Environmental importance and vegetative propagation of *Azadirachta indica* A.juss (Neem) by stem cuttings and air layering in Sudan

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عبد الحفيظ الرحلة
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**English Abstract**

Environmental importance and vegetative propagation of *Azadirachta indica* A.juss (Neem) by stem cuttings and air layering in Sudan.

The study is aimed at the documentation of the environmental importance of Neem tree (*Azadirachta indica*) and to investigate it’s vegetative propagation through stem cuttings and air layering.
The environmental importance was evaluated from the available literature. It was evident that Neem tree has multiple environmental benefits. Unlike many species, it can resist pollution and survives in such areas. Its uptake of oxygen helps in keeping the oxygen and Carbon dioxide level in the atmosphere well balanced. Neem grows in arid and semiarid lands and it can combat soil erosion and sand movement. Also, Neem is a suitable shelterbelt tree as used in many countries, and an excellent tree for urban planting as it provides shade and purifies air from dust and suspended elements. Neem is considered as a source of renewable energy for its rapid growth and sprouting ability after defoliation in the winter season. Also, the different parts of the trees contain compounds with proven medicinal and pesticidal values. For ecologically sound pest management, Neem has been identified as a source of environmentally friendly pesticide.

The vegetative propagation experiments were conducted at Khartoumm Forest Nursery in Elmogran and in a nursery at the Faculty of Forestry Shamabt. The stem cuttings were 20-23cm long, 05-1.3 cm in diameter. The effect of origin of cutting (sprouts or mature branches), defoliation of branches before the excision of cutting and the concentration of IBA on shoot flushing and rooting were assessed. Shoot flushes appeared in most of the cuttings a week after planting and decreased after the fourth week. Cuttings from mature upper branches showed 3.3 % rooting while that from sprouts failed to form roots. The 0.1% IBA showed the highest rooting percentage in comparison to other concentrations. Defoliation treatment resulted in the decrease of rooting percentage. The end of cuttings which failed to form roots turned black and rottened. The confirmatory experiment in shambat showed the rottening may not be due to fungal infection. It also revealed that high humidity increased rooting percentage.

Air layering in sprouts and upper mature branches was studied on trees at Elmogran Nursery. It was assessed on branches of 0.5-1.3 cm in diameter and 50-110 cm long. A 2.5-3.0 length of bark was scalped out from the selected branches and was wrapped with moist sand. The effect of origin of cutting, the concentration of IBA and defoliation treatment on rooting percentage of layering were evaluated. Layers in sprouts showed 41% of success while those on upper branches showed 27%. The 0.1% IBA showed the highest rooting percentage in comparison to other concentrations (0.3% & control). Defoliation treatment resulted in the decrease of rooting percentage of layers.
الخلاصة

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المواسير والترقية الساقية العقلية طريق

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البيئة على الحفاظ بالنيم أشجار تنلعبة الأرواحية دور تقصى

هوية هذه من أهدافها.

لتجرأ الأساليب

المواسير الساقية العقلية طريق الخضراء وتكتيرها

البيئة إمكانية المواسير من الترقية.

البحث الكالة

الصحيحة والجافة شبيهة النهار والماء

لمنموة النيم الشجرة المومية

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Chapter 1
INTRODUCTION

1.1 Background

The Forest tree species *Azadirachta indica* A. Juss, commonly known as Neem, is a multipurpose tree. It was introduced from India to Sudan as one of the first African countries to have it. It is a member of the family Meliaceae (Mohogany family), and has three synonyms: *Melia azadirachta* (L.), *Melia indica* (A.juss) BRNDIS, *Antennae azadirachta* (L.) Adelb. There is frequent confusion of *A. indica* with *Melia azadirachta* as they are closely related taxonomically and phytochemically (Schmutterer, 1995).

Neem trees are attractive broad-leaved evergreens that can grow up to 30m tall and 2.5m in girth, their spreading branches form rounded crowns as much as 20m across (Elteraify, 1996). They remain in leaf
except during extreme drought. The short, usually straight trunk has a moderately thick, strongly furrowed bark. The roots penetrate the soil deeply, at least where the site permits (NRC, 1992). Flowering occurs between March and September and fruiting takes place between April and October (Hamza, 1990). The fruit is a globose drupe 1cm across surrounded by fleshy yellow orange pulp turning brown, wrinkled when ripened.

Neem tree is a light demander and it has great capacity for pushing through thorny scrub. It is sensitive to weeds and frost especially in the seedling stage (Bogra, 1993). However, Puri and Swamy (2001) inferred that it can tolerate soil resources depletion caused by competitor species. It coppices well and produce root suckers especially in dry localities. The tree is drought resistant and it can thrives in dry areas with sub arid to sub humid conditions, annual rainfall between 400-1200m, and it grows best on deep, well drained sandy soils (NRC,1992, Schmutterer, 1995 ). Soil pH values between 6.2 and 7.00 seems to be the best for neem tree, but can tolerate pH from 5.00 and 9.00 and even 10 under certain circumstances. (Elteraify, 1996 ). Neem can exist at annul mean temperature between 21°C and 32°C, it can tolerate high temperatures, but it cannot tolerate low temperatures which may result in shedding of leaves or even death of young trees (Rundhawa and Parma, 1993).

