EVALUATION OF A DISORDER OF NEEM IN NIGER
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EVALUATION OF A DISORDER OF NEEM IN NIGER

Executive Summary

1. Neem, Azadirachta indica, is a very important tree species widely planted in the Sahel region of West Africa, where it is used for firewood, windbreaks, greenbelts, and as amenity plantings in cities, towns, and villages.

2. In the past two or three years, a serious problem of unknown etiology has been observed affecting neem in an area from Mali in the west to Chad and Cameroon in the east. The problem seems to have appeared more or less synchronously over much of this area and is characterized by the gradual loss of foliage, branch dieback, and finally a general debilitation of the tree and sometimes death. A previous study of the problem in 1991 tentatively identified the cause as infection by the wilt fungus Verticillium sp.

3. Observations made during the current evaluation of the problem in Niger did not reveal any symptoms or signs that would indicate infection by Verticillium. In fact, no symptoms or signs were seen that would indicate the presence of any type of primary infectious disease. The same was true for attack by primary insects.

4. The absence of any primary pathogens or insects, as well as the symptoms of general tree decline, pointed to an abiotic factor or factors as being the primary cause of the neem disorder. **The more or less synchronous appearance of the problem over a very wide geographic area indicated that moisture stress is likely to be the most important factor involved.** A preliminary analysis made of the rainfall patterns at selected stations across southern Niger for the period 1940-1991 (Appendix III, Fig. 23) clearly showed a significant decrease in mean rainfall for most decades starting with 1940. Rainfall in the years 1982-1985 and in 1987 was especially low and **at most stations, rainfall was below that commonly believed to be necessary for growth of neem (400 mm).** This analysis is in agreement with other reports which indicate that a severe drought has persisted across the Sahel region of West Africa from the late 1960s until the present time, with only three years of near normal rainfall.

5. **The severity of neem disorder in Niger appears to be correlated with the amount of other stresses the trees receive.** In general, trees in plantations, which are impacted by competition, animal traffic, and intercropping, are the most severely affected. This is also true in other countries in West Africa. Trees in certain locations in cities and towns, such as public markets and some large compounds, receive heavy vehicular traffic and other impacts, and may also be severely affected. Trees in windbreaks and small villages, and open-grown trees are less severely affected. Soil factors, such as hardpans,

deep water tables, compaction, waterlogging, etc., may affect the occurrence and severity of the neem disorder in localized areas. Poor nursery practices, such as inadequate nutrition and allowing seedlings to become rootbound before planting, may result in poor survival and growth.

Lasiodiplodia theobromae, a widely distributed fungus previously known to attack stressed neem trees and many other hosts, was recovered from died back branches. Two other fungi, Curvularia eragrostidis and Nigrospora sphaerica have also been recovered from dead branches and are currently being tested at ICRISAT for pathogenicity to neem. **These fungi, plus several insects occasionally observed on symptomatic neem, are believed to play only minor roles in the disorder.** Other factors, not yet identified, may also be involved.

6. Several recommendations were made to better understand the neem disorder in Niger and other West African countries, and to mitigate the effects of the problem. Key recommendations include:

a. **Convene a conference on neem to be attended by representatives of the countries of West Africa** in which neem is an important tree species. Agenda topics for the conference should include discussion of the most important problems currently affecting the growth of this species.

b. **Establish plots to periodically monitor trees affected by the neem disorder** so as to have better understanding of symptom progression.

c. Using more sophisticated methods, **make further analysis of rainfall data and bow it may be related to onset of neem disorder**. Data from other countries should be included where available.

d. **Study other stress factors that may contribute to the development of the neem decline syndrome**, such as intertree competition, animal impact, intercropping, adverse soil factors, and poor nursery practices. Results of such studies would help in the formation of management strategies which may help mitigate the effects of the problem.

e. **Establish provenance trials using seed from as wide a geographic base as possible in the countries of origin of neem so as to widen the genetic base of the species in Niger and elsewhere in Africa.** Selecting and propagating local landraces might also result in trees with more drought tolerance and other desirable characteristics.

EVALUATION DE L'AFFECTION DU NEEM AU NIGER

Résumé Exécutif

1. Neem, Azadirachta indica, est une espèce d'arbre trés important qui est plantée sur une grande étendue dans la région du Sahel en Afrique d'Ouest. Il est utilisé comme bois de chauffage, brise-vent, ceinture verte, et comme plantation d'alignement dans les villes, les petites villes, et les villages.

2. Il y a deux ou trois ans, un problème sérieux d'étiologie inconnue a été remarqué dans une zone qui s'étend du Mali à l'ouest jusqu'au Tchad et au Cameroun à l'est. Le problème a apparu plus ou moins en même temps dans une grande partie de la région. Il est caractérisé par une perte progressive des feuilles, la morte des branches, et, enfin, la débilitation générale et parfois la morte complète de l'arbre. Une étude antérieure du problème en 1991 a provisoirement trouvé que la cause était une infection par un champignon de flétrissement, un Verticillium.

3. Les observations faites pendant l'évaluation actuelle du problème au Niger n'ont découvert ni des symptômes ni des indications qui dénoteraient une infection par un Verticillium. En fait, il n'y avait ni des symptômes ne des indications d'une infection par aucune maladie infectieuse primaire. Il y avait les mêmes resultats quant aux attaques par les insectes primaires.

4. L'absence des gènes primaires et des insectes, en association avec les symptômes du déperissement géneral des arbres, indiquait qu'il y avait un élément ou des éléments abiotiques qui étaient la cause primaire de l'affection du neem. L'apparition synchrone du problème dans une grande zone géographique indiquait qu'un stress hydrique est vraisemblablement l'élément le plus important. Tenant compte de ce fait, on a fait l'analyse des précipitations aux stations choisies s'étendant sur tout le sud du Niger pour la période 1940-1992 (Annexe III). Bien qu'elle soit simpliste, l'analyse a nettement montré une diminution importante de la précipitation moyenne pour chaque décennie, commençant avec 1950. La précipitation pendent les années 1982-1985 et en 1987 était particulièrement basse, et à la plupart des stations, elle était plus basse que ce qu'on considère d'être le minumim pour la croissance du neem (400 mm). Cette analyse est en accord avec d'autres rapports qui indiquent qu'une secheresse grave a persisté d'un côté à l'autre du Sahel, des années soixante jusqu'à présent, avec seulement trois ans de précipitations normales.

5. La gravité de l'affection du neem au Niger paraît être en corrélation avec la quantité d'autres stresses auxquels les arbres sont soumis. En général, les arbres qui se trouvent

aux plantations sont les plus atteints, parce qu'ils sont touchés par la compétition, le passage d'animaux, et la culture intercalaire. Ceci est vrai dans d'autres pays de l'Afrique de l'Ouest. Des arbres en certains emplacements dans les villes et les villages, comme des marchés publiques et certains enclos grands, sont soumis au trafic de véhicules et aux autres impacts considérables, et ils peuvent aussi être gravement touchés. Les arbres dans les brise-vents et les petits villages et les arbres dans les espaces libres sont moins touchés. Les characteristiques pédologique de la terre, comme le sol résistant, les nappes phréatiques profondes, les sols compacté, et l'hydromorphie peuvent avoir un effet sur l'existence et la gravité de l'affection du neem dans les régions localisées. Des mauvaises techniques de pépinière, comme la nutrition insuffisante et le fait qu'on laisse s'enraciner les plantules avant la plantation, peuvent aboutir à une pauvre survie et à une croissance faible.

Lasiodiplodia theobromae, un champignon largement répandu qui est connu pour avoir jadis attaqué des arbres neems stressés et beaucoup d'autres hôtes, a été trouvé sur des branches mortes. Deux autres champignons, Curvularia eragrostidis et Nigrospora sphaerica ont aussi été trouvés sur des branches mortes et on est en train de les analyser à ICRISAT pour voir s'ils ont une pathogènicité au neem. On croit que ces champignons, avec plusieurs insectes qui ont été remarqués de temps en temps sur des neems symptomatiques, ne jouent qu'un rôle secondaire dans l'affection. D'autres éléments, pas encore identifiés, peuvent aussi jouer un rôle.

6. Plusiers recommendations etaient faites pour mieux comprendre l'affection du neem au Niger et aux autres pays de l'Afrique de l'Ouest, et pour mitiger les effets du problème. Les suivantes sont quelques recommendations principales:

a. Convoquer une conférence sur le neem, à laquelle assisteront des representants des pays de l'Afrique de l'Ouest ou le neem est une espèce d'arbre importante. Les sujets de discussion doivent inclure les problèmes les plus importants qui ont un effet sur la croissance de cette espèce actuellement.

b. Etablir des carrés pour contrôler périodiquement les arbres touchés par l'affection du neem, pour qu'on puisse avoir une meilleure compréhension de la progression des symptomes.

c. Utiliser des méthodes plus sophistiquées pour faire des analyses des données de précipitation, et pour déterminer comment la précipitation peut avoir un effet sur le commencement de l'affection du neem. Des données d'autres pays doivent être comprises autant que possible.

d. Etudier d'autres éléments du stress qui peuvent contribuer au développement

du syndrome du neem, comme la compétition entre arbres, l'impacte des animaux, la culture intercalaire, les éléments de mauvaise terre, et les mauvaises techniques de pépinière. Les résultats de telles études aideraient dans la mise en place des stratégies pour aider dans la mitigation des effets du problème.

e. Etablir des essais de provenance en utilisant des graines d'une base géographique la plus grande possible dans les pays d'ou le neem provient. Par cette action, la base génétique de l'espéce au Niger sera élargie. Si l'on choisit et propage les races primitives de la région, c'est possible qu le résultat sera des arbres avec une plus grande tolérance contre la secheresse et avec d'autres charactéristiques désirables.

EVALUATION OF A DISORDER OF NEEM IN NIGER

INTRODUCTION

Neem (Azadirachta indica) is native to Burma and northeast India where it is a common plant in the dry zones. It has been widely planted throughout Southeast Asia, the Middle East, and Africa, and more recently has been introduced into Latin America (National Research Council 1992). Its popularity in these areas is due primarily to its ability to grow well on dry, difficult sites and to furnish shade throughout the year. It is also relatively free of serious insect and disease problems.

