CHAPTER 2

THE NEEM TREE AND ITS ROLE IN THE ENVIRONMENT

2.1 Historical perspective

The Neem tree in Indian culture has been ranked higher than ''Kalpavriksha'', the mythological wish-fulfilling tree, because of its highly beneficial properties. The tree (Plate 2.1) traditionally occupies an important place in socio – cultural – religious events in many Indian communities. For example, the Hindus generally begin their new year (the first day of Baishakha, mid-April) by eating 5–7 Neem leaves (Plate 2.2) to have good health during the year. This festival is known as Rangali Bihu in the state of Assam and by other names in other states.

Plate 2.1: The Neem Tree

Plate 2.2: The Neem leaves

To generations of Indians, the Neem was known to provide protection from a large number of diseases, and therefore, protecting and planting the Neem tree is not only considered as a sacred duty, but it is encouraged by religious sanction. Brihat Samhita, an ancient Hindu treatise, contains a chapter of verses on plant medicines. It contains recommendations for specific trees to be planted in the vicinity of one's house. The Neem is one tree, which is widely recommended. This can also be borne out by the widely held Hindu belief that one who plants three Neem trees lives after death in Suryalok (Sun World) for three Yugas (epochs) and never goes to hell.

The Neem tree has found mention in every aspect of traditional Indian science and culture. Even in associated Indian astrology, the Neem finds a prominent place. The efficacy of Neem as a medicine has been documented in several different ancient treatises like the Atharva Veda, the Ghrhyasutra, and the Sutragrantha and in the Puranas. In Sanskrit, the language of ancient Indian literature, it is referred to as Nimba, which is a derivative of the term Nimbati swastyamdadati (to give good health). The Neem twig is nature's toothbrush to over 500 million people of India alone. Neem is used in Ayurveda, Unani and Homoeopathic medicine.

However, the advent of the Portuguese, the British and the French colonialists to the Indian subcontinent a few hundred years ago, the traditional practices like using the

Neem leaves to protect crops and stored grains came to be regarded as a backward practices and created a stigma, which led to the abandoning of these ecologically sound practices in fovour of modern chemical products imported from the west. Centuries of knowledge and wisdom accumulated in the minds of people based on the trials and errors of generations were threatened, slowly but surely. However, these were too deeply ingrained in the people to be totally abandoned and they have lingered in the minds of the masses. And to bestow good wishes (of longevity, strength, resourcefulness, and versatility) people still say to their offspring: "May you grow like the Neem tree".

2.2 Global importance of the Neem tree

The Neem tree has been known as the wonder tree for centuries in the Indian subcontinent. It has become important in the global context today because it offers answers to the major concerns facing mankind. Environmentally, the Neem has a reputation as a natural air purifier, exhaling out oxygen and keeping the oxygen level in the atmosphere balanced. Although scientific studies are still lacking, the Neem is reported to have the capacity to purify air and the environment of noxious chemicals discharged from traffic movements. The Neem tree's ability to withstand extreme heat and water pollution is well known from time immemorial though scientific study into these aspects has picked up only recently. It helps to improve fertility of the soil and rehabilitate degraded wastelands.

The ecosystem is a major issue on the global agenda and preserving the ecosystem is a top priority. A UN study predicts that by the years 2050, most of Asia and Africa will be reduced to a desert if the present state of activities continues unabated (Neem Foundation, 1997). Many pests have developed resistance towards the chemical pesticides and may soon be beyond control. The Neem seeds contain bioactive fractions that can help in pest management strategies and help us save the environment. The bioactivity of Neem-based products has been extensively evaluated and proven. Because of the fear of toxic residues in food products associated with the use of chemical pesticides, there is a growing need for pest control agents of plant origin, which do not leave any toxic residues. Though many plant chemicals have been reported to be suitable for this, the Neem is the only plant from which the bio-pesticides are commercially manufactured, found effective, eco-friendly and acceptable to the farmers.

With reference to the global poverty concerns, it is to be noted that poverty is related to (i) non-availability of fertilizers for crop production or pesticides for crop protection, (ii) absence of medical remedies for family welfare measures, (iii) shortage of fuel or firewood for cooking, (iv) want of timber for furniture or dwelling, (v) non-availability of appropriate technology for restoring wastelands, and (vi) the absence of income generation and employment opportunities (Neem Foundation, 1997). In all these respects, the Neem could play an effective role.

According to a recent report by Washington-based International Food Policy Research Institute, the world will be even more unfair in 2020 then at present, with mounting food surpluses in the industrialized world and with chronic instability and food shortages in the south, particularly in the African countries (Neem Foundation, 1997). The US Academy of Sciences has also attached very high importance to the Neem tree (Neem Foundation, 1997). The United Nations declared the Neem as "the tree of the twenty-first century" (Neem Foundation, 1997). All these developments indicate the growing global importance of the Neem tree. As a result, demand for the Neem products, especially the seeds as the basic raw material, has increased by leaps and bounds.

2.3 The Neem tree and its characteristics

2.3.1 General characteristics

Adrien Henri Laurent de Jussies first described the Neem tree in 1830 as *Azadirachta indica*. Its taxonomic position is as follows (Schmutterer, 1995):

Order – Rutales
Suborder – Rutineae
Family – Meliaceae (mahogany family)
Subfamily – Meliooideae
Tribe – Melieae
Genus – *Azadirachta*
Species – *Azadirachta indica*

There are many common names for the Neem tree prevalent in the countries where the tree has been known for a very long time. Some of these names are given in Table 2.1 (Schmutterer, 1995) below.

2.3.2 Botanical characteristics

Azadirachta indica is a fast growing plant that usually reaches a height of 15 – 20 m, and under very favourable conditions, up to approximately 35 – 40 m. As a rule, it is an evergreen tree but under extreme circumstances, such as extended dry periods, it may shed most or nearly all of its leaves. The trunk is relatively short, straight and may reach a girth of 1.5 – 3.5 m. The bark is hard, fissured or scaley, and whitish-gray to reddish-brown in colour. The wood is grayish-white in the outer core and reddish in the inner core becoming reddish-brown after exposure to air. The root system consists of a strong taproot and well developed lateral roots. The lateral surface roots may reach over 18 m. A Neem nursery in Dominican Republic and the planting of Neem trees as avenue trees at Port of Prince, Haiti are shown in Plates 2.3 and 2.4 (Schmutterer, 1995).