Neem appears to be a good candidate for planting throughout most of the warmer parts of the world. It grows vigorously in many types of semiarid and tropical sites. It is a multi purpose tree species that provides villagers with various products from which to drive an income during the years when the trees are maturing. This feature is important for motivating enthusiastic local tree planting (NRC, 1992). Neem is regarded as valuable forestry species in India and parts of Africa, but even there it could become more widely planted. It is also promising for planting in areas now suffering desperate fuel wood shortages. It is useful as a windbreak, specially around cities, and it can grow in (and perhaps neutralize ) acid soils that plague much of the tropics (NRC, 1992). Also, it is valued for its shade as the extended branching is excellent for parks, road sides villages, streets, courtyards and shelterbelts.

The commercial use of the species is based on the production of the insecticides, Azadirachtin, the main active ingredient in the seed extract (Ermel et al, 1986 and Ermel, 1996). It is the abundant source of environmentally safe insecticides for pest management in staple food crops (Saxena, 1996). Other valuable product is the Neem oil which can be used for lamps as well as mosquito net impregnation. Firewood and charcoal are additional benefits derived from Neem trees (Maramorosch, 1996).

Planting neem on large scales might improve the declining ecosystems of many areas considered fairly hopeless. In Haiti and other countries where the tree cover has been stripped away, vast plantings of Neem trees would likely bring environmental benefits, among them fewer floods, less siltation and reduced erosion (NRC, 1992 ). In agroforestry, Neem plantings can be integrated with grazing and local farming practices to restore and maintain soil fertility (Maramorosch et al., 1999).
As already noted, Neem was introduced to Africa earlier last century. It is now well established in at least 30 countries, particularly those in the regions along the Sahara’s southern fringe, where it has become an important provider of both fuel and lumber (NRC, 1992). Over the last century or so, the species has also been established in Fiji, Mauritius, the Caribbean, and many countries of Central and South America (NRC, 1992). It was introduced to Sudan by the officials working for the colonial administration in 1916 at Shambat station (latitude 15° 40’ N and longitude 32° 32’ E) and then it is widely spread all over the country (Elteraify, 1996).

1.2 Environmental importance of Neem

Neem has been known as the wonder tree for centuries. It has become important globally as it offers answers to the major concerns facing mankind like pollution, preserving the eco-systems, afforestation, desertification, poverty, and population explosion (NF.intro.net, 2003). Environmentally, neem has a reputation as a natural air purifier, exhaling out oxygen and keep the oxygen and Carbon dioxide level in the atmosphere balance (NF.intro.net, 2003). Satti et al. (2002) reported that many researchers have approved that many kinds of trees are affected negatively by air pollution in cities and industrial areas. On the other hand, a very important notification was proved recently which is the ability of Neem tree to resist air pollution. This phenomenon supported the trend of planting Neem trees in such areas, where other kinds of trees have failed to encounter human destruction of the environment. They also reported when branches were cut during the winter season, many branches with dense green leaves can be obtained in a short period of time providing a very comfortable shade during the second summer season. NF.enviro.net (2003) reported that the temperature under the Neem tree is~10ºC less than the surrounding temperature. Planting of Neem trees in streets makes the weather more humid and maintain shading for human and animals (Satti et al. 2002). NF.enviro.net (2003) reported that Neem ability to withstand extreme heat and water pollution is well known. It also helps to improve fertility of the soil and to rehabilitate degraded wastelands. The Neem can also play a vital role in controlling soil erosion, salination and preventing floods and it can grow vigorously in difficult sites. TNT.net (2003), also, reported that it can grow in certain marginal lands, and therefore does not have to displace food production because it can be raised where soils are too worn out for crops.

NF.enviro.net (2003) mentioned the Neem tree serves as a refugia to many beneficial organisms, bats, birds, honey bees, spiders and others. The litter of falling leaves improves soil fertility and the organic content. Sayda and Talaat (2002) reported that the crown of Neem tree is globalon and branches spread in all directions which permits the wind to pass through the branches without breaking them and then wind becomes weak, qualifying Neem as a good windbreak tree. In the Majjia Valley in Niger, over 500 km of windbreaks comprised of double rows of Neem trees have been planted to protect millet crops which resulted in 20% increase in grain yield (NF.enviro.net, 2003). Neem, windbreaks in smaller scale have also been grown in coastal Kenya. Large scale planting of Neem has been initiated in Tanzania. In countries from Somalia to Mauritania, Neem has been used for halting the spread of
Neem serves many options to increase the welfare of household particularly in rural areas through the availability of medical remedies, safe contraceptive for regulating family size, fuel or firewood for cooking, timber for furniture or dwelling (NF. intro. net, 2003). TNT.net 2003 suggested the centering of rural industries around Neem-extraction facilities. Pest control, as practiced today in most developing countries relies mainly in the use of imported pesticides, this dependence has to be reduced (NF. pest. net, 2003). Their use leads to the contamination of terrestrial and aquatic environments, damage to beneficial insects and wild biota, accidental poisoning of humans and livestock, and the problem of pest resistance. A study by FAO points out that some pests may soon be beyond control (NF. intro. net, 2003). Neem seeds contain bio-active fractions that can help in pest management strategies. 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 in food. Although many plant chemicals have been reported, Neem is the only plant from which the bio-pesticides are commercially manufactured, found effective, eco-friendly and acceptable to the farmers. Neem derivatives affect 500 species of insect belonging to Battodea, Coleifera, Hetroptera and even noxious snails and fungi including aflatoxin-producing Aspergillus flavus. Sideeg (2002) reported that Neem insecticides effects on insects are repellent effect, antifeedual effect, growth regulatory effect, insecticidal effect and oriposition effect. In certain old experiments, in the 1920s, it was reported that neem-leaf extracts seemed to overcome viral diseases in beans, tobacco, and some other crops (TNT.net, 2003).