In the past few years, interest in neem has increased tremendously because its seeds and leaves contain compounds which are effective in controlling a wide variety of insects. It has long been known in India that the tree also contains compounds which are effective against certain human diseases, and chewing neem twigs is a very common form of dental hygiene in India and many other countries.

Neem was introduced into Africa in Sudan about 1916 and into Ghana sometimes during the 1920's (National Research Council 1992) Since then, it has been widely planted in the drier regions of more than 20 countries in West Africa. In many areas it is the primary source of firewood. Equally important, however, is its use as an amenity tree in gardens and villages (Fig. 1), as a street and avenue tree (Fig. 2), for the prevention of soil and wind erosion, and as windbreaks. Its ability to produce beneficial compounds to control insects and prevent human diseases is only beginning to be exploited in the region.

Neem was introduced to Niger about 1925, and currently is widely planted throughout the southern third of the country. A recent survey showed that more than two million trees have been established in plantations, windbreaks, and in cities, towns and villages (USAID 1991).

Until recently, neem has been growing in Niger, and apparently in other West African countries, relatively free of serious insect and disease problems, with the single, significant exception to this statement being infestations by the oriental yellow scale (Aonidiella orientalis) in the Lake Chad Basin (Boa 1992; Ohabuike 1992). However, in late 1990, several neem trees died over a short period of time on a farm located near Sani-Tanko village, 80 km northwest of Dakoro. The cause of the problem was not determined, but because of the possibility of an infectious disease, it was recommended

that further studies be undertaken by an experienced tree pathologist.

During the period June 24-July 7, 1991, Dr. Paul Batra, plant pathologist of Biosystems/Atlanta, visited Niger to evaluate the situation. Dr. Batra (Batra 1991) found a disorder of neem trees in all the areas he visited in southern Niger. He described the symptoms of the problem as deformation and discoloration of leaves; early loss of older leaves; shortened internodes near the ends of branches, giving a bunchy appearance; dieback of branches from the tips; exudation of a clear white to yellow gum from the branch tips; and finally death of trees. He first believed that the problem was caused by a virus, but later reached the tentative conclusion that the problem was probably caused a Verticillium sp. This conclusion was based on the occurrence of "fungal hyphae similar to those belonging to Verticillium sp. in the vascular bundles of leaves and young shoots". However, the fungus was not isolated from symptomatic tissue. He termed the disease "vascular decline of neem".

Subsequent to the visit of Dr. Batra, the problem was confirmed to be present in Mali and northern Nigeria, and more recently in northern Cameroon and eastern Chad (see Boa 1992). Thus the problem now occurs through much of the area where neem is an important species, and there is considerable concern for the future of this valuable tree in West Africa.

During the period March 12-24, 1992, we made a visit to Niger to follow up on the findings of Dr. Batra, especially with respect to confirmation of the etiology of the problem. After leaving Niger, we also visited several research institutes, universities, and other facilities in England to discuss the neem problem and to get insect and fungal specimens identified. One of us (JSB) also visited FAO headquarters in Rome on the way to Niger to discuss possible cooperative efforts by international agencies on resolving the neem problem. This report documents the findings and conclusions based on the observations made during the trip and presents recommendations for future actions.

OBSERVATIONS ON THE NEEM DISORDER IN NIGER

Symptomatology

During the ten days we spent in Niger actually working in the field, the neem disorder was observed in a number of settings. These included street and yard plantings in cities or towns such as Niamey, Tera, Baleyara, and Maradi; amenity plantings in small villages; windbreaks, especially in the Maggia Valley and surrounding areas; and in more or less large plantations, such as in the greenbelt around Niamey and near some other villages and towns.

Assessing the extent and severity of the neem problem in Niger was severely hampered by the absence of a clear symptomatology and etiology relating to the disorder and lack of information on the normal phenology of the tree growing as an exotic in Niger. Observations, however, clearly indicated wide variation in the apparent vigor of individual trees manifested primarily by the loss of foliage and branch dieback in the upper crown. It is very difficult to determine the exact progression of symptoms exhibited by the trees when each tree is examined at only a single point in time. However, observations of numerous trees during the trip lead us to propose the following symptomatology of the neem disorder.

The foliage of healthy, vigorously growing neem trees is dark green and the leaves may cover the distal portion of the upper branches for a meter or more (Fig. 3). The first discernable symptom of the problem is the yellowing and premature dropping of the oldest leaves on branches in the upper portion of the crown (Fig. 4). As leaf drop becomes more pronounced, only a small tuft of leaves remains on the ends of the branches (Figs. 4, 5). Even at this stage the remaining leaves appear normal, except in a few cases when a general chlorosis was noted. Because of the upright growth habit of the upper branches of neem, this tufting of leaves on the end of the branches has been aptly termed "giraffe neck" by local officials, and is used as the most characteristic symptom of the disorder (Fig. 5). In many cases, there also appears to be a shortening of the distance between the leaf attachment on the twigs near the end of branches on trees affected by the disorder, indicating a possible decrease in the rate of shoot growth. However, some specimens of neem from India and Burma seen at Kew Herbarium often exhibited the same characteristic.

Yellowing and leaf drop continue until in some cases many of the branches in the upper crown of some trees will be completely bare of leaves. It was difficult to examine these bare branches on large trees, but on most small trees such branches were still alive, even on some trees which were completely defoliated. In some cases, new leaves and flowers were just developing on the tips of otherwise bare branches (Fig. 6).

On some trees the next stage in the development of the problem appears to be the progressive dieback of defoliated branches from the tip. In no case was tip dieback noted on branches which still had green leaves. In almost all branches examined, the zone between the living and dead parts of the branch was very diffuse (Fig. 7), indicating that the dieback was most likely due to physiological causes. In a few cases, however, the zone was more sharply defined and the dieback probably was at least in part due to activity of pathogenic organisms. Some trees, especially young trees less than five years of age, died back to below the level of the lowest branches and sometimes even to the root collar. In such cases the trees usually responded by the production of epicormic

sprouts from the still living portion. Generally these sprouts appeared vigorous and exhibited no abnormal symptoms (in sharp contrast to observations made by Batra). Very few dead trees were seen. In part this may have been due to the prompt removal of dead trees for use as firewood. More likely the problem has not yet progressed to the point where there is significant mortality.

Although the crown symptoms described above are generally characteristic of the problem in the areas visited, occasionally there were some interesting variations which may have some bearing on determining the cause. In some areas, trees were noted in which one side of the crown showed advanced symptoms of the disorder, while the other side appeared healthy or showed only slight symptoms (Fig. 8). One possible explanation of this was offered by Ed Bailey, an ex-USDA-Forest Service forester who is now director of the leprosy sanitarium near Maradi. He suggests that the symptomatic side is on the side from which the prevailing winds come and that the leaf loss is due to the drying effect of the winds. This observation could not be confirmed.

Several trees were seen which apparently had had severe leaf drop and then had been pollarded except for one or two major branches. The remaining old branches still showed severe symptoms but the new pollard shoots were growing vigorously and had full complements of leaves (Fig. 9). This may indicate that the loss of leaves may be due to a transient stress factor and that new growth will be normal. This can only be determined by making periodic observations on individual trees.

Rough, scaly bark apparently caused by sunscorch was often seen on young trees in plantations where defoliation was heavy and the stems of the trees had been exposed to the sun.

In Tera, large trees in the central market which exhibited severe dieback in the older branches also showed canker-like symptoms on some of the live branches. Most of these areas had callused over. A local forester, as well as Issa Adamou, told us about the occurrence of a problem on neem in which a foul-smelling, bubbly liquid issues forth from such areas, sometimes with considerable force. The local forester considers this as the major neem problem, and not the one associated with leaf drop and dieback. Adamou has seen the problem in Niamey, usually during the wet season. The symptoms are similar to those of a disease of many hardwood species commonly called wetwood. Wetwood is caused by a bacterium which invades the xylem and through the process of fermentation results in the production of gasses and a large quantity of liquid. Pressure exerted from the gasses may be great enough to rupture the wood, permitting the liquid to escape and run down the side of the tree. Usually the liquid discolors the bark and the disease is easily seen. However, we saw no evidence of this problem in any of the

other areas we visited.

Two additional symptoms were often associated with affected trees. One of these is an apparently abnormal reddish-orange or pink color of the inner bark on small branches (Fig. 10). This characteristic has been used by local officials as indicative of the problem. The inner bark of large branches and the trunk of normal neem is also orange in color. However, the inner bark of small branches of healthy trees and that of fast-growing shoots such as epicormic sprouts and pollarding shoots is usually green. Observations indicated that this characteristic was usually but not always present on trees showing abnormal loss of foliage, and was sometimes seen on some branches and not others on the same tree. Even when present, the coloration usually ended about 30 cm from the tip of the branch. According to Dr. Eric Boa, who made sections of branches after returning to England, the coloration is due to suberin-like material deposited in the cork cells. Deposition of such materials could be a response to stress and thus the orange coloration could be a part of the symptomatology of neem disorder.

Another common symptom associated with affected trees was the exudation of a clear or whitish gum from the base of the petioles and from the leaf rachis. According to Dr. Martin Cheek, Meliaceae expert at Kew, neem has two pairs of extrafloral nectaries at the base of the petiole and this is apparently where the gum is coming from. He expressed surprise as the amount of gum being exuded. The exudation of gum from the rachis was also surprising to him. Although the amount of exudation appeared to be greater on symptomatic trees, it was also present to some degree on apparently healthy trees.

Dr. Cheek informed us that he had also seen the symptoms referred to as "giraffe neck" in Melia azedarach.

There have also been reports in Niger that symptomatic trees sometimes have a bright yellow heartwood. We did not see this in the field associated with living trees, but did see it in the trunks of several trees which had been harvested and piled in villages. The relationship of the yellow color to the neem disorder is not known.

Roots were examined on several trees which showed advanced symptoms of the disorder. **In all cases, even on trees that had died back to ground level, the root systems were apparently healthy** (Figs. 11, 12), and with even the smallest roots still alive and not exhibiting any discoloration or other abnormality.