The unpaired, pinnate leaves are 20 – 40 cm long and the medium to dark green leaflets, which number up to 31, are approximately 3 – 8 cm long. The terminal leaflet is often missing. The petioles are short. Very young leaves are reddish to purplish in colour. The shape of mature leaflets is more or less asymmetric and their margins are dentate with the exception of their basiscopal half, which is normally very strongly reduced and cuneate.

The white, fragrant flowers (Plates 2.5 and 2.6, Schmutterer, 1995) are arranged in axillary, normally more-or less drooping panicles, which are up to 25 cm long. An individual flower is 5 – 6 mm long and 8 – 11 mm wide. The overy is tricular. There are ten glabrous anthers that are inserted at the base of the flowers. The nectary is annular and fused at the base of the ovary.

Plate 2.3: A Neem nursery in Dominican Republic

Plate 2.4: The Neem as an avenue tree in Port of Prince, Haiti

Plate 2.5: The Neem flowers

Plate 2.6: The Neem flowers from a close distance

The fruits are olive-like drupes (Plates 2.7 and 2.8, Schumetterer, 1995) that vary in shape from elongate oval too nearly roundish and when ripe are 1.4-2.8 x 1.0-1.5 cm. They are green when young and yellowish-green to yellow when mature. The fruit skin is thin and the bitter-sweet pulp is yellowish-white and very fibrous. The seeds measure 0.9-2.2 x 0.5-0.8 cm, and the seed kernals are 0.8-1.6 x 0.4-0.5 cm.

2.3.3 Geographical distribution

The exact region of origin of *A.indica* is not known. Some authors suggest that it may lie in Myanmar (Burma) and/or in parts of southern India, such as Karnataka (Schmutterer, 1995). Others consider large parts of southern and southeastern Asia from Indonesia to Iran as the area of oigin. Nowadays, *A.indica* is widely distributed by introduction, mainly in the drier (arid) tropical and subtropical zones of Asia, Africa, the Americas, Australia and the South Pacific islands. Mountainous areas (> 1000 m) are generally avoided.

A.indica is also a typical tree in the northern parts of Bangaladesh, in many parts of India and Pakistan.Ketkar (1976) reported more than 14 million Neem trees in India. According to other sources, there are more than 20 million in this vast country. The largest number seems to occur in Uttar Pradesh and Tamil Nadu. In Nepal, Neem trees are found in the southern, low-lying areas (Tarai region). In Sri Lanka, it is widespread but most frequent in the drier northern parts of the islands; the cooler central mountainous parts of the country are not suitable for Neem.

It is not known who brought the first neem seeds to the Americas or where they were planted – perhaps by Indian immigrants to the islands of Trinidad and Tobago, or Guyana. At present, the tree is spreading rapidly in the New World. In Haiti, a successful planting program was started about 15 years ago to provide firewood, shade and protection against soil erosion to the ecologically devastated country. Large-scale planting has started recently in Cuba. Some neen trees were planted in Puertorico and on the Virgin Islands, others occur in Montserrat and Antigua.

In the North American continent, individual groups of neem trees occur in and around Miami and in some other parts of Florida. Small experimental plantations are present in southern California, Oklahoma and Arizona (Benge, 1989). *A. Indica* is recorded from low-lying regions of Mexico, southwestern Guatemala, El Salvador,

Plate 2.7: The Neem fruits

Plate 2.8: Ripe Neem fruits on a tree branch

Table 2.1: A few common names of the Neem tree

	Asia, Australia, South Pacific
India	Limba, Limbo, Neem, Nim, Nimb, Nimb, Nimba, Vembu, Vepa, Veppam, etc.
Pakistan	Nimmi
Myanmar	Tamarkha
Sri Lanka	Kohomba
Thailand	Sadao India, Kwinin, Dao
Indonesia	Imba, Mindi, mimbo, Intaran
Malaysia	Mambu
Singapore	Nimbagaha
Iran	Azad-darakht-I-hindi, Nib
Yemen	Meraimarah
Australia	Neem
Papua New Guinea	Neem
Fiji	Neem
	Africa
Nigeria	Babo Yaro, Dogon Yaro
Tanzania	Mwarobaini
Cameroon	Ganye, Marrango
Madagascar	Nim
	Americas
USA	Neem
Latin America (Spanish speaking)	Nim
	Europe
Germany	Indischer Zedrach, Grobblattriger Zedrach, Indischer Flieder, Niem, Nim, Niembaum
France	Azadira d'Inde, Azadirac, Lilas de Indes, Margousier
Portugal	Margosa
Spain	Nim, Margosa
United Kingdom	Indian Lilac, Neem

Costa Rica, Panama, western Colombia, northwestern Venezuala, Bolivia and western Ecuador. In Brazil, neem was planted in various tropical parts of this vast country during the last 12 years. *A. Indica* is also recorded from Surinum and Guyana, where it grows principally in towns along avenues and near houses (Klein Koch,1986).

2.3.4 Environmental influences

The Neem tree is famous for its drought resistance. Normally it thrives in areas with sub-arid to sub-humid conditions, with an annual rainfall between 400 and 1200 mm. Neem can grow in many different types of soil, but it seems to develop best on well-drained, deep sandy soils. A soil pH value of between 6.2 and 7.0 seems to be best for this tree but pH up to 5.9 and 10 may also be tolerated under certain circumstances. Waterlogged and poorly drained soils are unsuitable for neem, as they may lead to rot of the taproot and finally death (Radwanski, 1977; Radwanski and Wickens, 1981).

Neem tree exists at annual temperatures between 21 and 32°C. It can tolerate high to very high temperatures, for instance in northeast and Central Africa where temperatures in the shade can reach 50 °C during the summer. Temperature below 4 °C, and frost, are unfavourable and may result in shedding of leaves and even death of young plants. In the sud-Himalayan zone where temperatures may fall below 0 °C in winter, neem seems to be better adapted to cold conditions but young plants have to be protected by screens. Strong winds in coastal areas and eleswhere can cause considerable damage to young branches and consequently hamper the growth of the trees.

Light is another important environmental factor for Neem's growth. Although young seedling is often raised under shade, mature trees need a lot of light. The net rate of photosynthesis was 10-17 micromol CO_2 $m^{-2}s^{-1}$, which is intermediate to high compared with tropical fruit trees (Gruber, 1991). To enable regular growth and the development of a broad crown with numerous flowers and fruits, the tree also needs sufficient space. Consequently, solitary neem trees are much more productive than others in dense groups or plantations.