1.3 Neem in Sudan:
The Neem tree was probably introduced to Sudan from India in 1916 by a colonial forester who knew its value for producing shade, fuel, timber and oil for lamps. The first trees appeared in Shambat (NRC, 1992). It is almost everywhere, where the environmental conditions are suitable for this exotic tree (Peschke, 2003). The tree is found in Kassala in the East, in towns and villages along the Blue- and White Nile, in the Northern part of the country from El Gaili to Wadi Halfa, in the irrigated central Sudan, in Gezira and rain fed areas in the Western Sudan, Darfur and Kordofan provinces.

Sayda and Talaat (2002) reported that Neem trees were not planted in a systematic way and in a large scale except in southern Sudan, specifically in Nyan Akok Forest (Bahr Elgazal state). In small scales planting of Neem trees was practiced in Altaboon (West Kordofan) and Eldebibat (south of Elobied), but trees died after the third year of planting due to lack of rains. They also mentioned that Neem trees grow vigorously in Upper Nile region. Planting of Neem was carried out in small plots round residential areas during the period of 1925 to 1933 in Sowleel (south of Elfong), Khartoum, Gezera and Joba. The success of this program encouraged plantation during 1938 and 1945. Between 1945 and
1955 the drive to plant Neem decreased. Inspite of that, Neem trees are preferable to the majority of population in cities and rural areas.

Peschke (2003) reported that first inspiration for an intensive global research on the tree was initiated in the Sudan by Heinrich Schmutterer (a German entomologist) at the end of 1950s. The value of Neem as pesticides has been known in the country for nearly 30 years but its potentialities as an environmental friendly one is not exploited up to now. However, it is believed that the Fallata tribe, a tribe of Nigerian origin, has a deeper knowledge and usage of Neem components and products. Peschke (2003) also reported that Neem trees are widely utilized in rural areas in construction and as fuel. One of the most important non-tradable goods is its use in marking of land use rights and property rights. Providing of shade is another important non-tradable good of the Neem tree. Furthermore parts of the tree are used as local medicine and insecticides. Furthermore their evergreenness is used as a fire barrier to protect neighboring houses in case of fire. However, there is no commercial use of Neem trees at the present.

1.4 Propagation of Neem
Propagation of Neem is done either sexually by seeds or vegetatively using root suckers or tissue culture plantlets. However, it is normally grown from seed either sown directly on the site or transplanted as seedlings from a nursery (Elteraify, 1996). Rapid loss of viability of Neem seeds within a short time period is a major constrain in seed storage (Marambe et al., 1998). Attempts to develop methods of long term storage for recalcitrant tree seeds have not so far been completely successful (Longman and Jenik, 1987).

Collection and storage of Neem seeds is not a common practice in Sudan as no seed source is identified and the genetic quality of seed available is unknown, added to this are the very poor storage facilities (Elteraify, 1996). Therefore vegetative propagation may be employed as an alternative to seed propagation in order to overcome these limitations.

Gill (1983) reported that vegetative propagation always develops plants identical to the parent. Accordingly desirable characteristics such as Azadirachtin content, fast growth, good form and high yield, which could be lost in seed propagation are easy to preserve by vegetative propagation. It is now widely realized that vegetative propagation offers a mean to greatly enhance the yield and quality of forest products from commercial plantings in the tropics (Leakey, 1987).

1.4.1 Vegetative propagation methods
Vegetative propagation techniques are increasingly being applied to the domestication of tropical tree species (Leakey et al., 1990). A range of approaches can be utilized (Hartmann and Kester, 1983, Leakey, 1985) including grafting, stem cuttings, hardwood cuttings, marcotting, suckering and in vitro techniques such as meristem proliferation, organogenesis and embryogenesis.
1.4.1.1 In Vitro micropropagation of neem

A micropropagation system was developed to overcome the difficulties in conventional propagation techniques used for the Neem tree (Tawfiq, 1997). Yousif et al. (1999), Rahima et al. (1998) and Sarita et al. (1998) reported methods for Neem propagation by tissue culture. However, it was noted earlier that these techniques have the disadvantage of low rate of multiplication, high requirements for skilled labour, or the need of for high capital investment (Leakey et al., 1992). These problems have been overcome by development of low technology propagation system (Leakey et al., 1990, Newton et al., 1992, Newton & Jones 1993), which has enabled the successful propagation of a wide range of species by leafy stem cuttings (Leakey et al., 1992). Kijkar et al. (1998) indicated only rooting of stem cuttings seems to support establishment of large plantations.

