Call No DNAL S645 J68)

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Response of the larvae and pupae of the oriental rat flea (Siphonaptera Pulicidae) to chemicals of different chemical types
JEENAI Chamberlain W F Maciejewska J ~Matter J J College Park Md Entomological Society of America Journal of economic entomology Oct 1988 v 81 (5) p 1420-1425 Includes references (NAL Call No DNAL 421 J822)
Tests with 31 different compounds representing six chemical groups plus a miscellaneous group against larvae of the oriental rat flea Xenopsylla cheopis (Rothschild) were used to define toxic action as indicated by the ratio of C (LC for larvae) divided by A (LC for pupae) An insect growth regulator (IGR) was distinguished by a high pupal-to- larval mortality ratio i e when the C/A was < 2 the compound was not active as an IGR but when the C/A was > 4 the compound acted as an IGR The most active compound was a dodecadienoate S-methoprene (isopropyl (2E 4E)-11-methoxy-3 7 11-trimethyl-2 4- -dodecadienoate (S)) which had an LC50 of 0 00011 ppm With the addition of the R isomer the LC50 doubled but most strikingly the C/A increased from 6 to 137 Two of the three diphenylureas acted as IGRs whereas the third diflubenzuron acted as a larval toxicant probably because of the activity on the moult from the second to third instar All compounds tested were more toxic to the oriental rat flea than

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