There is strong competition by herbaceous weeds and grasses during neem's seedling stage. However, after development of the taproot and numerious lateral roots young neem plants can compete well with wild plants and crops.

2.3.5 Disease resistance

During the last few years, there were alarming reports of the occurrence of a devastating disorder of Neem, mainly in southern and southewestern Niger, northern Nigeria and Mali (Anon., 1992). Neem trees of various ages were affected and suffered from defoliation and dieback of shoots and branches; finally many of them dried up completely. Even trees about 20 years of ages were killed. Trees in plantations were more sensitive than solitary ones. The following are the main diseases suffered by the neem trees: (Schmutterer, 1995):

Bacterial Disease

Pseudomonas azadirachtae. This bacterium was described in India, where it was reported for the first time in Gujarat State. It causes small, translucent, water-soaked, angular leaf spots measuring 4-6 x 2-3 mm. Subsequently, the area surrounding the spots becomes yellowish, then necrotic and finally dries up. A narrow, translucent area of infection of 0.1-0.3 mm on either side of the midrid of the leaves extends into veins and veinlets. The leaves affected by vein blight become yellowish, dry up and fall off. The petioles are also susceptible. The becterium is able to survive on neem bark, leaves and leaf debris (Chakravarti and Gupta, 1975).

Xanthomonas azadirachtii. This pathogan was also described in India. It causes small, translucent, water-saoked spots, which become necrotic from the center. Veins and veinlets, giving an angular appearance, often delimit the coalesced lesions. The infected leaves may eventually become chlorotic, dry up, and fall off prematurely.

Fungal diseases

Pseudocercospora subsessilis. This is probably the most widespread and important fungus attacking neem leaves. It causes an obvious leafspot and shot-hole disease. The infected tissue first becomes light green and later turns brown. As the infected parts separate from the surrounding healthy tissue, the damaged leaflets eventually show holes of different size and shape. This type of damage may be confused with insect damage (Castellani and Mohamed, 1984).

Other fungi. There are some other phytopathogenous fungi attacking neem under field conditions. *Corticium salmonicolor* provokes stem and twig blight. Another twig blight is caused by the *Colletotrichum* state of *Glomerella cingulata. Oidium azadirachte*, a powdery mildew diseses, occurs mainly on the leaves of young plants in damp, shady places (India)(Kausik et al, 1993). Other fungi causing leaf spot are *Curvularia* sp. and *Exserohilum* sp. Stem rot on seedling is caused by *Sclerotium rolfsii*; web blight by *Rhizoctonia solani*; leaf spot by *Colletotrichum capsici*; and a wilt disease by *Fusarium salani*. In India, the fungi causing stem rot, leaf blight, web blight and wilt seem to be rather damaging for neem seedling growing under unfavourable conditions such as a high soil water content (Alam, 1993).

Pests. In neem tree nurseries under humid conditions, some damage is caused by unidentified molluscs, which feed on the leaves.

Acarina: Mites. *Schizotetranychus hindu*stanus, this spider mite species attacks the lower surface of neem leaves and causes light, roundish spots. It is common in the southern parts of India, espiecially during the dry season. Other spider mite species are occasionally observed on old leaves, usually in low population densities (Schmutterer, 1995).

Insects. Neem-wood and bark are considered resistant or semi-resistant to termites, but even so there are some records of damage by this group of social insects, for instance by *Microtermes thoracalis* in Sudan, *Macrotermes bellicosus* in Nigeria and *Odontotermes obesus* in India.

Many grasshopper and locust species in Asia and Africa, espicially the voracious desert locust, *Schistocerca gregaria* are repelled from feeding on neem leaves. The long-horned grasshopper *Idiarthron sp.* causes damage by feeding on neem buds (Radwanski and Wickens, 1981).

2.3.6 Growth characteristics

The neem tree generally grows rapidly under favourable conitions. The pH value and water table in the soil, rainfall, irrigation, nutrients, inter and intra specific competition, mycorrhiza, temperature and genetic factors all play a role. Little is known about the impact of the last, but environmental influences seem to dominate in many regions of the tree's distribution ranges. In very dry areas, in high altitudes at colder temperatures, and in high rainfall area, the growth may be hampered to some extent. At high altitudes (> 1000 m), relatively low temperatures may be the main reason for slow growth. Approximately 130 mm annual rainfall enables *A. indica* to survive but its growth is then very slow. Drought may even lead to death of trees in plantations already 3-5 years after planting due to intraspecies competition for water, especially if spacing between the trees is less than 3 m. Much faster growth occurs with 800-1200 mm annual rainfall, but access to ground water may have the same consequence (Schmutterer,1995).

According to Radwanski (1977), 66 % of the total growth of the neem tree in northern Nigeria takes place during the first 3 years, when a hight of 4-7 m may be reached; during the following 5 years, the height will increase to 5-11 m. Other figures from Africa indicate that in good soils, the trees in a plantation may reach a height of 1.5 m in the first year, 2 m in 2 years and 4.5 m, with a diameter of 7-8 cm, during the fourth year. In Cameroon, 30 year old trees reached a girth of more than 1 m.

Young plants have to be protected against competition from weeds, espetially during the first year after transplanting, or growth is strongly hampered for some time. In India, seedlings, which were weeded, reached a hight of 0.6 - 1.4 m by the end of the second year, but if not weeded these reached only 0.5 - 1 m. Frost may also hamper the growth of young neem plants.

2.4 Medicinal products from the Neem tree

Perhaps, no other plant yields as large a range of useful products as the Neem. Some of the products that have been extracted from the Neem are given in Table 2.2.

Apart from the use of neem products for integrated pest management, in medicine, for soap production, as manure and as inhibitor of nitrification, as the feed for domestic animals, and for population control, there are many other uses for the various parts of this wonderful tree. The following have emerged as other possible uses for the neem tree and its products (Schmutterer, 1995):

Table 2.2: Useful products extracted from the Neem

Anti Malarial	Anti Inflammatory	Anti Fungal
Anti Tuberculosis	Anti Periodontitic	Anti Furancular
Anti Viral	Ameobicidal	Bactericide
Anti Allergic	Diuretic	Insecticidal
Anti Enzemic	Spermicidal	Larvicidal
Anti Scabic	Anti Pyrrhoeic	Piscidal
Anti Dermatic	Anti Seborrhoeic	Anti Cardiac arrest
Anti Gingivitis	Anti Freedant	Nemacticidal

(i) **Timber/Wood:** Owing to the wood's resistance to termites and woodworms, the timber is suitable for use in making poles, fence posts, furniture, door and window frames, carts, axles, yokes, building of boats and ships, oars, boards, door panels, boxes, toys, and various agricultural implements. It is also used as excellent firewood and the smoke is known to drive away mosquitoes.