1.4.1.2 Macropropagation
1.4.1.2.1 Stem cuttings

Vegetative propagation by stem cuttings is becoming an important tool for forestry trees improvement activities and for the establishment of clonal plantation. It is considered as an excellent method for reducing time to implement tree improvement activities and for immediate mass production of high quality and genetically uniform planting stock of selected superior individuals (Lo.1985, Rana et al., 1987, Shamet & Kumar, 1988, Leakey & Stoerton-West, 1992).

Cuttings can be used to raise plants in nurseries when there is no seeds available or difficult to germinate (Bossard, 1966). Kijkar et al., 1998 reported that Neem can be propagated by rooting of cuttings of juvenile seedlings or rejuvenate shoots from coppicing or from root-reservoirs. they also showed that a leafy 1-2 node section will root well under appropriate conditions of relative humidity above 80% and temperature less than 30ºC with partial shade of 50%. And using of rooting hormones, will induce earlier rooting earlier and a more vigorous root system. A feasibility study by them revealed that for large-scale production of rooted cuttings will cost slightly less than raising seedlings.

Rooting of Neem stem hard wood cuttings using sandy soil gave 37% and 38% with and without using growth regulators (Elkalifa, 1989). However, Mohinder et al., (1992) reported that the semi-hard wood cuttings of Neem tree failed to root by using growth regulators Indole 3yle-Butaric Acid (IBA) and phenols, while about 30% of leafy soft wood cuttings rooted even without hormonal treatment. A combination of IBA with the phenols inhibited rooting of Neem.

Elteraify (1996) reported that vegetative propagation of Neem by hard wood stem cuttings taken from mature trees was not possible even with different concentration of Indole 3yle-Butaric Acid (IBA) and Naphthalene Acetic Acid (NAA) and only small callus was formed at the base of few cuttings. Palanisamy et al. (1998) evaluated the influence of auxins (IBA, Inole Acetic Acid (IAA), NAA) on the adventitious rooting of Neem cuttings. They found that IBA was the most effective in rooting percentage and density.
El Nour (2000) reported that the use of IBA had led to rapid drying in the cutting of Neem, while the use of NAA increased the percentage of the rooted cutting (80%) and also increased root volume (number, length and diameter). In the control (no hormone) most of cuttings formed only callus (75%). Defoliation had significant effect on rooting ability of many species. Experiment done by Eltayb (2002) on Mulberry species confirmed that cuttings obtained from defoliated plants at experimental site showed 100% rooting without hormonal treatment.

1.4.1.2.2 Air layering:
Gupta et al. (1998) have propagated Neem by air layering. They observed formation of callus after 20 to 30 days) and root formation after 40 to 50 days. The percentage of rooting was 60 to 100 % with the use of IBA and 30% in the control. Palanisamy (1999) reported that propagation by air layering is season specific with successful air layering of Neem during the monsoon season (July to September) with rooting percentage of 90 of 100% (treated or not treated with IBA). However, it drops to between 30 to 40% in October and November.

1.5 Objectives
It is evident that Neem is an environmentally, socially and economically important species for Sudan in general and for urban planting in particular. To propagate the superior trees there is a need to overcome the difficulties associated with the vegetative propagation. Accordingly the objectives of this study are:

1- To document the environmental importance of Neem.
2- To investigate the rooting ability of stem cuttings and rooting percentage of air layering in Sudan.
Chapter 2
MATERIALS AND METHODS

The methods used in this study were:

1) Literature search to document the environmental importance of neem trees.

2) Development of vegetative propagation methods by stem cutting and air layering through two experiments.

2.1 Experiment 1.
This experiment was designed to evaluate the possibility of rooting of stem cuttings and air layering. It was conducted at Khartoum Forest Nursery- Elmogran (plate 1) during July to October 2000. It examined the effect of tree stage (mature or sprout), defoliation and hormonal treatment.

2.1.1 Study area:
The study was conducted in a Khartoum Forest Nursery (Elmogran), eastern bank of the White Nile, South Elengaz bridge. It falls in Khartoum Province of Khartoum State at latitude 15°-37 N and longitude 32°- 35 E. The tree cover consists of *Acacia nilotica*, *Acacia seyal*, *Eucalyptus* sp., *Azadirachta indica* and some other domesticated species.

The area is a semi desert that is generally hot and dry. The mean annual rainfall is between 110 and 170mm. Temperature ranges between 20°C - 47°C and the coolest months of the year are December, January and February while the hottest months are April to July.
2.1.2 Stem Cuttings:
Cuttings were harvested from sprouts and from upper mature branches. They were about 20 to 23 cm long (with 3 to 5 node) and 0.5 to 1.3 cm in diameter. Half of the sprouts and mature branches were defoliated 10 days before excision of the cuttings. The cuttings from the two treatments (age and defoliation) were randomly assigned for three levels of IBA treatment which were 0%, 0.1% and 0.3% in powder forms. The basal end of the cuttings were briefly dipped in the IBA powder and then immediately inserted in bags filled by sandy soil. The number of cuttings per unit of the treatments were 50.

The bags were kept in the nursery under partial shade of trees. The sandy soil medium was kept moist with daily watering. The cuttings were observed weekly for leaf flushing and after 50 days for callus and root formation.