Affected trees were carefully examined for the presence of symptoms of commonly recognized types of diseases. A general yellowing was the only leaf symptom

evident, and even this was usually associated with senescing older leaves. There were no necrotic areas such as would be typical of fungal or bacterial leaf spot diseases. Nor were there mosaic patterns, chlorotic ring spots or any other symptoms which might indicate virus infection. No isolated necrotic lesions were seen on branches or stems which would be indicative of canker diseases, nor were flagging branches (dead branches with leaves still attached and which stand out in sharp contrast to the remaining healthy crown) seen that would indicate girdling of branches or stems by canker organisms. There was no evidence of sudden wilting of leaves on individual branches or whole crowns, or vascular discoloration which might indicate the presence of wilt diseases.

There were no witches' brooms which are commonly associated with infection by rust fungi or mycoplasma-like organisms. At two locations (in plantations near Tera and Niamey), however, several trees were seen with symptoms termed fasciation (Fig. 13). This is an abnormal flattening or coalescence of stems or shoots, which often are also curled or bent. The cause of fasciation is variously attributed to mycoplasma-like organisms, viruses or physiological abnormalities. In Niger, the problem was not commonly seen and is unlikely to be related to the neem disorder. It is interesting, however, that one of the herbarium specimens seen at Kew, which came from Burma, also had a fasciated branch.

As mentioned earlier, there were no symptoms on the root system that would point to any kind of root disease.

Association of Pathogenic Organisms

We did not make any isolations for potentially pathogenic fungi during the visit, primarily because there was little evidence for their occurrence. However, the transition zones between living and dead tissue on branches exhibiting dieback were collected and placed in moist chambers (plastic bags with wet paper towels) and taken to England where they were examined in the laboratory at the Natural Resources Institute. The only fungus of interest recovered was Lasiodiplodia (Botryodiplodia) theobromae. This fungus sporulated profusely in the transition zone of several specimens collected from plantations at the Seed Multiplication Center near Maradi and the greenbelt near Niamey. Together with Dr. Eric Boa we made isolations from exuding spores and recovered pure cultures of the fungus. **These cultures are still at NRI and will be available to anyone who would like to use them for inoculation experiments.**

Drs. Farid Waliyar and Dale Hess of ICRISAT have isolated two fungi from died back branches of neem trees around Niamey, and are currently conducting inoculation

experiments to determine their pathogenicity to neem. These fungi were identified at the International Mycological Institute (IMI) as Curvularia eragrostidis (imperfect state of Cochliobolus eragrostidis) and Nigrospora sphaerica. These fungi both have a wide distribution and host range, and are usually associated with dead and dying tissue. Both are also commonly isolated from soil.

Another fungus tentatively identified as Thielavia terricola by Hodges was isolated by Issa Adamou of DPV from roots of symptomatic neem. This fungus was also submitted to IMI for identification, and Dr. P.F. Cannon sent the following report: "This is an unusual isolate, which I cannot place precisely even to genus. Its very dark ascospores and its peridial anatomy are not typical of Thielavia sensu strictu, and there are some similarities both with Corynascella (though the germ pore is not suitably prominent) and with the Chaetomium uniapiculatum group. A sober re-appraisal of generic limits within the Chaetomiaceae is needed before deciding on the correct placement for your culture. This isolate has been placed in the IMI culture collection" (IMI number 352199). Fungi in this group generally are saprophytes, and are common in soil and on organic matter.

The fungi collected in Niger were not brought to the United States for identification because current Animal and Plant Health Inspection Service (APHIS) regulations make it difficult, if not impossible, to obtain a permit to bring in living unidentified specimens or cultures. It is possible, however, to bring in specimens for identification by having them fumigated at the port of entry. This may take several days, after which the specimens are sent to the person bringing them in.

England has much less restrictive quarantine regulations than the U.S., and it is possible to bring in or send living material for identification, even without a prior permit. This is especially true for material destined for the International Mycological Institute, which has one of the few fungal identification services in the world. Specimens submitted by contributors to the Commonwealth Agricultural Bureau International are identified free; the charge for other non-commercial identifications is 30 pounds. It should be noted that as of October 1, 1992, IMI will move from its current quarters in Kew to Bakeham Lane, Egham, Surrey, TW20 9TY.

Short segments of roots, shoots and petioles from both symptomatic and apparently healthy trees were collected and fixed in 2.5 percent glutaraldehyde in 0.1 M phosphate buffer for use in screening for the presence of mycoplasma-like organisms using the DAPI test. A portion of these specimens were taken to NRI by Dr. Boa and the remainder returned to the United States and sent to Dr. Wayne Sinclair at Cornell University. **Results of the tests for MLO's at both locations were negative**, including

those made on tissue from the fasciated branches collected at Tera.

We also collected yellow leaves from symptomatic trees and took them to NRI where Dr. Boa will have them tested for the presence of viruses. Results of these tests have not yet been received.

Association of Insects

During the visit, attention was also given to the presence of insects which might be associated with the problem. This was especially true for scale insects, in particular the Oriental yellow scale Aonidiella orientalis, which have been reported to cause serious damage to neem in other parts of West Africa, especially in the Lake Chad region (Ohabuike 1992). Two distinct species of scales were noted. A large yellowish-brown scale, which has been identified as Macropulvinaria jacksoni by the International Institute of Entomology (IIE), was seen on small branches and leaves of several trees at the Department of Environment compound in Maradi, and in the DPV compound in Niamey. In both cases the infestation was associated with general leaf yellowing on the affected branches (Figs. 13, 14). A small white scale, identified as Parlatoria crypta by IIE, was of much more common occurrence in many of the areas visited during the trip. Damage, however, was limited to small chlorotic spots on leaves beneath the scale (Fig. 15). Neither scale is involved in the neem disorder.

Dr. Eric Boa (National Resources Institute, United Kingdom) recently made a survey for scale insects in several West African countries. In his report, Dr. Boa (1992) indicates that heavy infestations, mostly by A. orientalis but also by other as yet unidentified species, occurred primarily in northern Cameroon, southern Chad, and northeastern Nigeria. The oriental yellow scale apparently does the most damage in towns to older trees and is likely to be spread by large trucks from market areas in the center of towns. Heavy scale infestation results in a general browning of the crown. Dead leaves remain attached to the infested trees for extended periods.

Dr. Boa also found symptoms of the neem disorder in the area generally corresponding to that of the distribution of the oriental yellow scale but not on the same trees. Furthermore, trees affected by the neem disorder were present in both cities and the countryside. Dr. Boa also found neem severely affected by the neem disorder widely distributed in western Nigeria and Niger during his survey, but found no evidence of attack by the oriental scale in this same area. This insect has, however, been previously reported to occur in this region (Ohabuike 1992). **We concur with Dr. Boa that the neem disorder and attacks by scale insects constitute two separate problems.**

Another insect was found boring into the stems of epicormic sprouts on several neem trees in the greenbelt around Niamey. Although the sprouts were relatively vigorous, the trees on which they were formed showed severe symptoms of the disorder. The adults of this insect bored holes several mm in diameter and up to 20 cm long in the center of the stem (Fig. 16). Two adults were present in each gallery, but neither eggs nor larvae were observed. Other than the entrance holes, no outward manifestation of the infestation was evident. This may be the same insect mentioned by Walter Knausenberger (AID Africa Bureau) in a memo to George Taylor dated January 1991. The same or a similar insect has also been observed on neem in Niger by Mana Diakite, forester for CARE.

The insect was identified as Apate monachus by IIE. This insect has a wide host range and geographic distribution, and is usually associated with plants under stress. It probably has no role in the development of the neem disorder, except as a occasional secondary invader of stressed trees.

Mud-covered tunnels made by termites commonly occur on the trunks of neem trees. However, these insects attack only dead wood and do not damage living trees.

Assessment of the Extent and Severity of the Disorder

Using the symptomatology described above as a basis for identification of trees suffering from the neem disorder, the following is an assessment of extent and severity of the problem in Niger, at least in the areas visited during our visit. In the absence of any known etiologic agent, however, it must be emphasized that all trees exhibiting this symptomatology might not share the same etiology.

The most severe problem occurs in neem plantations. Several large plantations of neem were visited, including those in the greenbelt around Niamey, near Tera, and at the Seed Multiplication Center near Maradi. In the plantations visited, nearly all trees exhibited severe symptoms of the disorder, including in some cases complete defoliation and branch dieback (Fig. 17). Many trees with branch dieback responded by producing epicormic shoots on the lower trunk or from the root collar. In general, these sprouts appeared vigorous and exhibited no symptoms of disease problems. Very few dead trees were observed, although some trees in plantations had been cut and removed, and presumably would have been dead.

In the young (3-4 years) plantation at the Seed Multiplication Center, nearly all

the trees were completely defoliated except for those in a small low area in which there was evidently better water retention in the soil (Fig. 17). Even though most of the trees were completely defoliated, very little branch dieback could be found.

An interesting situation was observed at the leprosy sanitarium near Maradi. A small planting of neem, perhaps 2-3 years old, had been established near the main buildings. Part of the planting was over the drain field of the septic tank, and the trees were growing vigorously (Fig. 19). Those away from the field were almost completely defoliated (Fig. 20).

Although all the plantations visited were surrounded by fences, the gates were open or the fences were down, and there was clear evidence of heavy animal use. In addition, all of the plantations were used to grow millet or other crops. These factors, plus the relatively close spacing with no thinning in most of the plantations, undoubtedly put the trees under considerable stress.

We heard many anecdotal reports in Niger that neem does not do well in plantations, so there must have been problems in the past. Dr. Boa (Boa 1992) also reports heavy damage to neem in plantations in Nigeria, and his illustrations show that the problem is similar to that seen in plantations in Niger.

The amount and severity of the neem disorder in the larger cities and towns was extremely variable and patchy. Neem is used in the larger communities as street trees, as ornamental and shade trees in gardens, in government and private compounds, and in commons areas such as public markets and parks. In general, neem trees in these settings appear to be fairly healthy. Many trees, however, exhibit some degree of leaf drop, but this can only be noted when making comparisons with other trees on which leaf retention is obviously better. Other trees, or small groups of trees, show much more severe symptoms, including considerable branch dieback. Very few recently dead trees were observed. No pattern to the occurrence of the disorder could be determined, although there was an impression that trees with dieback occurred most often in areas that received considerable vehicular and pedestrian traffic, such as public markets and government and private business compounds.