(ii) **Bark:** The fiber of the bark is utilized for making ropes, but its economic value is considered low (India). Some toothpaste in Europe and India contains extracts of neem bark.

(iii) **Leaves:** The leaves are fed to goats and camels when other feed is scarce. Sometimes they are used as mulch in gardens to improve growth and yield of vegetables and tobacco. Powdered neem leaves are used as a component of various cosmetics (India), and extracts of leaves for hair lotions in Germany.

(iv) **Flowers:** The flowers provide nectar, which is collected by honeybees and converted into neem honey. This honey has a bitter taste and is therefore not popular with consumers.

(v) **Resin (gum):** The neem gum, an exudate from the stems and branches of old trees is used, apart from medicinal purposes, as a stimulant. Silk dyers use it for the preparation of colors.

(vi) **Seed oil:** Apart from use in pest control and soap making, neem oil is used as a material for burning in lamps, and for making candles. Car wheels are greases with it. Purified neem oil is a component of nail polish and other cosmetics.

(vii) **Seed Husk and fruit pulp:** The husk from the seed is used as fuel. The pulp can be utilized for generating methane gas or for the production of alcohol, as it is rich in carbohydrates.

(viii) **Control of wind and water-erosion:** Owing to their foliage, which is not shed even during the dry season in parts of Africa, neem trees are very suitable as wind breaks. They have been planted in hundreds of thousands in West Africa mainly for this purpose. The trees prevent the loss of large amounts of valuable topsoil by wind-erosion, especially during winter, when the strong harmattan wind blows from the north. The superficial parts of the well-developed root system of mature neem trees can prevent or at least reduce the loss of topsoil.

(ix) **Neem as shade tree:** The shade produced by mature neem trees can improve the quality of life for many people in tropical and subtropical countries, especially in places where temperature in the shade reach 40-50^{0}C during summer.

(x) **Neem as an ornamental tree:** In a number of countries neem is planted as an ornamental tree in parks, near public buildings, along roadsides and in gardens (Raju et al, 1993).

(xi) **Reduction of carbon dioxide and production of oxygen:** Millions of neem trees with their intensive assimilation activity may contribute at least to some extent to the reduction of carbon dioxide in the air and consequently slow down global warming (due to the greenhouse effect). The steady production of oxygen by the foliage is another positive feature of the tree, which is therefore sometimes called an air purifier.

(xii) **Tolerance against air pollution:** Recently it was observed in India that neem trees tolerate heavy pollution of air by CO_2, SO_2 and other gases in cities with heavy car traffic, whereas other well-known ornamental trees are badly damaged by these pollutants.

(xiii) **Agroforestry:** Neem is generally considered as among the less suitable candidates for agroforestry as it may strongly reduce yields of crops grown alongside it, owing to competition for water. When growing together with other tree species it may play a useful role in preserving or even improving the fertility of the soil.

2.5 Chemical composition of Neem Leaves

The composition of fresh Neem leaves with respect to various chemical constituents is well known (Neem Foundation, 1997) and is presented in Table 2.3. Schmutterer (1995) has given the average chemical constituents of the Neem leaves as given in Table 2.4.

The properties of the various segments of the Neem tree are due to a multitude of ingredients. The main chemical ingredients consist of 3 or 4 related components, backed up by about 20 others. These belong to a general class of natural products called "triterpenes", or more specifically "limonoids"; the main ones present in Neem are azadirachtin, salannin, meliantriol, nimbin and nimbidin. For extracting the active principles, the plant materials (seed, leaves, bark) should be dried in a shade to avoid decomposition. Generally methanol, ethanol, or acetone is used as the extractant (Schmutterer, 1995). Analysis and separation of the active components is very difficult because of the complex mixtures consisting of a few major and numerous minor components, all of them being very similar in polarity. Chromatographic methods are the only way to isolate pure components.

Structures of the main active components of the Neem and their important characteristics are given below.

Azadirachtin. This has been isolated and identified as the chief ingredient in Neem responsible for its pesticidal activity. It has the following characteristics:

Empirical formula: $C_{35}H_{44}O_{16}$
Molecular weight: 720
Chemical family: Tetranortriterpenoids

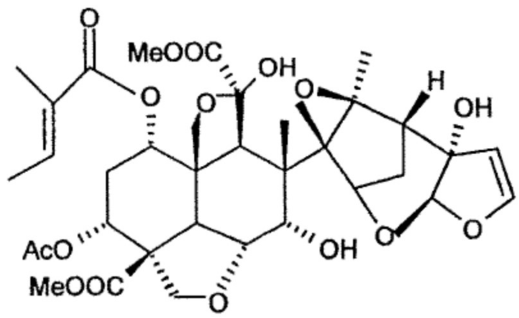
Table 2.3: Chemical composition of Neem leaves

Moisture	59.4 %	Proteins	7.1 %
Fat	1.0 %	Fiber	6.2 %
Carbohydrates	22.9 %	Minerals	3 .4 %
Calcium	510 mg/100g	Phosphorous	80 mg/100g
Iron	17 mg/100g	Thiamine	0.04 mg/100g
Niacin	1.40 mg/100g	Vitamin C	218 mg/100g
Carotene	1998 microgram/100g	Calorific value	1290 kcal/kg
Glutamic acid	73.30 mg/100g	Tyrosine	31.50 mg/100g
Aspartic acid	15.50 mg/100g	Alanine	6.40 mg/100g
Proline	4.00 mg/100g	Glutamine	1.00 mg/100g

Table 2.4: Chemical constituents of the Neem leaves

	Constituent	Percentage		Constituent	Percentage
1.	Crude protein	12.40 – 18.27	5.	Total ash	7.73 – 18.37
2.	Crude fibre	11.40 – 23.08	6.	Calcium	0.89 – 3.96
3.	N-free extract	43.32 – 66.60	7.	Phosphorous	0.10 – 0.30
4.	Ether extract	2.27 – 6.24			

It has the structure



Azadirachtin

Azadirachtin acts by (i) Disturbing or inhibiting the development of the egg, larvae, or pupae, (ii) Blocking the molting of larvae or nymphs, (iii) Disturbing mating and sexual communication, (iv) Repelling larvae and adults, (v) Deterring females from laying eggs, (vi) Sterilizing adults, and (vii) Deterring feeding.