2.1.3 Air-layering:
Healthy mature and coppice Neem trees were selected and air layering was conducted on sprouts (plate 2) and upper branches (plate 3). Branches were 0.5 to 1.3 cm in diameter and 50 to 110 cm in length. Half of the branches was defoliated before making the layers. In middle of each branch a portion of 2.5 to 3.0 cm was designated for the layering. The bark in the designated portion was scalped with a sharp blade and then the scratched area was immediately wrapped with moist sandy soil that contain the three levels of IBA treatment (0%, 0.1% and 0.3%) and finally wrapped with transparent plastic sheet.

Plate 2: layers in sprouts of a Neem tree at Khartoum Forest Nursery- Elmogran
The layering was done in July 2002 and watered daily for 50 days and then observed for rooting and callus formation. The number of air layers per hormonal level within the defoliation and the age treatments was 26 layers.

2.2 Experiment 2:
This experiment was designed according to the results obtained in experiment 1. It aimed at investigating the reason(s) for the blackness and rottenning of the cutting ends whether due to fungus infection or humidity. It was conducted at Forestry College Nursery-University of Khartoum, Shambat between October and December 2002.

Neem trees were chosen in shambat area in October 2002. Cuttings were obtained from the upper branches of these trees where half of the branches were defoliated 10 days before taking the cuttings. They were 20 to 23 cm long, with 3-5 node, and 0.5 to 1.3cm in diameter. The cuttings were then dipped in 0.1% IBA, similar to experiment 1. In addition, the basal end of half of the cuttings were dipped in Benellate (fungicide).
The cuttings were planted in pot trays containing sandy soil and then placed in two sites where they were watered daily. One site was in the nursery under the nursery conditions and the other site was in the nursery but under plastic cover to maintain the relative humidity. The plastic cover was put on a wooden frame of 200 x 80 x 100 cm). The number of cuttings per unit treatment in each site was 50. The cuttings were observed for rooting after 50 days.

Chapter 3
RESULTS and DISCUSSION
3.1 Environmental importance of Neem

The literature reviewed showed that Neem tree can help in solving many environmental problems facing the globe. It is reputed to purify air and the environment of noxious elements and keep the oxygen level in the atmosphere well balanced. Also it has remarkable ability to survive in cities and to withstand excessive heat, as well as water pollution (NRC, 1992, Satti et al., 2002, NF.intro.net, 2003, NF.enviro.net, 2003). These characteristics must encourage the planting of Neem trees throughout Khartoum state around factories and crowded areas in the center. Neem is widely valued for its shade in Sudan (Peschke, 2003). Also, it is reported as an excellent candidate for parks, streets, and shelterbelts (NRC, 1992, Bosshard, 1966).

Neem tree plays a vital role in providing and improvement of eco-system. It controls soil erosion, salinitation, preventing flood and maintaining soil fertility (NRC, 1992, NF.enviro.net2003). These properties may be considered in the plantation programmes in marginal and pastoral lands. Also Neem is a suitable tree species for reforestation programs and rehabilitating degraded, semiarid and arid lands.

Neem is the abundant source of environmentally safe insecticide for pest management (Saxena, 1996, Nasr et al., 2002, NF.pest.net, 2003). Sudan was noted as one of the first countries to know its pesticidal potential. A lot of work is needed to realize this potential.

Other valuable products of the tree include Neem oil, fuelwood and medicinal extracts. Neem oil can be used for lamps and mosquito net impregnation. Fire wood is derived from Neem in rural areas (Maramorosch, 1996). In addition to this, Neem medicinal extracts can be used in relation to Malaria, Cancer, AIDS, skin diseases and birth control.

According to these values, countries like India, Nijer, Tanzania, Australia, Haiti, Saudi Arabia, Germany and many other countries
adopted systematic programmes to plant Neem for environmental and commercial purposes.

3.2 Stem cuttings

3.2.1 Shoot flushes

In experiment 1, shoot flushes appeared in the upper nodes of the cuttings by the end of the first week. The number of cuttings that showed shoot flushing increased up to the third week for the sprouts and fourth week for the mature branches (Tables 1 and 2). The number decreased after the fourth week with associated signs of death (plate 4). The number was consistently lower in the cuttings from the defoliated branches from sprout (Table 1) and mature origin (Table 2). It was observed that cuttings of small stem diameters showed less flushing and death signs appeared earlier. Comparing table 1 with 2 showed that the cuttings from the mature upper branches flushed more than those from sprouts.

The effect of IBA concentration on flushing was evident in tables 1 and 2. The 0.1% IBA showed higher number of cuttings from the mature upper branches, with shoot flushing, than the other concentrations (defoliated or not).

Experiment II results, showed similar pattern for shoot flushing. The cuttings under the relatively more humid conditions showed more shoot flushing (Table 3).