Considerable concern has been expressed about the health of the extensive windbreaks of neem in the Maggia Valley and surrounding area. Examination of these windbreaks indicate that numerous trees show minor to moderate loss of foliage, but only a few could be described as having severe symptoms. Here again we could discern no apparent pattern to the problem, with trees showing symptoms more or less randomly distributed among nonsymptomatic trees (Fig. 21). One exception to this generalization

was at the lower end of the valley in an area nearer the foothills where the trees were obviously much smaller, showed much less leaf retention, and the leaves and leaflets were smaller. Even here, however, there was considerable variation in the degree of leaf retention among individual trees, but the general aspect of the problem was more severe. Mana Diakite, the CARE forester, told us that the soil in the area was much shallower and more rocky than in the other areas. The second point was quite obvious, as numerous small stones could be seen on the soil surface.

Dr. Boa (Boa 1992) reports moderate to severe damage to neem in shelterbelts in parts of Nigeria.

Neem trees were examined in a few small villages, and many more were observed in "windshield surveys" during trips from Niamey to other areas. The overall impression is that neem growing in this setting is generally healthy (see Fig. 1), but still exhibits considerable variation in the amount of foliage retention among individual trees. Very few trees with severe foliage loss or dieback were seen in the villages.

During the course of the visit, we also made general observations on the health of other tree species. Symptoms similar to those which occurred on neem were seen on Albizia lebbeck, Eucalyptus camaldulensis, and Cassia siamea. In the Niamey greenbelt, individual trees in the plantations of E. camaldulensis exhibited the same symptoms of loss of foliage and branch dieback as were seen in the adjacent neem plantations, but to less degree. It is interesting to note that Khaya senegalensis (like neem a member of the Meliaceae), which is commonly used as a street tree in many cities and towns, seldom showed any symptoms, even in areas where there were moderate to severe problems with neem.

Several nurseries were visited where neem seedlings were being grown. At the time of the visit, the seedlings had only recently germinated. No disease or insect problems were noted, but in some nurseries the seedlings showed obvious symptoms of nutrient deficiency, probably nitrogen or iron, or both. We were told there was no mineral fertilizer available for the nurseries, and that the only source of nutrients was manure. In some nurseries we noted that some seedlings had been left over from the previous year. These seedlings were quite large, and the root systems were severely coiled within the plastic container. Such seedlings should not be planted in the field, as the roots usually fail to develop normally (Fig. 22), and many trees die by the time they are 3-4 years old. We saw considerable evidence of this in the field, especially in the plantation near the Seed Multiplication Center near Maradi.

We also noted that the soil used in the containers was quite sandy in most cases.

When the container is removed for planting in the field, much of the soil will likely fall away from the roots, and survival will probably be decreased. It would be better if heavier subsoil were mixed with the sand, probably in a 50-50 ratio. This plus the manure should give a good planting mix.

DISCUSSION AND CONCLUSIONS

The primary objective of the trip was to follow up on the findings reported by Dr. Batra during his visit in July, 1991, especially with regard to confirming Verticillium sp. as the cause of the neem disorder. We generally agree with Dr. Batra's conclusion that there is a serious problem affecting neem wherever it is planted across southern Niger. The problem is especially severe in plantations where in all areas visited, almost 100 percent of the trees show severe symptoms of foliage loss and branch dieback, and in some cases, death. The problem is present, but much less severe, in neem planted in cities and towns, and in windbreaks. Neem planted in small villages and individual trees seen in the countryside appear to be much less affected. The major problem in making assessments of the seriousness of the problem is that very little is known about the normal phenology of neem in Niger. While it is quite obvious that the heavy to complete defoliation and branch dieback commonly seen in plantations and on some trees in other settings are not normal, it is more difficult to say whether the slight to moderate loss of older leaves is normal for neem during the dry season or represents an incipient stage of the problem.

We are also in agreement with most of the symptoms of the problem described by Dr. Batra, such as yellowing and loss of older leaves, shortened internodes (we presume he means leaf internodes), branch dieback, and gum exudation. However, we did not see symptoms described by Dr. Batra as "general deformation, crinkling and curling of younger leaves, stunting of young branches, and dwarfing of the tree in general". Young leaves and shoots, even those forming on trees with otherwise severe symptoms of the problem, appeared normal to us. This was also true of leaves and shoots of epicormic sprouts on affected trees, which Dr. Batra also indicated were symptomatic. It is possible that the differences observed could be due in part to the time of year the observations were made (March vs July).

Unlike Dr. Batra, **we could find no pattern of distribution of affected trees which would lead us to believe that the problem was present in localized and spreading centers. On the contrary, in plantations most of the trees appeared to be in a similar stage of decline and must have been affected in a more or less synchronous fashion.** Except in areas obviously associated with localized site factors, occurrence of symptomatic trees in

the windbreaks in the Maggia Valley appear to be random. In cities and towns, small to relatively large localized groups of affected trees could sometimes be seen in compounds or market areas. However, there was no evidence that these were spreading from an initial center. Such spread is usually characterized by a progressive decrease in degree of symptoms from the center outwards.

Especial attention was given to any symptoms which might indicate infection by Verticillium. A selective medium for isolation of Verticillium from soil and plant tissue was prepared in the U.S. and taken to Niger. However, nothing was seen in the symptomatology of neem disorder which pointed to infection by this fungus, and thus no isolations were made. Verticillium wilt in trees is characterized by sudden wilting of individual branches or groups of branches in the crown. Usually the tree would not have exhibited any previous symptoms of disease. The wilted and yellowed leaves which remain attached to infected branches stand out in sharp contrast to those on unaffected branches. Wilting is usually irreversible and the infected branch dies. Other branches are subsequently infected and eventually the entire tree may die. On large trees this may take several years. Another common symptom of verticillium wilt is a brownish to black discoloration in the outer xylem of infected branches and stems. None of these characteristic symptoms of the disease were present in any of the neem trees examined during the course of the visit.

It is therefore concluded that the neem disorder is not caused by Verticillium. Other common wilt diseases of trees, such as those caused by species of Ceratocystis and Pseudomonas, have essentially the same symptomatology as verticillium wilt, and they too are unlikely to be involved in the neem disorder. **Thus the name "vascular decline of neem" coined by Dr. Batra describes neither the symptoms nor the possible etiology of the neem disorder.**

We also saw no evidence of any of the other types of diseases of pathological origin which commonly infect trees, such as leaf spots, anthracnoses, cankers, rusts, or root diseases. Although we cannot definitely rule out the possibility of viruses until the results of the tests are available, the symptoms usually associated with diseases caused by these organisms are not consistent with those of the neem disorder we have seen in Niger. The more or less sudden and synchronous occurrence of the problem (last 2 or 3 years, or possibly longer in some cases) over a wide geographic area (Mali to Cameroon and Chad) would be extremely unusual for any type of disease caused by pathogenic organisms. This is especially so since there has never been any disease of neem previously reported from Africa and only a few minor foliage and root diseases reported from its countries of origin and in other regions where it has been introduced (see Appendix II).

The symptomatology of the neem disorder in Niger more closely resembles a type of disease commonly known as "decline". Decline diseases can be defined as diseases initiated by predisposing effects of abiotic environmental stresses which usually culminate in attacks by pathogenic organisms and/or insects of secondary action. (See Chapter 18 in Manion 1991 for a detailed discussion of these types of diseases). In the absence of stress, the secondary organisms are unable to successfully attack the tree. Conversely, trees under stress may recover after the stress factor is removed were it not for attack by secondary organisms. Repeated and prolonged stress, even in the absence of secondary organisms, may sometimes cause severe damage or even death of the tree. In general, the degree of damage depends on the severity and continuity of the initial stress factor; presence of disease organisms and/or insects capable of attacking the stressed trees; and the interrelationships of these organisms, such as their sequence of occurrence and how they are themselves influenced by environmental and site factors.

Decline diseases are often difficult to diagnose since the symptomatology of most declines is remarkably similar, usually a general deterioration of the crown including loss of foliage and dieback in the upper branches. Deterioration of feeder roots and mycorrhizae may also occur on declining trees. However, the rate of such deterioration is probably dependent in part on the presence of pathogenic soil microorganisms and on abiotic factors such as waterlogging which directly affect roots. Decline symptoms can be caused by many biotic and abiotic agents, either alone or in combination. Often the initial abiotic stress factor which triggers the decline is ephemeral, and may have disappeared by the time an attempt is made to diagnose the cause of the problem.

Moisture stress is one of the most important factors associated with the initiation of decline diseases. Severe and prolonged drought can put trees under considerable stress and predispose them to attack by secondary pathogenic organisms and insects. If the reports concerning the occurrence of neem disorder are correct; i.e., that it appeared rather suddenly (in relative terms) and synchronously (also in relative terms) over a wide geographic area, decreased rainfall is just about the only abiotic factor that could result in such a pattern. A rather simple analysis was made of the annual rainfall for several stations in southern Niger for the period 1950-1990 (see Appendix III). These stations generally represent the region in Niger where most neem is planted. This analysis indicates that there has been a gradual decrease in annual rainfall at all stations except one (Birni N'Konni) in each decade since 1950. The percentage decrease for the decade 1980-89 compared to 1950-59 ranged from 30 to 41 percent. Perhaps even more important, rainfall for the years 1982-85 and 1987 was significantly below the mean annual rainfall for the decade 1980-89 for most of the reporting stations. The amount of rainfall reported in many cases was less than the minimum of 400 mm needed for growth of

neem, and could have been at least partially responsible for the problem currently being experienced. This may have been the basis of a remark made at the USAID exit meeting (by Mr. Siry of FAO we believe) that planting of neem in pure blocks was no longer recommended because of the drought which occurred in the 1980's.

The results presented in Appendix III are similar to those reported to occur throughout West Africa, which has been plagued with an almost unbroken period of below normal rainfall since about 1968 (Lamb 1982, 1985; Lamb and Peppler 1991, 1992; Katz and Glantz 1986; Nicholson 1980, 1983; Winstanley 1985). The rainfall pattern in this area is well illustrated by Figure 23, which is taken in part from Lamb and Peppler (1992) and from other data furnished by Lamb (personal communication). The data included in Figure 23 represent an analysis of 20 stations in West Africa between 11° and 18°N, and west of 10°E, and covers the period 1941-1990. The figure also contains data for four Niger stations - Agadez, Birni n'Konni, Niamey, and Zinder - which are also included in the average of the 20 West African stations.