It has the advantages of broad spectrum activity, no known insecticide resistance mechanism, compatible with many commercial insecticides and fungicides, new mode of action with possible multiple sites of attack, classified as a biological insecticide for registration purposes, low use rate, compatible with other biological agents for IPM programme, not persistent in the Environment, minimal impact of non-target organisms, formulation flexibility, no re-entry restrictions, supply available from pre-existing infrastructure, application flexibility - can be sprayed or drenched, non-phytotoxic formulation.

The Neem has aroused a lot of interests in the scientific circle because of its multidimensional properties. The literature is full of reports describing the use of the tree and its parts for a very large number of different uses. A selection of recent literature is given in Table 2.5.

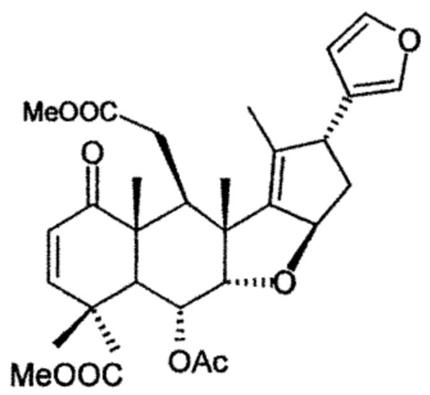
Nimbin and Nimbidin. These two have been isolated and identified as the chief ingredients in Neem responsible for its antifeedant and bacterial activity. Nimbin has the following characteristics:

Empirical formula: 466.67

Molecular weight: $C_{30}H_{42}O_4$

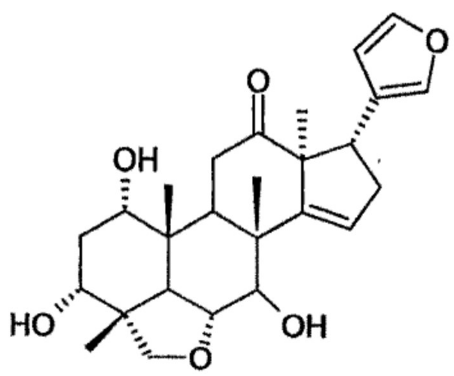
Chemical family: Tetranortriterpenoids

It has the structure



Nimbin

Nimbidin has the structure



Nimbidin

with the following properties

Empirical formula: $C_{25}H_{32}O_6$

Molecular weight: 428.30

Chemical family: Tetranortriterpenoids

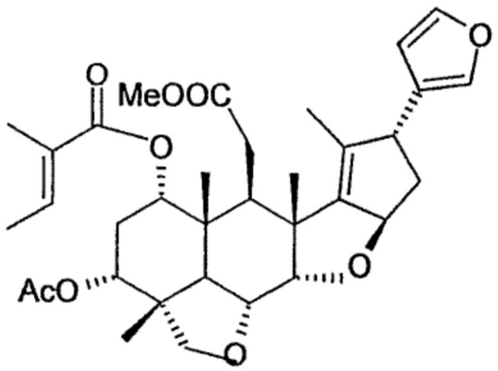
Both Nimbin and Nimbidin have the following properties

(i) Very low toxicity to mice, rats, and hamsters
(ii) Active against certain *Staphylococcus* strains and to *Plasmodium falciparum*
(iii) Cytotoxic towards human tumor cell lines, but not mutagenic in the Ames test.

Salannin. Salannin is the first compound of this group isolated from neem leaf extract, responsible for its antifeedant activity comparable to that of aza group. It has the following characteristics:

Empirical formula: $C_{31}H_{48}O_6$
Molecular weight: 516.98
Chemical family: Tetranortriterpenoids

It has the structure



Salannin

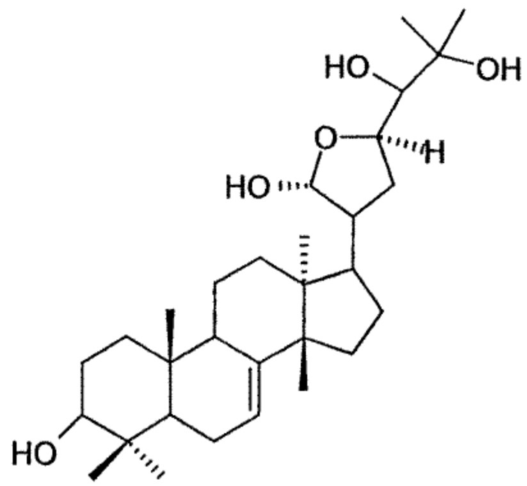
It has the following properties

(i) Antifeedant activity to termites
(ii) Growth disrupting activity to various insects

Meliantriol. The triterpenoids meliantriol isolated from the fruits of neem. It has very strong antifeedant properties against desert locust, *Schistoceria gregaria*. The meliantriol has the following characteristic,

Empirical formula: $C_{31}H_{52}O_5$
Molecular weight: 504.20
Chemical family: Tetranortriterpenoids

Its structure is



Meliantriol

It has the following properties

(i) Growth-inhibitory effect on various insects
(ii) Larvicidal effects on various insects

2.6 Objectives of the present work

One of the ticklish problems faced by a large number of industries is the safe disposal of effluents containing a large number of toxic and aesthetically undesirable pollutants. The industries, which are the cornerstone of the civilization today, such as the petroleum refineries, the iron and steel manufacturing units, the cement factories, the textile and dye manufacturing industries, the pulp and paper mills, the tanneries, the electroplating factories, the distilleries, etc., have been responsible in a way in vitiating our precious air, water and land resources. The industries produce very useful products without which life on earth will be impossible. At the same time, they spew out chemicals into the atmosphere through gaseous emissions, liquid effluents and solid wastes, which have threatened the safe existence of humanity.

In most cases, the pollutants are present in trace amounts, but through the process of biomagnification and other ways, they can be the invisible enemies of animal and plant kingdom. Some of the pollutants are acutely toxic, others are carcinogens and mutagens, and some others are nearly indestructible in nature. These can no longer be ignored even if their concentration in air, water and soil may not be the cause for immediate alarm.