The results obtained in experiment 1 and II were inline with those reported by El Nour (2000) who indicated that flushing is possible in the neem cuttings and root formation is very low and most of the flushed cuttings died back. This finding is also in agreement with those reported by Ahmed (1998) working on Acacia senegal where shoot flushes appeared in most

<table>
<thead>
<tr>
<th>IBA conc.</th>
<th>No. of stem cuttings</th>
</tr>
</thead>
<tbody>
<tr>
<td>control</td>
<td>12</td>
</tr>
<tr>
<td>0.1%</td>
<td>15</td>
</tr>
<tr>
<td>0.3%</td>
<td>9</td>
</tr>
</tbody>
</table>

b) Defoliated branches

<table>
<thead>
<tr>
<th>IBA conc.</th>
<th>No. of stem cuttings</th>
</tr>
</thead>
<tbody>
<tr>
<td>control</td>
<td>6</td>
</tr>
<tr>
<td>0.1%</td>
<td>10</td>
</tr>
</tbody>
</table>
Table (2): The effect of IBA concentration and cuttings age (week) on number of Neem stem cuttings from upper mature branches showing shoot flushes.

a) Un-defoliated branches

<table>
<thead>
<tr>
<th>IBA conc.</th>
<th>No. of stem cuttings</th>
<th>Week 1</th>
<th>Week (2)</th>
<th>Week(3)</th>
<th>Week(4)</th>
<th>Week(5)</th>
<th>Week(6)</th>
<th>Week(7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>control</td>
<td></td>
<td>11</td>
<td>19</td>
<td>31</td>
<td>34</td>
<td>23</td>
<td>18</td>
<td>12</td>
</tr>
<tr>
<td>0.1%</td>
<td></td>
<td>15</td>
<td>26</td>
<td>33</td>
<td>37</td>
<td>21</td>
<td>19</td>
<td>16</td>
</tr>
<tr>
<td>0.3%</td>
<td></td>
<td>9</td>
<td>14</td>
<td>28</td>
<td>33</td>
<td>17</td>
<td>11</td>
<td>7</td>
</tr>
</tbody>
</table>

b) Defoliated branches

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>control</td>
<td></td>
<td>10</td>
<td>15</td>
<td>19</td>
<td>23</td>
<td>17</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>0.1%</td>
<td></td>
<td>14</td>
<td>29</td>
<td>38</td>
<td>61</td>
<td>35</td>
<td>19</td>
<td>13</td>
</tr>
<tr>
<td>0.3%</td>
<td></td>
<td>13</td>
<td>21</td>
<td>27</td>
<td>33</td>
<td>26</td>
<td>12</td>
<td>7</td>
</tr>
</tbody>
</table>
Table 3: The effect of humidity and cuttings age on number of Neem stem cuttings showing shoot flushes.

<table>
<thead>
<tr>
<th>Cuttings age</th>
<th>Humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry</td>
</tr>
<tr>
<td>Week (1)</td>
<td>0</td>
</tr>
<tr>
<td>Week (2)</td>
<td>14</td>
</tr>
<tr>
<td>Week (3)</td>
<td>29</td>
</tr>
<tr>
<td>Week (4)</td>
<td>35</td>
</tr>
<tr>
<td>Week (5)</td>
<td>28</td>
</tr>
<tr>
<td>Week (6)</td>
<td>17</td>
</tr>
<tr>
<td>Week (7)</td>
<td>10</td>
</tr>
</tbody>
</table>
It is clear from the above findings that shoot flushing (enhancement of axillary and lateral buds) is affected by the cuttings origin, defoliation, hormonal concentrations and the humidity conditions. Leakey et al. (1992) had shown that many tropical trees species actively photosynthesize and transpire prior to root formation. This could indicate the importance of shoot flushing and it is possible effect on rooting. Shoot flushing is considered by some gardeners as indication for root formation. However, in this study shoot flushing is not an indicator for rooting. There may be a mechanism in the cuttings to sustain water absorption in the absence of roots at the earlier weeks and cannot continue more. The humidity results in experiment II may points to the need for more humid conditions to increase shoot flushing and possibly rooting percentage.

3.1.2 Rooting of Stem cuttings

3.1.2.1 The effect of origin

In experiment 1, cuttings from sprouts failed to form roots (table 4). This is an unexpected result and in contradiction with those of Kijkar et al. (1998) who reported that A. indica species can be vegetatively propagated by rooting cuttings of juvenile seedlings or rejuvenated shoot from coppicing. Leakey (1991) had concluded that the juvenile shoots, such as seedlings or coppices are preferable source of cuttings. It is also clear that, as stockplant get bigger in diameter and more complex, it become more difficult to obtain shoots in a physiological/morphological condition that confers good rooting ability,
i.e. loss of rooting ability is frequently attributed to the loss of juvenility (Leakey et al., 1992).

As shown in table (4) cuttings obtained from the upper branches gave 3.3% rooting percentage (plate 5). This results is close to that of Bosshard (1966) who reported 5.8% of Neem cuttings succeeded to be established when planted directly into irrigated field at the western end of Khartoum Greenbelt. But it is less than that obtained by Elkhalifa (1989) who reported 37% and 38% with and without growth regulators, respectively. However, Elteraify (1996) reported rooting of cuttings from mature trees was not possible.

Among upper branches, rooting percentages were 2% and 6% with and without defoliation, respectively (Table 4). Among the defoliated upper branches, rooting was obtained only on 0.1% IBA (2%) (Table 4). Among defoliation rooting was higher with 12% and 6% on 0.1% and 0.0% IBA respectively with no rooting on the 0.3% IBA.