Lamb and Peppler (1992), and others, use an analysis called the Standardized Anomaly Index. This index is constructed by computing an individual station's mean annual rainfall (or mean seasonal rainfall as in the data presented in Figure 23) and standard deviation from an historical record. The annual (or seasonal) total rainfall for a given year is subtracted from the station's mean and the difference divided by the standard deviation. These standardized rainfall deviations (anomalies) are then averaged over all the stations within the region to obtain a single annual value for the index.

Figure 23 contains four distinct periods when rainfall anomalies occurred across West Africa. The 1940s included six dry years, three of which were moderately severe. During 1950-1958, however, rainfall was abundant. The period 1959-1967 generally showed relatively small positive deviations. From 1968 to 1990, the region has experienced a negative deviation in rainfall every year but 1969, with 1983-1984 being especially severe, but with 1988 being near normal.

The data for the four Niger stations are somewhat variable in comparison to the data for West Africa as a whole, but generally show greater negative departures from the mean during the dry periods and greater positive departures during the wet periods.

While drought is often the triggering factor for decline, other abiotic factors often contribute to the overall problem. A **possible explanation for the more severe problem in the neem plantations is that they receive considerable additional stress from intertree competition, soil compaction by animals, and root damage and competition from intercropping. Similarly, trees in city markets may be further stressed by soil**

compaction due to vehicular, pedestrian and animal traffic. Other soil factors such as texture, depth to the water table, presence of hardpans, waterlogging, etc. may be locally important. Many of these same factors were mentioned as possible contributors to the neem disorder in the short notes on the problem prepared by F. Brunck of Centre Technique Forestier Tropical and R. Catinot of FAO (in correspondence furnished to us by USAID, Niamey).

The degree to which secondary organisms play a role in the neem disorder is not known. We believe that much of the dieback is due to stress factors per se. However, Lasiodiplodia theobromae is certainly present in some places and this fungus is widely regarded as a secondary invader of stressed trees. It was previously reported to occur on neem in Africa by Dr. Brunck (see above paragraph) and from Ghana (herbarium records of the IMI) under the name Botryodiplodia theobromae. Pathologists at ICRISAT have isolated two fungi, Nigrospora sphaerica and Curvularia eragrostidis, from died back branches of neem and are currently testing their pathogenicity. A third fungus, tentatively identified as Thielavia terricola, but apparently a new species, was isolated from roots of symptomatic neem by Issa Adamou of the Plant Protection Directorate (DPV).

No insects were observed which play a significant role in the neem disorder in Niger.

During our stay in England, we, along with Dr. Eric Boa, visited several specialists in pathology, entomology, mycology, and taxonomy and morphology of the Meliaceae (see Appendix I) to discuss the results of our findings in Africa. Presentation of these results was greatly enhanced by the use of color slides and photographs of the disorder which had been taken by Dr. Boa. The general consensus from all these discussions was 1) the symptomatology does not fit known types of diseases of pathological origin and 2) the problem appears to be due to some soil-related factor or factors but no firm hypotheses were suggested.

The prognosis for the future of neem in Niger and other parts of West Africa is uncertain. **We feel confident about our conclusions that the disorder is of primarily nonpathological etiology, with drought and other stress-producing factors playing important roles in its development. For this reason the occurrence and severity of the problem in the future will depend in large part on rainfall. Unfortunately the trend for the past 40 years has been steadily downward, and unless this changes, the problem is not likely to improve.** It is interesting to note, however, that mean rainfall for the past four years since the last year of low rainfall (1987) has exceeded the mean rainfall for the decade 1980-89 at every station except Zinder (Appendix III). Even with continued

decrease in rainfall, there are a number of management and silvicultural options which might be utilized to mitigate the effects of drought. These will be enumerated in the section on recommendations.

RECOMMENDATIONS

1. **A conference should be convened as soon as possible to discuss the important problems currently affecting this species.** The conference should be attended by representatives of the countries of West Africa in which neem is important. The neem disorder and infestations by scale insects (Boa 1992, Ohabuike 1992) should receive the highest priority. **Overall responsibility for planning the conference should be assumed by an international agency, and FAO has agreed to coordinate convening the conference and other cooperative activities relating to the problem.** Firm plans to study, resolve, or mitigate the effects of current problems of neem should be made, and individual countries, and/or national and international institutions, should accept responsibility for specific projects. Some of the recommendations made in this report for Niger, such as Nos. 3-7, might also be appropriate for wider consideration at the conference.

A coordinating committee would be helpful in assigning responsibilities and monitoring results.

2. **In view of our conclusion that no primary pathogen is associated with the problem, the recommendations made by Batra in 1991 relating to the possible pathological nature of the problem can be <u>disregarded</u>.** That is, burning infected plants, sterilization of mechanical tools with hypochlorite solution, quarantine, and indexing resistance in seedlings, etc. (Batra 1991) are unnecessary. We also see no reason for a moratorium on the further planting of neem, at least not one based on the possibility of occurrence of an infectious disease.

3. **To better understand the normal phenology of neem and the progressive symptomatology in trees with the neem disorder, it is recommended that plots be established so that periodic observations can be made.** Together with Dr. Eric Boa, we developed a suggested protocol for this and have already sent a copy to USAID in Niamey for implementation (Appendix IV). Although not mentioned in the protocol, we feel that the observations should be made over a minimum of two years, but longer would be better. CARE has agreed to be the agency responsible for implementing the monitoring system in areas where they have existing agroforestry projects.

Similarly, it also might be interesting to **set up a study in which trees in the different disease classes are pollarded and the effect of disease severity on vigor of the pollarding shoots be determined.** We observed a number of times that the new shoots resulting from pollarding trees with advanced symptoms of the disorder appeared quite vigorous.

4. **Further and more sophisticated analysis should be made of rainfall data and how it may be related to the onset of the neem disorder.** Rainfall data should examined from other pertinent locations where available, especially from the more southerly areas where neem is relatively free of problems. Perhaps these analyses could be done by the climatology unit at ICRISAT.

5. **Studies should be initiated on soil factors relating to growth of neem, e.g. depth to water table, compaction, soil texture, hardpans, waterlogging, etc.** Results of such studies would serve as the bases for recommendations on where to plant, or not plant, this species.

6. To better understand the factors influencing the poor growth of neem in plantations, starting with deficient nursery practices, such as those leading to root-binding (Fig. 21). Thus,

- **exclosures should be established which would exclude animals and intercropping, and which would superimpose various thinning regimes;**

- **new plantations could be established** where various combinations of animals, intercropping and spacing may be studied; and

- **current plantations more than seven years old should be thinned** (removing about one-half of the basal area), and

- **intercropping and use by animals should be halted in all plantations.**

7. No data is available for Niger or other parts of West Africa on the number of introductions of neem which have been made, but the general consensus is that the number has been small, and that the genetic base of the neem currently being planted is quite narrow. This has in part been due to the belief that neem seesd do not remain viable for very long in storage. Recent studies (see National Research Council, 1992) indicate this is not necessarily so, and **it is recommended that a concerted effort be made to collect seed in as wide a geographic area as possible in the countries of origin so that provenance trials can be established in the Sahel.** Such studies would likely turn up neem which is more drought tolerant and with other more desirable characteristics. Similar results also might be obtained from the selection and propagation of local landraces.

8. **Studies already underway by Drs. Waliyar and Hess of ICRISAT (Niger) on**

the pathogenicity of Curvularia eragrostidis and Nigrospora sphaerica to neem, and on the effect of application of fungicides to roots of symptomatic neem trees, should be continued. We suggest that fertilizers be added as an additional treatment to the second study. These studies should provide experimental evidence, thus far lacking, on what is believed to be a complex etiology of the disorder.

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KEY CONTACTS

The following is a list of key contacts we made during the visit to Rome, Niger and England; and in the United States before departure and after return.

Rome

FAO: Bill Ciesla, Jim Ball

Niger

USAID: George Eaton, George Taylor, Barry Rands, Meg Brown, Hamadou Bourahima

FAO: L.W. Siry

UNDP: Eric de Munch, Bettina Fuhrmann

ICRISAT: R.W. Gibbons, Charles Reynard, Farid Waliyar, Dale Hess, Andrew Manu.

CARE International: Charles Tapp, Mana Diakite

INRAN: Haougui Adamou

DPV: Issa Adamou, Guero Chaibou

Dept. Environment: Hamani Saley, M. Adamou

England

Natural Resources Institute: Eric Boa, Simon Eden-Green, Jill Lenne, Nicholas D. Jago, Mike Jager

International Mycological Inst.: Brian Sutton, David Minter

Overseas Development Administration: Jim Waller (IMI), Mike Ivory (University of Oxford), I.A.S. Gibson (retired, London)

Kew Herbarium: Martin Cheek

International Inst. Bio. Control: Harry Evans, Sean Murphy

United States

Cornell University: Wayne T. Sinclair

USAID/Africa Bureau, AFR/ARTS/FARA: Walter Knausenberger

North Carolina State University, Dept. Marine, Earth and Atmospheric Sciences: Frederick Semazzi

USDA-Forest Service, Forestry Support Program: Julia Morris

University of Oklahoma, Cooperative Inst. for Mesoscale Meteorological Studies: Peter J. Lamb

We would especially like to express our appreciation to George Taylor, Barry Rands, Hamadou Bourahima, Issa Adamou, and Eric Boa for their help with our logistical and personal needs during the trip.

APPENDIX I

ITINERARY

Beatty

March 9. Leave Portland, Oregon, 7:00 a.m.

March 10. Arrive Rome, Italy via New York 8:50 a.m. Visit with Bill Ciesla at FAO headquarters.

March 10. Leave Rome 8:00 p.m.

March 11. Arrive Niamey, Niger via Paris, 3:40 p.m.

Hodges

March 11. Leave Raleigh, North Carolina, 3:15 p.m.

March 12. Arrive Niamey, Niger via New York and Paris. 6:10 p.m. Meet with Eric Boa (NRI) to discuss his recent trip to several West African countries to look at neem problems.

Hodges and Beatty

March 13. USAID-Niamey. Various meetings with USAID officials (George Eaton, George Taylor, Barry Rands) and later with USAID officials and representatives of other organizations (FAO, ICRISAT, CARE, NRI, etc.) to discuss neem disorder.