The tremendous increase in the use of heavy metals over the past few decades has inevitably resulted in an increased flux of metallic substances to the aquatic environment. The metals are of special concern because they are persistent. Industrial wastes constitute the major source of various kinds of metal pollution in natural water. The important toxic metals like Cd, Cr, Ni, Pb and Hg, find their way to the water bodies through wastewater from metal plating industries, industries of cadmium-nickel batteries, phosphatic fertilizer, mining, pigment stabilizer, alloys, and electroplating, corrosion of galvanized piping, etc. Similarly, a large number of organic substances find their way into the environment from different industrial and other sources. Many of these organic compounds are as harmful as the toxic metals. They also impart undesirable color, odor and taste to water.

Removal of organic and inorganic pollutants from wastewater by adsorption on activated carbon and synthetic resins has been widely studied. Though activated carbon is an ideal adsorbent for organic matter due to its organophillic character, high cost of preparation and regeneration of activated carbon and synthetic resins prohibit their large-scale use in wastewater treatment. This has prompted the use of many novel materials as adsorbents with a two-fold objective – to replace activated carbon with cheaper alternatives and to utilize various waste products for the purpose. Thus, fly ash, peat, lignite, bagasse, wood dust, saw dust, fertilizer waste, waste tea leaves, waste rubber tyre, coconut shell, etc., have been used either directly or through carbonization for adsorptive scavenging of various pollutants. Use of low cost materials such as rice husk, cotton bale, etc., has also been reported (Pollard et al., 1992). However, adsorbent-grade activated carbon is cost-prohibitive and regeneration of the used carbon is not straight forward (McKay, 1982).

It is assumed that Neem Leaf powder has the potential to be used as such an adsorbent. With this hypothesis, the following objectives have been formulated:

a) To design an adsorbent from dry, mature Neem leaves by converting the same into a powder form to be known as Neem Leaf Powder (NLP). The powder is to be thoroughly washed to remove all soluble impurities and to be fractionated by sieving.

b) To characterize the adsorbent (NLP) by spectroscopic and other methods.

c) To use the NLP for removal of various micro-pollutants such as dyes and metal ions in aqueous medium by using synthetic effluents.

d) To study the influence of various factors such as concentration, pH, temperature, and agitation time on the adsorbate-adsorbent equilibrium in a batch process.

e) To test the validity and applicability of different adsorption isotherms to the adsorption equilibrium and hence to find out adsorption affinity and adsorption capacity of the NLP for the pollutants.

f) To study the kinetics of adsorption processes with a view to computing the adsorption rate constants.

g) To validate the adsorption processes by determining the thermodynamic parameters, ΔH^o, ΔS^o and ΔG^o.

h) To carry out a column study for obtaining the break-through curves with respect to the various pollutants and hence to find out the practical applicability of the adsorbent.

i) To carry out desorption studies with respect to each pollutant so that the pollutant can be recovered and the adsorbent can be regenerated.

Table 2.5: A selection of literature reporting on various uses of the Neem tree and its parts.

Author (s)	Subject matter	Area
Abatan et al., 1986	Screening Azadirachta indica and Pisum sativum for possible antimalarial activities	Neem tree
Alam et al., 1989	Treatment of diabetes through herbal drugs in rural India.	Neem tree
Amadioha, 2000	Controlling rice blast in vitro and vivo with extracts of azadirachta indica	Leaf, Seed, bark
Akudugu et al., 2001	Cytotoxicity of azadirachtin A. in human glioblastoma cell lines	Leaf, Seed, bark
Bhatnagar et al., 1993	Neem Leaf Extracts (Azadirachta Indica) inhibit biosynthesis in aspergillus flavus and A. parasiticus.	Leaf
Banarjee et al., 1992	Azadirachtin A interferes with control of serotonin pools in the neuroendocrine system of locusts.	Neem tree
Banarjee, S. 1994	Serotonin immunoreactivity and its content in Azadirachtin treated locusts.	Neem tree
Chattopadhyay et al., 1992a	Active effects of Azadirachta indica leaves on some biochemical constituents of blood in rats.	Leaf
Chattopadhyay et al., 1992b	Hepatoprotective activity of azadirachta indica leaves on paracetamol induced hepatic damage in rats.	Leaf
Chattopadhyay et al., 1994	A comparative evaluation of some antiinflammatory agents of plant origin.	Neem tree
Chinnassamy et al., 1993	Toxicological studies on debitterized neem oil.	Neem oil
Dhar et al., 1996	Effect of volatiles from neem and other natural products on gonotrophobic cycle and oviposition of Anopheles stephensi and An. culicifacies (Diptera; culicidae)	Neem tree
Dunkel et al., 1995	Influence of insecticidal plant materials used during storage on sensory attributes and instrumental hardness of dry edible beans (phaseolus vulgairs L.).	Neem tree
Garg et al., 1993a	The gastric antiulcer effects of the leaves of the neem tree.	Leaf
Garg et al., 1993b	Identification and characterization of the immunomodulatory fraction from neem-seed extract responsible for long-term antifertility activity after intrauterine administration.	Neem seed

Author (s)	Subject matter	Area
Garg et al., 1994	Comparison of extraction procedures on the immunocontraceptive activity of neem seed extracts	Neem seed
Garg et al., 1993c	Studies on the contraceptive efficacy of Praneem polyherbal cream.	Neem tree
Gupta et al., 2004	Protective role of extract of neem seeds	Seed
Govindachari et al., 1999	Triterpinoidal constituents of an aqueous extract from neem kernals	Neem kernel
Garg et al., 1991	Mechanism of anti-ulcer action of leaves of the neem tree.	Leaves
Gajalakshmi & Abbasi, 2003	Fertilizer cum pesticide vermicompost as a source of neem leaves	Leaf
Johnson and Morgan, 1997	Comparison of chromatographic systems for triterpenoids from neem (azadirachta indica)	Leaf, Seed, bark
Juneja et al., 1994	Neem Oil inhibits two-cell embryo development and trophectoderm attachment and proliferation in vitro.	Neem oil
Jaiswal et al., 1994	Anxiolytic activity of Azadirachta indica leaf extract in rats.	Leaf
Jones el al., 1994	Sexual development of malaria parasites is inhibited in vitro by neem extract and its semi-synthetic analogues.	Neem tree
Jongen & Koeman, 1983	Mutagenicity testing of two tropical plant materials with pesticidal potential in Salmonella typhimurium: Phytobacca dodecandra berries and oil from seeds of Azadirachta indica.	Neem oil
Khan & Awasthy, 2003	Cytogenetic toxicity of neem	Leaf, Seed, bark
Kumar et al., 1996	Extract of limonoids from the seeds of azadirachta indica	Seeds
Koley & Lal, 1994	Pharmacological effects of Azadirachta indica (neem) leaf extract on the ECG and blood pressure of rat.	Leaf
Kroes et al., 1993	Impact of the preparation process on immuno-modulatory activities of the Ayurvedic drug Nimba arishta. Phytochemistry	Neem tree
Khanna et al., 1995	Antinociceptive action of Azadirachta indica (neem) in mice: possible mechanisms involved.	Neem tree