Callus was observed in five cuttings: three of them were treated with IBA 0.3% and defoliation, and another two were in the control. This callus failed to differentiate into roots (Plate 5). It was also observed that the small size cuttings (around 0.5 mm in diameter) showed no rooting. The complete failure of cuttings with small stem volume was explained by Leaky et al. (1992) as due to saturation of these cuttings with starch, which can inhibit photosynthesis and consequently rooting. Cuttings taken from different parts of the same shoot differ in their capacity to form roots (Leakey, 1991).
and this is influenced by cutting volume. This has been called “within-shoot” variation (Leakey, 1985).

Ends of cuttings which failed to form roots turned black and rottened with death of the cuttings. This was attributed to fungal infection or humidity that led to experiment 2. The results of experiment 2 showed similar rotting under dry and wet conditions with or without the use of Benellate (Table 5). Only 1 cutting out of 300 showed root formation under the dry conditions (table 5a). However, under the wet conditions rooting percentage was higher as shown in table (5b). These indicate the importance of humid environment for the cuttings. Leakey et al. (1990) emphasized the need for minimization of physiological stress for root initiation in leafy stem cuttings by using of shade to lower air temperature and by providing high humidity to reduce transpiration losses. Nonetheless this rooting percentages of cutting under the wet condition of experiment 2 were less than that obtained in experiment 1 with the same cutting origin. This may be due to the effect of seasonality. Similarly El Nour (2000) reported that the highest percent of root formation in A. indica occurred during the hot and humid period (May-August). (experiment 1 was carried during July-October and experiment 11 during October-December).

3-1-2.2 Effect of defoliation
As table (6) shows defoliation of leaves from branches 10 days before excision of the cuttings have resulted in less rooting percentages as compared to those without defoliation with 0.3 % and 3% rooting with and
without defoliation, respectively. With defoliation treatment all cuttings harvested from sprouts failed to give roots, while cuttings from upper branches showed 2% of rooting. Un-defoliated upper branches gave 6% of rooting, where un-defoliated sprouts failed to form roots. Among defoliated upper branches, rooting (2%) was obtained only on 0.1% IBA. Among un-defoliated mature branches, the highest rooting percentage (12%) was obtained on 0.1% IBA.

These results indicate that rooting of Neem cuttings is affected adversely by defoliation, unlike Morus species (Mulberry). Eltayb (2002) reported that the defoliation treatment has resulted in 100% rooting success for all Morus species cuttings.

3.1.2.3 The effect of IBA concentration

As shown in table (7), 0.1% IBA revealed, in general, the highest rooting percentage (3.5%), then the control (1.5%), while 0.3% failed to form roots completely. Among the 0.1% IBA, cuttings from upper branches showed 7% rooting. Among the mature cuttings, 0.1% IBA gave 12% and 2% without and with defoliation.

The rooting of cuttings is influenced by the application number of post-severance treatments. The most common treatment is application of auxin treatment that often hasten rooting, increase the percentage of cuttings rooted and increase the number of roots formed (Leakey et al., 1992). The result of this study is close to that reported by Palanisamy et al. (1998) where IBA increased rooting percentage. However El Nour (2000) reported that the use of IBA did not improve rooting and had led to rapid drying in the cuttings of neem. With other species, vegetative propagation of Acacia
*nilotica* was very successful using IBA (Ahmed, 1998). Cuttings of *Albizia* sp. and *Cordia alliodora* were very responsive to IBA treatment (Leakey *et al.*, 1992).

The suitable concentration used in this study was 0.1% while higher concentration inhibited rooting ability. This area needs more investigations in order to define the optimal concentration of IBA.

3.1.3 Air layering  
3.1.3.1 Effect of origin:  
As table (8) shows, the sprouts showed in the overall higher success than the upper mature branches, where 41% in the former and 27% in the later. Within sprouts, un-defoliated branches showed higher rooting percentage (49%) than the others, which were defoliated (33.3%). Among upper branches, similar trend was obtained, where 49% in the un-defoliated upper branches and 5% in the defoliated one.
Among the defoliated sprouts, the IBA control showed the highest percentage (54%), where the 0.3% IBA showed the lowest one (16%). Un-defoliated sprouts exhibited the same behavior, where 61% was obtained with IBA control and 24% with 0.3% IBA. However, Among the defoliated upper branches, only IBA 0.1% gave rooting (13%).

Among the non-defoliated upper branches the highest rooting percentage was obtained with 0.1% IBA, and the lowest percentage was with 0.3% IBA, where 68% in the former and 20% in the later.

These findings are consistent with those of Gupta et al. (1998), who reported rooting of 60-100% in Neem air layers with IBA. The higher percentages realized with sprouts in this study are close to those of Palanisamy (1999) who obtained rooting of 90-100% in Neem layers using 8-10 yr old trees.

It was observed that 32% of the layers formed callus which may indicate that if the period of the experiment was increased to more than 50 days, this callus may differentiate into roots and higher rooting percentage may be acquired (plate 6 and 7).