Visit to neem plantations in greenbelt around Niamey in p.m.

March 14. Off

March 15. Off

March 16. Visit to neem plantations in greenbelt around Niamey in a.m. In p.m. visit Balayara to look at neem.

March 17. Visit Tera to look at declining neem in city marketplace, around town, and in plantations outside of town.

March 18. To Maradi with Issa Adamou and Hamadou Bourahima, stopping at various places along the way to look at neem.

March 20. Brief visit with the Director of Department of Environment in Maradi and at the INRAN Center with pathologist Haouqui Adamou. In p.m. visit neem plantings around leprosy sanitarium and near USAID Seed Multiplication Center.

March 20. Visit Maggia Valley windbreak plantings of neem. Joined by George Taylor, Dale Hess (ICRISAT), and Mana Diakite (CARE).

March 21. Return to Niamey, stopping off at lake near Dogondouchi to look at putative waterlogging damage to neem along lake shore.

March 22. Accompanied by George Taylor and Barry Rands, excavate roots of affected neem trees in Niamey green belt.

March 23. Debriefings on observations made during visit.

At ICRISAT: Reynard, Waliyar, Hess, Manu, Rands, Taylor.

At Department of Forests and Water: Saley, Bourahima, Adamou, Chaibou, Rands, Taylor.

At USAID: Eaton, Rands, Taylor, Brown, Haynes, Sullivan, Siry, de Munch, Fuhrmann, Hopkins, Garden.

March 24. Leave Niamey, 12:45 a.m. Arrive London via Paris at 8:30 a.m.

March 25. At Natural Resources Institute (NRI), London, with Eric Boa. Discuss details of his trip to Nigeria, Chad, Cameroon and Niger to look at neem problems. In afternoon, Hodges gave seminar on tropical forest plantation diseases. Briefly discussed neem problems in Niger with NRI pathologists Lenne, Jager, and Eden-Green and entomologist Jago. With Boa, went to International Institute of Biological Control and discussed neem problem with pathologist Harry Evans and scale specialist Sean Murphy.

Beatty

March 26. Leave London 11:00 am. Arrive Portland, Oregon via Seattle, 4:15 p.m.

Hodges

March 26. With Boa spent day at International Mycological Institute (IMI) and Herbarium at Kew. Left fungal specimens from ICRISAT and DPV for identification. Discussed neem problem with mycologists Brian Sutton and David Minter of IMI and pathologist Jim Waller of the Overseas Development Administration. Prepared list of fungi relating to neem from IMI records. At the herbarium, looked at specimens of neem from India, Burma, and Africa. Discussed biology and morphology of neem with Meliaceae taxonomist Martin Cheek.

March 27. At NRI with Eric Boa. Prepared a protocol for monitoring progression of neem disorder through periodic observation and photography of individually marked trees. This protocol was faxed to Niger. Examined specimens of neem brought from Niger and made cultures.

March 28. Off

March 29. In p.m. left for Oxford by train.

March 30. Discuss neem problem with pathologist Mike Ivory of Overseas Development Administration at the School of Forestry, Oxford University. Leave beetle specimens from neem with Dr. Martin Speight for identification. Return to London.

March 31. Discussed neem problem with pathologist Ian Gibson, who before retirement worked for the Overseas Development Administration and lived for many years in Africa.

April 1. Could have left for United States (took personal holiday). Actually returned on April 27.

April 21. At NRI with Eric Boa. Discussed latest developments on neem disorder and verified that we had pure cultures of Lasiodiplodia theobromae.

APPENDIX II

A REVIEW OF THE DISEASES REPORTED TO OCCUR ON NEEM

Neem is remarkedly free from serious disease problems, even in its countries of origin. Even fewer reports of diseases of neem planted as an exotic can be found. Following is a discussion of the diseases of neem found as a result of a review of the literature and examination of the herbarium records at the International Mycological Institute at Kew, England.

Nursery Diseases

Several fungi have been reported to attack neem in nurseries in India, most of them affecting the foliage. The foliage fungi include Rhizoctonia solani, Sclerotium rolfsii, Colletotrichum capsici, and Pseudocercospora subsessilis (synonym Cercospora subsesslis) (Mehrotra 1990; Sankaran et al. 1986). The first three species are widely distributed pathogens which commonly cause problems in nurseries on a wide range of hosts. Although they have not been reported from Africa on neem, they are present in the region and could cause problems to this host under favorable conditions. Pseudocercospora subsessilis attacks both seedlings and larger plants of neem and closely related hosts such a Melia azedarach and Swietenia mahogani. Personal observations (by CSH) in a nursery in Ecuador indicates that neem is much less susceptible to the fungus than M. azedarach. A more detailed description of the disease and the fungus will be given in the section on foliage diseases.

Fusarium solani, another widely distributed fungus with numerous hosts, has been reported to cause wilt of neem seedlings in India (Sankaran et al. 1986).

Foliage Diseases

Six foliage diseases of neem have been described, four caused by fungi and two caused by bacteria. By far the most widely distributed is the leaf spot caused by Pseudocercospora subsessilis. This disease is very common on neem in its countries of origin (Chupp 1953; Ellis 1976; Jamaluddin and Sahare 1988), and also has been reported from Somalia (Castellani and Mohamed 1984), Sudan (Gibson 1975) and Sierra Leone (Ellis 1976) in Africa. It also occurs in South America on neem and M. azedarach (Hodges, personal observations). The disease is characterized by dark reddish brown circular to angular lesions, 2-5 mm in diameter, which are visible on both sides of the leaf. The fungus is also reported to cause lesions on new shoots and fruits (Jamaluddin

and Sahare 1988). Fruit infection reduces seed viability.

The fungus sporulates profusely on the lower leaf surface. The conidia are borne on fascicles of greenish-brown conidiophores, and are pale golden-brown, multiseptate, and 30-56 microns long and 3-4 microns wide at the base. A variety, C. subsessilis var. azadirachtii has been described from India (Srivastava 1980), and differs from the species in having conidia 5.25-8.4 microns wide at the base. The distribution of the variety is not known, as no additional reports of its occurrence have been published. Under favorable conditions (high humidity) the disease can cause premature leaf fall, but in general causes little serious damage to affected trees, and no control is usually warranted. In the nursery, the disease may cause more serious damage, but can easily be controlled with applications of benlate or fungicides containing copper.

Cercospora leucosticta (now considered a synonym of Pseudocercospora meliae, which also attacks M. azedarach), has been recorded on neem in India (Gibson 1975), but there is little information on the effect of the disease on the tree.

Neem was reported to be attacked in India by the fungus Phoma jolyana (Singh and Chohan 1984), which caused a leaf spot and small cankers on young twigs. The leaf spot caused by this fungus is quite different from those caused by P. subsessilis and P. meliae in that the spots are quite large, and in the latter stages of the disease, the necrotic tissue falls out of the leaf leaving shot-hole like symptoms. The causal fungus attacks a number of different hosts, including citrus, guava, and banana.

A powdery mildew caused by Oidium azadirachtae has been reported to occur on neem in India (Narayanasamy and Ramakrishnan 1971) and an Oidium sp. has been reported from Pakistan (Gibson 1975). Powdery mildews are characterized by superficial white patches of mycelium and conidia on leaves and young shoots. Infection usually causes yellowing and sometimes premature leaf fall. Powdery mildews are never serious enough on large trees to consider using control measures, but control in nurseries may sometimes be warranted. Dr. Haougui Adamou, INRAN pathologist in Maradi, has seen powdery mildew on neem in the Maradi area.

Two leaf diseases caused by bacteria have been reported from India. Infection by Xanthomonas azadirachtii is characterized initially by small, round, light green, watersoaked spots surrounded by clear halos (Moniz and Raj 1967). These spots later develop into necrotic lesions which were most commonly noted at the margins of the leaves. The lesions increase in size, coalesce, form irregular, distorted blotches, and finally result in the death of the leaf.

Initial symptoms caused by Pseudomonas azadirachtae are similar to those caused by X. azadirachtii (Desai, et al. 1966; Srivastava and Patel 1969). Translucent, watersoaked spots 4-6 x 2-3 mm in diameter appear on the leaves. As the disease progresses, the area surrounding the spots become yellowish, then necrotic, and finally dries up. A narrow translucent area of infection of 0.1 to 0.3 mm on either side of the midrib extends into the veins and veinlets, and leaves infected in this manner invariably become yellow, and then die. Conspicuous oozing of bacteria occur when infected lesions are sectioned.

Neither of these bacterial diseases have been reported to occur outside India. However, a bacterial leaf spot (Xanthomonas khayae) of Khaya senegalensis and K. grandifoliola, which also belong to the Meliaceae, has been reported to occur in Sudan (Sabet 1959). The relationship of this disease with the two bacterial diseases which occur in India, if any, is not known.

Pseudomonas viticola, a bacterium which causes a leaf and stem disease of grape in India, will also infect neem under conditions of artificial inoculation (Nayudo 1972). The same is true for the neem pathogen, Pseudomonas azadirachtae, on grape. However, the two species are quite distinct in their physiological and morphological characteristics. Infection under natural conditions is known only on their respective hosts.

Cankers

Neem has been reported to be one of many hosts of Corticium salmonicolor, the cause of a pathological problem commonly known as the pink disease (Mordue and Gibson 1976; Rao 1936). The disease gets its name from the pink colored mycelium and spores which develop externally over the bark covering infected areas of the trunk and larger limbs. The trunk or limbs may be girdled at the point of infection, and the part distal to the infection usually dies. Trees infected low on the trunk may be completely killed.

Corticium salmonicolor is widely distributed throughout the humid tropics, including Africa. The disease is favored by high rainfall and humidity, and is seldom a serious problem in areas where the annual rainfall is less than 2000 mm. For this reason, the disease is never likely to be a problem on neem, either in its area of natural distribution or where it is normally grown as an introduced species.