Author (s)	Subject matter	Area
Khan et al., 1991	The effect of petrol ether - extract of neem leaves on fungi pathogenic to humans in vitro and in vivo.	Leaf
Khan & Wassilew, 1987	The effects of raw material from the neem tree, neem oil and neem extracts on fungi pathogenic to humans.	Neem oil, extract
Khalid et al., 1989	Gedunin is molecule responsible for anti-malarial activity, found in bark of neem tree.	Neem bark
Larson, R.O. 1987	Development of Margosan-O, a pesticide from neem seed	Neem seed
Larson, R.O., 1993	Neem: the tree for today, tomorrow and beyond	Neem tree
Mohammad Akhtar, 1998	Biological control of plant- parasite nematodes by neem products in agricultural soil	Leaf, Seed, bark
Mateenuddin et al., 1986	Assessment of estrogenicity of neem (Azadirachta indica) leaf extracts in rats	Leaf
Mukerjee & Talwar, 1996	Termination of pregnancy in rodents by oral admin-istration of Praneem, a purified neem seed extract.	Neem seed
Nagpal et al., 1995	Control of mosquitoes breeding using wood scrapings treated with neem oil.	Neem oil
Parida et al., 2002	Inhibitory potential of neem leaves on dangu virus type-2 replication	Leaf
Rojanapo et al., 1985	Mutagenic and antibacterial activity testing of nimbolide and nimbic acid.	Neem tree
Paranjapo & Paranjapo, 1993	Use of neem oil (azadirachta indica) suppositories as contraceptive.	Neem oil
Pai et al., 2004	Evaluation of antiplaque activity of azadirachta Indica leaf extract gel- a six week clinical study.	Neem tree
Pillai et al., 1978a	Anti-gastric ulcer activity of nimbidin.	Neem ingredient
Pillai et al., 1980	Analgesic and anti-pyretic actions of nimbidin.	Neem ingredient
Pillai & Santhakumari, 1981a	Anti-arthritic and anti-inflammatory actions of nimbidin.	Neem ingredient
Pillai & Santhakumari, 1981b	Hypoglycemic activity of Melia azadirachta Linn (Neem).	Neem

Author (s)	Subject matter	Area
Pillai & Santhakumari, 1984a	Toxicity studies on nimbidin, a potential anti-ulcer drug.	Neem ingredient
Pillai & Santhakumari, 1984b	Effects of nimbidin on acute and chronic gastro-duodenal ulcer models in experimental animals.	Neem ingredient
Pillai & Santhakumari, 1984c	Some pharmacological actions of 'nimbin' - a bitter principle of azadirachta indica - A juss. (Neem).	Neem ingredient
Palanisamy & Kumar, 1997	Effect of position, size of cutting and environmental factors on adventitious rootng in neem (azadirachta indica)	Leaf, Seed, bark
Pillai et al., 1978a	Anti-gastric ulcer activity of nimbidin.	Neem tree
Pillai et al., 1980	Analgesic and anti-pyretic actions of nimbidin.	Neem tree
Pillai & Santhakumari, 1981a	Anti-arthritic and anti-inflammatory actions of nimbidin.	Neem tree
Pillai & Santhakumari, 1981b	Hypoglycemic activity of Melia azadirachta Linn (Neem).	Neem tree
Pillai & Santhakumari, 1984a	Toxicity studies on nimbidin, a potential anti-ulcer drug.	Neem tree
Pillai & Santhakumari, 1984b	Effects of nimbidin on acute and chronic gastro-duodenal ulcer models in experimental animals.	Neem tree
Pillai & Santhakumari, 1984c	Some pharmacological actions of 'nimbin' - a bitter principle of azadirachta indica - A juss. (Neem).	Neem tree
Prakash et al., 1991	Effect of ethanolic extract of Azadirachta indica seeds on organs in female rats.	Neem seed
Prasad et al., 1993	Research on two medicinal plants from 'Ayurvedic' system of medicine Azadirachta indica A juss and Melia Azadirach Linn. Their past, present and future.	Neem tree
Ramakrishna et al., 1993	Cold processing neem seed.	Neem seed
Rao et al., 1969	Study of antiviral activity of tender leaves of margosa tree (Melia azadirachta) on vaccinia and variola virus - A preliminary report.	Leaf
Rao et al., 1995	Development of combined use of neem (Azadirachta indica) and water management for the control of culicine mosquitoes in rice fields.	Neem tree

Author (s)	Subject matter	Area
Rao et al., 1986	In vitro antibacterial activity of neem oil.	Neem oil
Ray, A. 1992	Anti-stress effects of some indigenous drugs: Role of Dopamine.	Neem tree
Riar et al., 1988	Mechanism of anti-fertility action of neem oil.	Neem oil.
Riar et al., 1991	Antifertility activity of volatile fraction of neem oil.	Neem oil
Riar et al., 1993	Neem as a contraceptive.	Neem tree
Raizoda et al., 2001	Azadirachtin, a neem biopesticide subchronic toxicity assesment in rates	Leaf, Seed, bark
Ragasa et al., 1997	Extraction of tetratriterpenoids from azadirachta indica	Leaf, Seed, bark
Raval et al., 2003	Necessity of a two- stage process for the production of azadirachtin- related limonoids in suspension cultures of azadirachta Indica.	Neem tree
Sidhu et al., 2004	Variability of triterpenoids	Leaf, Seed, bark
Salehzadeh et al., 2003	Anti mitotic effect of neem seed	Leaf, Seed, bark
Shafie & Basedow, 2003	Insect control properties of different neem trees	Leaf, Seed, bark
Siddique et al., 2000	Extract of two tetratriterpen oids from azadirachta indica.	Leaf, Seed, bark
Schaaf et al., 2000	Rapid and sencitive analysis of azadirachtin and related triterpenoids from neem (azadirachta indica)	Leaf, Seed, bark
Sharma et al., 1998	Two nonterpenoid constituents from azadirachta indica leaves	Leaf
Siddique et al., 1998	Tetracyclic triterpenoids of the fruit coats of azadirachta indica	Fruit coats
Sundaram et al., 1995	Uptake, translocation, persistence and fate of azadirachtin in aspen plants and its effect on pestiferous two spottedspider mite	Leaf, Seed, bark
Santhoshumari et al., 1990	Hypoglycemic effect of a few medicinal plants.	Neem tree