3.1.3.2 Effect of defoliation:

Table (9) shows that defoliation reduces obviously the ability of Neem layers to form roots. Hence, defoliated branches showed 19% of rooting where un-defoliated branches gave 49%. Among defoliated branches, layers in sprouts revealed higher ability of rooting than other in upper branches, where 16% in the former and 2.5% in the later. Among un-defoliated, layers in sprouts and upper branches showed 24% rooting.

Among the defoliated sprouts, the IBA control showed the highest percentage (54%), where the IBA 0.3% showed the lowest one (16%). Un-defoliated sprouts exhibited the same behaviour, where 61% was obtained with IBA control and 24% with 0.3% IBA. Among the defoliated upper branches, only 0.1% IBA gave rooting (13%).

Within the non-defoliated upper branches the highest rooting percentage was obtained with 0.1% IBA, and the lowest percentage was with 0.3% IBA, where 68% were obtained in the former and 20% in the latter.
These findings conclude that the application of defoliation treatment is not desirable with neem vegetative propagation.

3.2.3.3. Effect of IBA concentration:
Table (10) shows that 0.1% IBA resulted in the highest rooting percentage (52%) followed by the control (44%) and then 0.3% IBA (32%).

Among 0.1% IBA, layers in sprouts showed 59%. Among the control, layers in sprouts revealed more ability for rooting than those in upper branches (44% in the former and 28% in the later). The 0.3% IBA layers in sprouts had higher rooting (19%) than others in upper mature branches (9%). Within layers in sprouts treated by 0.1% IBA, defoliation treatment reduced the rooting percentage (24% in defoliated branches and 60% in non-defoliated one). Other set treated by IBA (the control) gave 54% where defoliated and 61% where not defoliated. The later set treated by 0.3% IBA, showed 16% with defoliation treatment and 24% with non-defoliation.

Layers in upper branches applied with 0.1% IBA showed 13% with defoliation and 68% without defoliation. Within mature upper branches treated with 0.3% IBA and defoliation, failed to root while others un-defoliated gave 20%.

The application of IBA resulted in induction of rooting where low concentration used (0.1%) increased the success rate versus 0.3% IBA that resulted in reduction of rooting. This results do not agree with Gupta et al. (1998) who reported that all IBA treatments increased rooting in Neem.
layers. This may indicate the need for more studies to define the optimum concentration of IBA.
This study showed the environmental values of neem (*Azadirachta indica*) trees. It also confirmed its ability to be propagated vegetatively by stem cuttings and air layering.

**Environmental importance:** Neem is considered to be one of the most promising trees of the 21st century. It has great potentials in the fields of pest management, environmental protection, and medicine. It is known to help control diseases like Malaria, Cancer and AIDS (NF. indix. net, 2003), combat desertification and deforestation, reduce excessive global temperature, exhibit remarkable ability to survive in cities, and as contraceptive to control population growth.

Ecologically it is a sound, equitable, and ethical pest management tool as there is a need for control agents that are pest-specific and not toxic to humans and other biota, biodegradable, less prone to pest resistance and resurgence, and relatively less expensive. Among various options, Neem has been identified as a source of environmentally “soft” natural pesticide (NF. Pest.net, 2003). Research has shown that Neem extracts can influence nearly 200 species of insects (NF. pest.net, 2003).

**Vegetative propagation:** Rooting of stem cuttings was affected by origin of cuttings, volume of cuttings and concentration of the rooting hormone (using IBA rooting powder). High rooting percentage was obtained in cuttings harvested from upper mature branches with diameter larger than ~1 cm. High rooting percentage was observed with the IBA 0.1%. The pretreatment of defoliation by removing all the leaves from the branches and then taking the cuttings after 10 days, has resulted in...
Appearance of shoot flushes was observed in most of the cutting. Shoot flushes are not evidence of rooting. This area needs more investigations to understand the relation between rooting and shoot flushes.

The second confirmatory experiment revealed that the blackness at the end of cuttings that failed to root was not due to fungal infection. It also pointed to the importance of keeping the environment as humid as possible. The results also pointed to the effect of season on rooting ability of Neem cuttings. High rooting percentage was obtained at monsoon season.

The air-layering study showed that layers would produce more propagules than stem cuttings. High rooting percentage was obtained (68%) and callus or callus-like structures were observed at layering joints. The sprouts showed higher rooting success than the upper mature branches. Rooting percentage increased with 0.1% IBA. Also, defoliation treatment had lessened the rooting ability of neem layers.

These results indicate the possibility of propagation of selected trees that are known for their high production of secondary metabolites (insecticide and others), which will result in increased environmental gains.
**Recommendations:**
From this study and the above findings, the following recommendations were made:

1. To promote Neem plantations in towns and encouragement of the rural communities to plant Neem trees for different benefits around homes, and to be used as wind breaks.

2. To increase public awareness towards Neem economical benefits.
3. To Campaign and to survey for Neem trees in Khartoum area.
4. Vegetative propagation of Neem by air layering is suggested for selected superior trees in term of growth habits and yielding ability of secondary products..
5. Further studies for vegetative propagation by stem cuttings and air-layering to determine:
   - The optimum concentration of IBA.
   - The optimum cutting diameter.
   - The optimum conditions for propagation (shade, humidity and temperature.)


TNT.net, 2003: http://www.theneemtree.com