Root Diseases

Ganoderma lucidum is the only fungus that has been reported to cause a root disease of neem (Bagshee and Bakshi 1950; Anon. 1975). This is primarily a tropical fungus but also occurs in many temperate regions of the world. It has numerous hardwood hosts and is primarily a weak pathogen which usually infects through wounds on roots or at the base of the tree. In addition to killing the cambium, the fungus causes a spongy white rot of the sapwood and heartwood. Death of the tree may occur from girdling at the base or from windthrow because of decayed roots. The fruiting body of the fungus is woody. up to 15 cm or sometimes more in diameter, and is usually attached to the base of the tree by a lateral stem 6-10 cm long. Both the upper surface of the fruiting body and the stem are characteristically covered by a shiny, reddish, varnish-like crust. The pore surface on the under side of the fruiting body is white in fresh specimens.

The disease on neem has been reported only from India. However, the fungus is known to occur at higher elevations in central Africa and has the potential for becoming a problem in that and perhaps other areas.

Miscellaneous

While in England, Hodges went with Boa to the International Mycological Institute at Kew. Here the records of the Institute were examined for the fungi on neem that had been sent for identification. A total of 58 fungi were listed in the records. The majority of these were clearly saprophytic species. However, there were a few species other that the ones listed above which could be considered potential pathogens. These are listed below:

Ascochyta sp.
Calonectria camelliae
Glomerella cingulata
Phomopsis abdita
Botryodiplodia theobromae
Nectria episphaeria
Pseudocercosporella sp.

Botryodiplodia theobromae (now known as Lasiodiplodia theobromae) is a fungus of widespread distribution in tropical and temperate areas of the world and has a very wide host range among both conifers and hardwoods (Punithalingam 1976). It is almost always associated with diseases of trees under stress, and can infect roots, stems and branches. It is most commonly associated with branch dieback. Specimens in the herbarium came from India and Ghana. The Ghana specimen represented the only fungus on neem in the herbarium which came from Africa.

Although the remainder of the fungi on the above list are known to be pathogenic to various plants, their status on neem is not clear from the herbarium records.

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APPENDIX III

ANNUAL PRECIPITATION (IN MILLIMETERS) AT SELECTED STATIONS IN SOUTHERN NIGER DURING THE YEARS 1940-1991

	Station				
Year	Niamey	Maradi	Birni N'Konni	Tahoua	Zinder
1940	--	657	494	374	439
1941	--	538	433	310	426
1942	--	456	353	209	340
1943	860	527	590	--	751
1944	369	536	466	304	547
1945	557	671	718	434	543
1946	725	749	724	480	800
1947	432	654	515	438	470
1948	592	676	482	531	371
1949	429	367	440	208	256
Decade Average	**566**	**583**	**521**	**365**	**494**
1950	609	891	742	493	610
1951	542	541	673	353	500
1952	980	758	990	528	662
1953	767	676	931	462	584
1954	454	610	644	546	700
1955	639	555	562	468	500
1956	541	723	502	397	610
1957	733	736	686	388	600
1958	523	625	622	534	526
1959	617	537	696	478	481
Decade Average	**640**	**665**	**705**	**465**	**577**

APPENDIX III (continued)

1960	562	616	429	315	583
1961	634	697	551	582	577
1962	740	643	526	555	468
1963	474	567	461	343	363
1964	854	730	628	441	659
1965	728	631	572	478	434
1966	506	632	618	464	487
1967	898	595	568	498	405
1968	555	362	523	408	376
1969	610	641	589	317	436
Decade Average	**656**	**611**	**546**	**440**	**479**

Year	Niamey	Maradi	Berni N'Konni	Tahoua	Zinder
1970	477	585	557	422	355
1971	468	399	388	267	353
1972	343	288	328	267	328
1973	395	350	289	245	298
1974	500	491	428	421	480
1975	690	351	488	421	471
1976	589	530	546	392	475
1977	556	608	542	360	257
1978	666	508*	642	566	607
1979	543	613	494	291	443
Decade Average	**523**	**472**	**470**	**365**	**407**
1980	428	507	496	313	524
1981	518	385	396	350	288
1982	341	286	321	206	446
1983	606	307	387	235	304
1984	294	284	375	276	283
1985	396	378	359	220	425
1986	412	521	450	325	441

1987	382	314	334	272	220
1988	499	551	546	316	533
1989	616*	607*	485*	367*	337*
Decade Average	**449**	**414**	**415**	**288**	**380**
1990	507	396	448	354	265
1991	386*	338*	524*	434*	251*
1988-91 Average	**502**	**473**	**501**	**368**	**346**

* Some data missing, but only for dry months.

APPENDIX IV

MONITORING NEEM DISORDER[1]

Sampling Method and Scoring

Trees should be individually marked so that repeated observations can be made and progress of the tree followed. A minimum of 20 trees should be included in a sample plot, which, ideally, should include trees in categories 0-3. (Some sites may lack trees in categories 3 or 4). Avoid sample plots which include mainly trees in categories 3-4. The assessment consists of a simple score for overall health which must be noted for each tree. Site history should also be noted. It may prove more time consuming and difficult to note the features listed under "supplementary observations" but such information would greatly assist studies of the development of the disorder.

Observations should be made on a minimum of two occasions. It is difficult to be sure of the best times to carry out these observations due to a lack of information on the normal pattern of leaf production (phenology) of neem. In the absence of information we would suggest a) towards the end of the dry season (March/April) and b) towards the end of the wet season (August?/September?). If possible, a third observation within two weeks of the beginning of the rainy season should be made, assuming that rapid growth occurs at this time.

Photographs of individual trees at each observation period would be helpful in documenting changes in development of the disorder.

Scale for Assessing Damage

0 Healthy. Full complement of leaves present.

1 Small amount of leaf loss (<10%). Tufts of leaves ("giraffe necks") beginning to form on upper branches. Yellowing of leaves restricted to natural senescence of older leaves.

2 Significant leaf loss (10-40%). Pronounced formation of giraffe necks leading to noticeable sparseness in upper canopy. Yellowing of leaves restricted to natural senescence of old leaves.

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[1] Developed in conjunction with Dr. Eric Boa, Natural Resources Institute, U.K.

3 Severe leaf loss (>40%). Only small terminal tufts of leaves remaining with some completely bare branches seen. Yellowing of remaining foliage may be seen which is not
natural senescence. Bare branches may or may not show dieback.

4 Total leaf loss from tree. Tree may or may not be dead (note flushing of shoots from bare branches separately).

Supplementary Observations

The following information would be very helpful in gaining a more detailed knowledge of the disorder and in helping to determine its cause. If possible, please note any of the following:

1 Presence of insects. Scale, others (eg. stem borers).

2 Flushing of new growth from branches which had previously lost all their foliage.

3 Presence of wilted shoots (browning of leaves)

4 Stem or branch lesions (dead bark tissue in localized areas).

5 Presence of pink/red/orange color in inner bark of branches >lcm diameter. Check at least 30 cm below branch apex.

Site History

1 Age of trees (generally)

2 Diameter at breast height (for each tree)

3 Pollarded (yes or no for each tree)

4 Soil information (generally, if available)

5 Human/animal interference (generally)

6 Water table (generally)
7 Planting scheme (shelter/windbreak; village; plantation; roadside; other)

ILLUSTRATIONS

Fig. l. In Niger, as well as many other countries in West Africa, neem is commonly used as amenity trees in villages and .....

Fig. 2. .....as avenue trees in large cities.

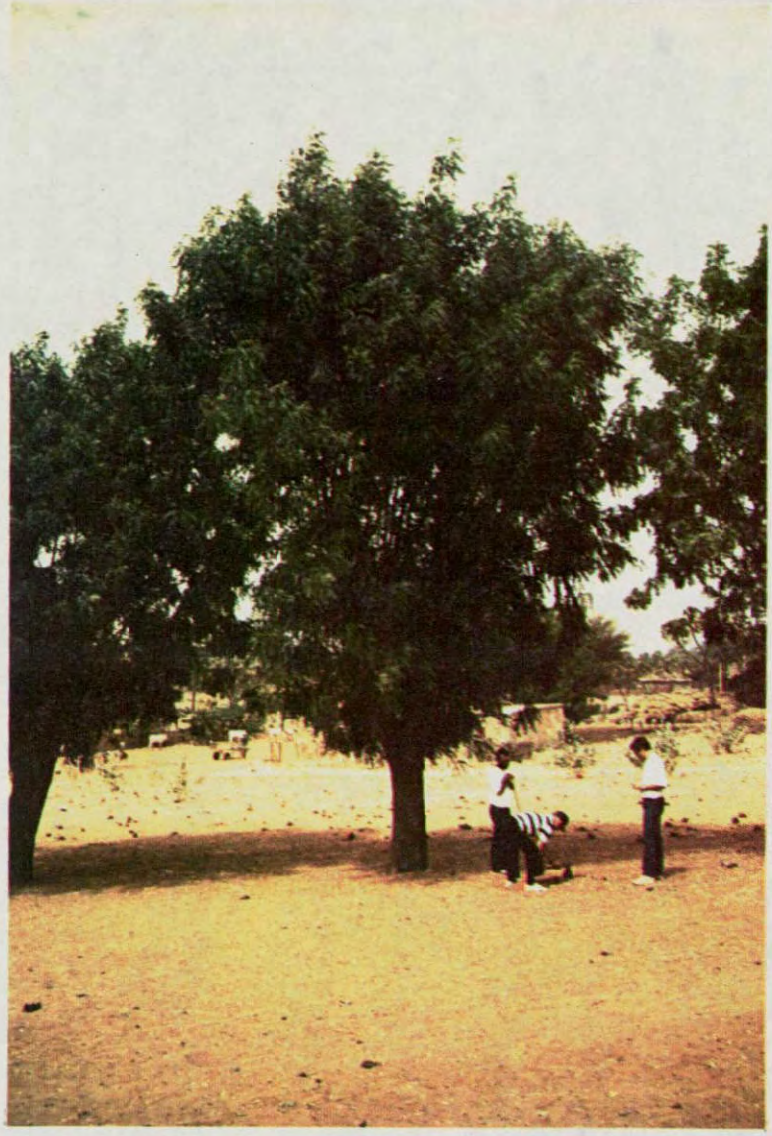

Fig. 3. Healthy neem trees, especially those that have been pollarded, show a full complement of dark green foliage.

Fig. 4. Two neem trees exhibit moderate (right) and severe (left) symptoms of the neem disorder.

Fig. 5. Tufting of leaves at the tips of upper branches is aptly termed "giraffe neck", and is the most characteristic symptom of the neem disorder.