Author (s)	Subject matter	Area
Sawanobori, H. 1978	Melia azadirachta (neem) extracts for skin cosmetics.	Neem tree
Saxena et al., 1985	Neem seed derivatives for preventing rice tungro virus transmission by the green leafhopper.	Neem seed
Schmutterer, 1992	"Neem - A Tree for Solving Global Problems"	Neem tree
Schmutterer, 1985	Natural pesticides from the neem tree and other tropical plants.	Neem tree
Schneider, 1986	The effect of neem leaf extracts on Epilachna varivestis and Staphylococcus aureas.	Neem leaf
Seddiqui et al., 1992	Constituents of Azadirachta indica: isolation and structure illucidation of a new antibacterial tetranortriterpenoid, mahmoodin, and a new protolimonoid, naheedin.	Neem tree
Sen et al., 1993	An experimental evaluation of azadirachta indica (neem) in normal and stressed rats and adaptogenic effects.	Neem tree
Shah et al., 1958.	Clinical trials with parenteral sodium nimbidinate, a new diuretic.	Neem tree
Shankaranarayan, 1978	Effect of neem oil and its constituents on cotton pellet inflammation.	Neem oil
Sharma & Saksena, 1959	Sodium nimbidinate in vitro study of its spermicidal action.	Neem tree
Sharma et al., 1983	Effect of neem oil on blood levels of normal, hyperglycemic and diabetic animals.	Neem oil
Sharma et al., 1987	Antiandrogenic properties of neem seed oil (azadirachta indica) in male rat and rabbit.	Neem seed oil
Sharma et al., 1993	Mosquito repellent action of neem (Azadirachta indica) oil.	Neem oil.
Sharma & Dhiman, 1993	Neem oil as a sand fly (Diptera psychodidae) repellent.	Neem oil
Sharma et al., 1993	Effectiveness of neem oil mats in repelling mosquitoes.	Neem oil
Singh et al., 1987	Azadirachta indica neuro-psychopharmacological and anti-microbial studies	Neem tree

Author (s)	Subject matter	Area
Singh & Sastry, 1981	Anti-microbial activity of neem oil.	Neem oil
Singh et al., 1979	Melia azadirachta in some common skin disorders, a clinical evaluation. Antiseptic	Neem tree
Sinha et al., 1984	Neem oil as a vaginal contraceptive.	Neem oil
Sinha et al., 1984	Anti implantation effect of neem oil	Neem oil
Sinniah & Baskaran, 1981	Margosa oil poisoning as a cause of Reye's syndrome.	Neem oil
Sinniah et al., 1985	Investigation of an animal model of a Reye-like syndrome caused by margosa oil.	Neem oil
Skula et al., 1973	Preliminary clinical trials on antidiabetic actions of Azadirachta indica.	Neem tree
Sadre, et al., 1984	Male anti-fertility of Azadirachta indica in different species.	Neem tree
Sankaram et al., 1987	Chemistry, biological activity and utilization aspects of some promising neem extractives.	Neem tree
Thompson et al., 1978	Cardiovascular effects of Azadirachta indica extract	Leaf, seed, bark
Tirimanna, A.S.L. 1984	Surveying the chemical constituents of neem leaf by two-dimensional thin layer chromatography	Leaf
Thind and Dahiya, 1977	Inhibitory effects of essential oils of four medicinal plants against keratinioholic fungi	Neem tree
Thaker and Anjaria, 1986	Antimicrobial and infected wound healing response of some traditional drugs.	Neem tree
Tewari et al., 1989	Biochemical and Histological studies of reproductive organs in cyclic and ovariectomized rats supporting a non-hormonal action for neem oil	Neem tree
Tewari et al, 1986	Post-coital antifertility effect of neem oil in female albino rats	Neem oil
Tiwary et al., 1999	Biosorptive behaviour of azadirachta indica bark for Hg^{+2}, Cr^{+6} and Cd^{+2} toxic ions from aqueous solutions	Neem bark
Tandan et al., 1990	Pharmacological effects of azadirachta indica leaves	Leaves

Author (s)	Subject matter	Area
Tandan et al., 1988	Increasing action of vascular permeability by azadirachta indica seed-oil (neem oil).	Neem oil
Talwar et al., 1997	Induced termination of pregnancy by purified extracts of Azadirachta Indica (Neem): mechanisms involved.	Neem tree
Talwar et al., 1995	Safety of intrauterine administration of purified neem seed oil (Praneem Vilci) in women and effect of its co-administration with the heterospecies dimer birth control vaccine on antibody response to human chorionic gonadotropin	Neem seed oil
Upadhyay & Arora, 1975	Sporostatic nature of neem smoke and its possible ecological influence on air fungal flora of a polluted site	Leaf, seed, bark
Unander, 1992	"Neem - A Tree for Solving Global Problems	Neem tree
Upadhyay, et al., 1992	Immunomodulatory effects of neem (Azadirachta indica) oil.	Neem oil
Upadhyay et al., 1990	Antifertility effects of neem (Azadirachta indica) oil by intrauterine administration: a novel method for contraception.	Neem oil
van der Nat et al., 1986	Ethnopharmacological study of azadirachta indica. A conceptual evaluation	Leaf, seed, bark
van der Nat et al., 1987	Immunomodulatory activity of aqueous extract of Azadirachta indica stem bark.	Stem bark.
van der Nat et al., 1989	Characterization of anti-complement compounds from Azadirachta indica	Leaf, seed, bark
Wali et al., 1993	Anti inflammatory effect of neem leaf extract	Leaf
Wolinsky et al., 1996	The inhibiting effect of aqueous Azadirachta indica (neem) extract upon bacterial properties influencing in vitro plaque formation	Leaf, seed, bark