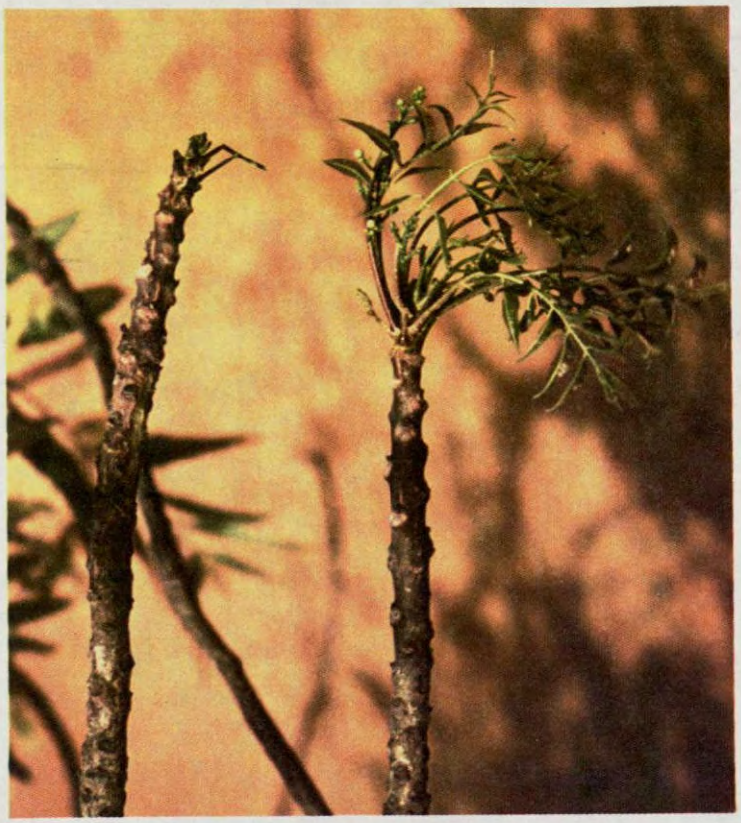

Fig. 6. Branches on trees severely affected by the neem disorder may lose all their leaves (left) but some may refoliate (right).

Fig. 7. Some branches may die back, but in most cases the zone between living and dead tissue is very diffuse.

Fig. 8. Loss of foliage on one side of these trees may be due to the drying effect of prevailing winds.

Fig. 9. New shoots resulting from pollarding severely affected trees often grow vigorously.

Fig. 10. The inner bark of small branches on trees affected by the disorder is often a pink to reddish color (above), in sharp contrast to the normal green inner bark (below).

Fig. 11. Excavating symptomatic tree in the Niamey greenbelt to look for root damage.

Fig. 12. Root system of tree shown in Fig. 11. No evidence of root disease was seen and the inner bark on all roots exhibited normal coloration.

Fig. 13. Branches from neem tree showing symptoms of fasciation.

Fig. 14. Yellow-brown foliage on neem tree symptomatic of infestation by the scale Macropulvinaria jacksoni.

Fig. 15. Heavy infestation of Macropulvinaria jacksoni on petioles and branch of neem.

Fig. 16. Leaves of neem infested with the scale Parlatoria crypta.

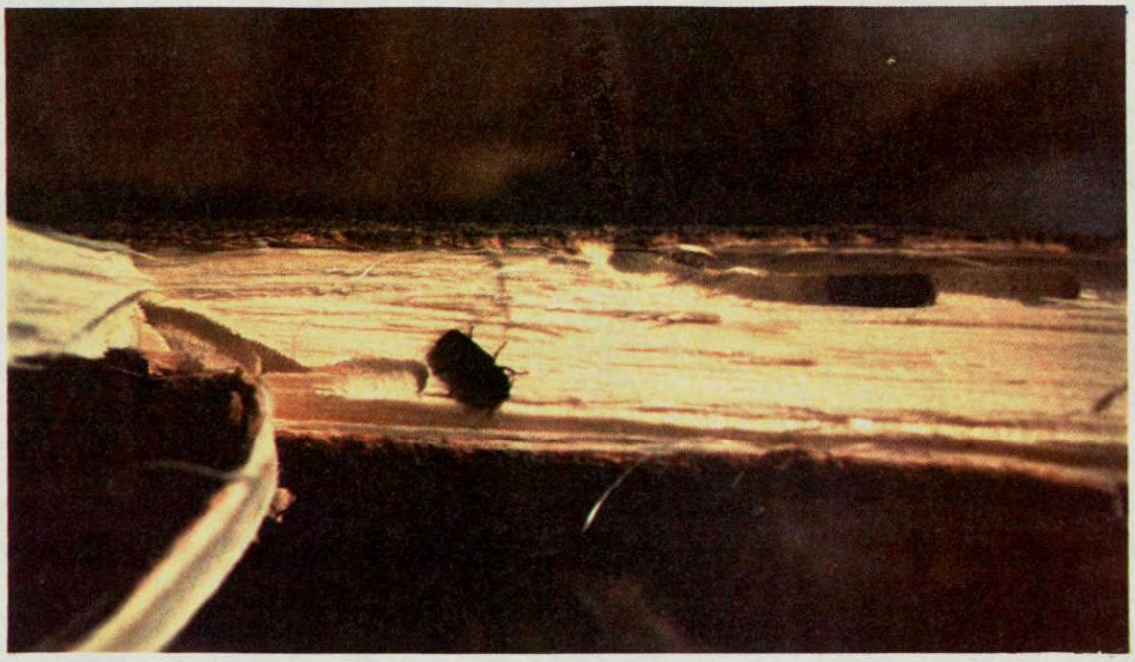

Fig. 17. Adult and galleries of Apate monachus in shoot of neem.

Fig. 18. Young plantation heavily affected by neem disorder. Most trees are completely defoliated, but note small group of trees in center right of picture which still maintains considerable green foliage.

Fig. 19. Young neem trees planted over drain field of septic tank at leprosy sanitorium near Maradi. Note vigor and color of foliage.

Fig. 20. Part of planting shown Fig. 19, located immediately adjacent to septic tank drain field, but not over it. Note heavy defoliation on most trees.

Fig. 21. Part of windbreak plantings in Maggia Valley. Most trees appear healthy, but note few randomly distributed trees showing various degrees of neem disorder symptoms.

Fig. 22. Root system of young neem tree showing severe root binding due to leaving seedling too long in plastic bag. Tree has died back to root collar.
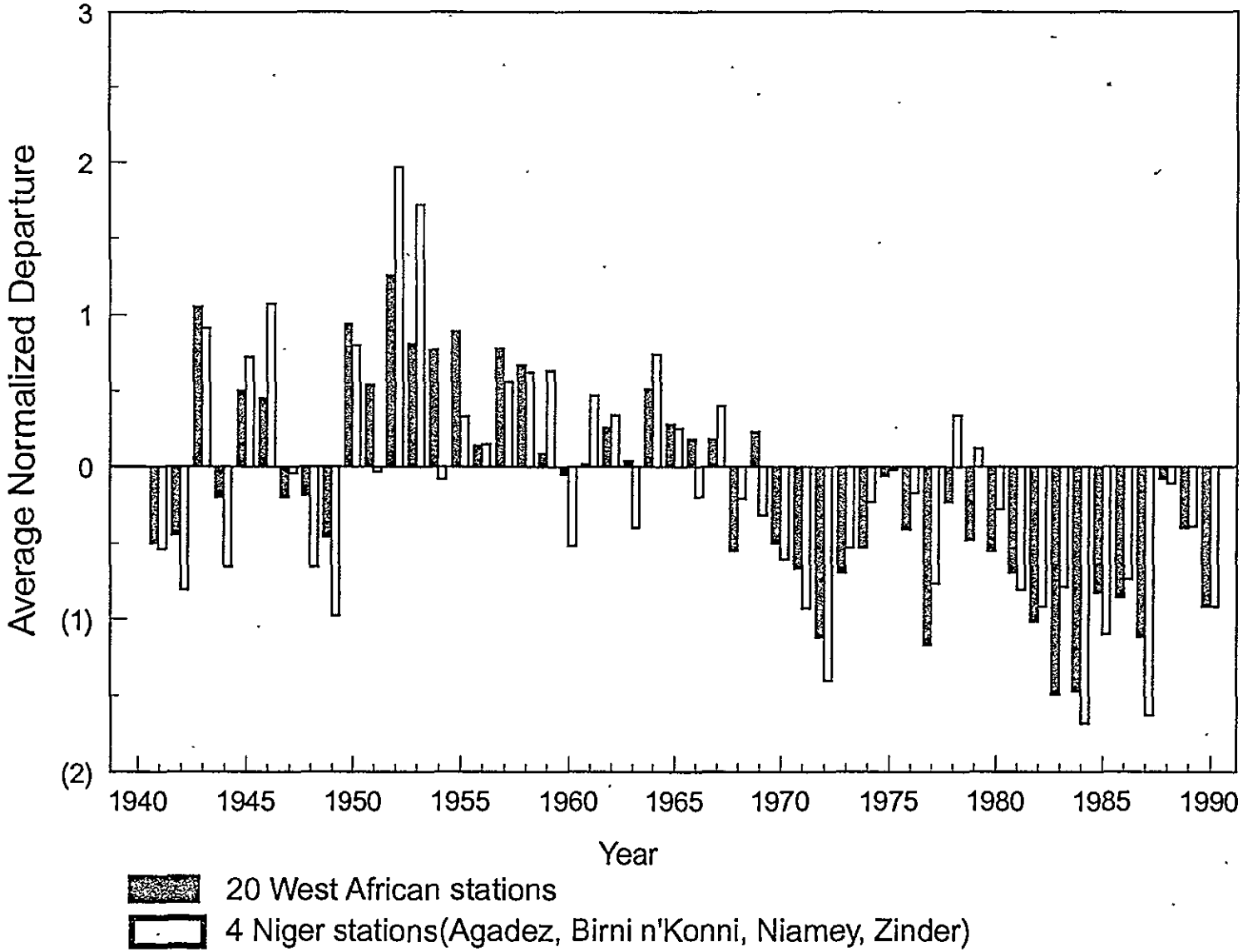
Fig. 23. Yearly rainfall index values for the period 1941-1990.